Energy Efficiency, Acoustics & Daylighting in building
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Lecture – 52
Daylighting (contd.)

So, looking at then externally reflected component. One way is to simply find the sky factor as I said you can find it from the table this again given as L by d h by d and I just forgot to mention sky component tables there are two sets of table. One is for horizontal surfaces, another for vertical surface for example, if it is a blackboard in a school board in a school so how much daylight you.

So, that is for the vertical one same principle is applied because the points you can take on to the vertical surface and same principle is applied. So, there is one table for vertical ones, 1 table for the horizontal. So, and then there is a third table for sky factor there is a table for sky factor as well.

Now, sky factor again you can find out in another manner how see you have found out the basically you know we found out from basic principles, but supposing I know the sky component for that area, and divide by is average brightness then also I will get the sky factor am I right.

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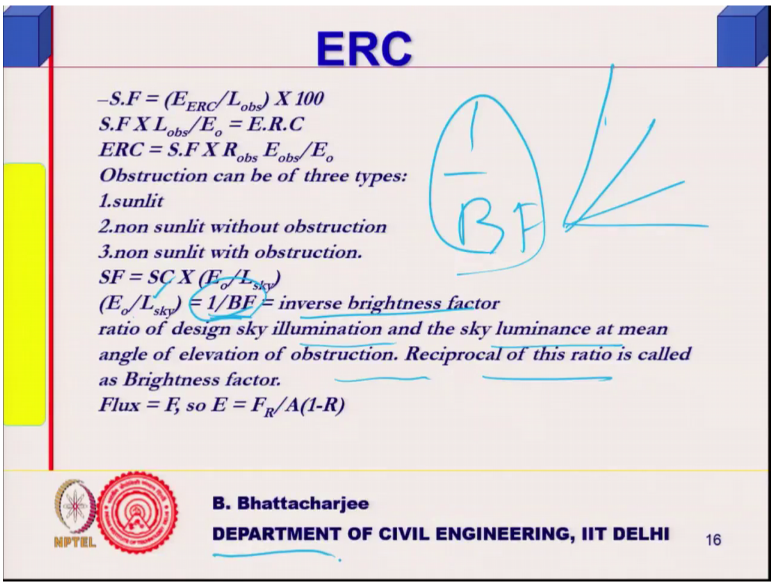

Because you see the sky component actually I found out for a given for a small area if I consider and average brightness let us say which is L o b s or I mean L of the sky sorry L sky. So, I have found out sky component for same integral etcetera average if I take in a small area I consider this area is small then I can say that for that area I can take the average sky brightness divide the sky component by average sky brightness that will be the sky factor again.

Because if I assume that the brightness is constant which is average value so I sky come from sky component also I can find out that from the sky component also I can find out the sky factor by dividing it by average brightness for that zone average brightness for that zone so that is also can be done. So, skycap factor can be obtained in that manner.

So, basically sky component divided by L sky L sky we are saying is nothing, but sky factor nothing, but is also sky factor so this also sky factor. But if sky component I mean sky component is usually is given as E sky divided by E SC E SC illumination due to SC divided by E 0, so I multiply again by E 0.

Let me repeat what is sky component it was actually E sky you know is E SC E sc divided by E 0. What is E SC E SC divided by average of fraction of the sky L o b s will give me sky factor, this will give me sky factor. So, sky factor can be obtained in terms of you know. So, this sky factor can be obtained in terms of this sky factor is sky component multiplied by E 0 that is nothing, but illumination due to the that portion of the sky and if I divide by the average brightness of the sky then I get sky factor average brightness of the sky factor is independent of the brightness sky factor you know we said it is just integration of sin 2 theta by 2 d theta d phi over theta 1 to theta 2 d obstruction area we are assuming that obstruction area is having uniform brightness. So, sky they are also having uniform brightness which I am calling as L sky which I am calling as L sky.

So, let me just rewrite this again so let me explain and E sky component E sky component is equals to divided by E 0 is equals to sky component SC. So, E SC is nothing, but E 0 into SC all right E SC. Now E SC divided by L sky L sky on both sides L sky that should give me sky factor that should give me sky factor that should give me sky factor. So, sky factor is nothing, but E 0 into SC divided by L sky. So, that is what we are saying sky component is E 0 divided by L sky so that is that is what we are saying sky factor is this.

Now, sky factor therefore, you can find directly from the table or also from the sky, you know SC S C value which is again from another set of table. So, you can find out, but E 0 is known to you which is 8000 lakhs and L sky which is known, but supposing this is given as a ratio, this is given as a ratio then you can you know it is given as a ratio you can multiply simply sky component by this to get the sky factor ok.

So, these are given in tabular form first of all as I said that brightness of the obstruction for that purpose 3 types of sky have been 3 types of obstruction has been classified one is a sunlit, one is sunlit, directly you know direct sunlight is reaching onto the obstruction that is that building next. Non sunlit without any obstruction so it could be sunlit means this is your building obstruction I am talking of and it receives the sunlight it receives us direct sunlight so that is the sunlit.

There can be another one which is not sunlit. So, here it would be something like this is not there this portion is not there, but the sunlight comes from there let us say and your point is somewhere there. So, this is non sunlit, but there is no obstruction to that building itself. Now supposing this building itself has got an obstruction may be obstructed the sun is coming from this side and your building is somewhere there and this is obstructed.

So, it is shadow I mean it is under they are not receiving direct sunlight, but obstructed and this will also this will actually contribute to the sky component to this building itself you know this it will also contribute to the sky component you know like externally reflected component to this building itself. So, there are 3 possibilities sunlit, non sunlit without obstruction, and non sunlit with obstruction right. So, it is classified in 3 class and for each of them actually this value is given what is given R obstruction value is given reflectivity of the obstruction is given reflectivity of the obstruction is given.

So, reflectivity of the obstruction is given or what is given is actually in a tabular form R E obstruction divided by E 0, E obstruction by E 0 this is given in tabular form and R obstruction values are given and one can obtain this values again from table and multiplied by sky factor to get E R C multiplied by sky factor to get E R C.

Let me see if I can solve a problem that would make it life easier looking at the table what is actually looking at the table looking at the table. Because E of the obstruction, illumination of the obstruction that of course, one can calculate out by E 0, but these are given on a gross manner depending upon angle similarly E 0 by L sky is given by 1 by inverse brightness factor 1 by BF it is called inverse brightness factor for the obstruction.

As I said the sky factor can be obtained from E 0 you know it can be obtained as E a SC into E 0 by L sky and E 0 by L sky is given E 0 by L sky is given as 1 by bright you know it is called inverse brightness factor 1 by BF. Now this 1 by BF value is tabulated for various angles of obstruction because it involves L sky. So, this will change with the angle this will change with the angle.

So, this is you know 1 by BF values are given in a table for various angle of elevation or average angle of elevation of the obstruction right. So, ratio of design sky mean this is given reciprocal of this is called brightness factor. So, this is what is given.

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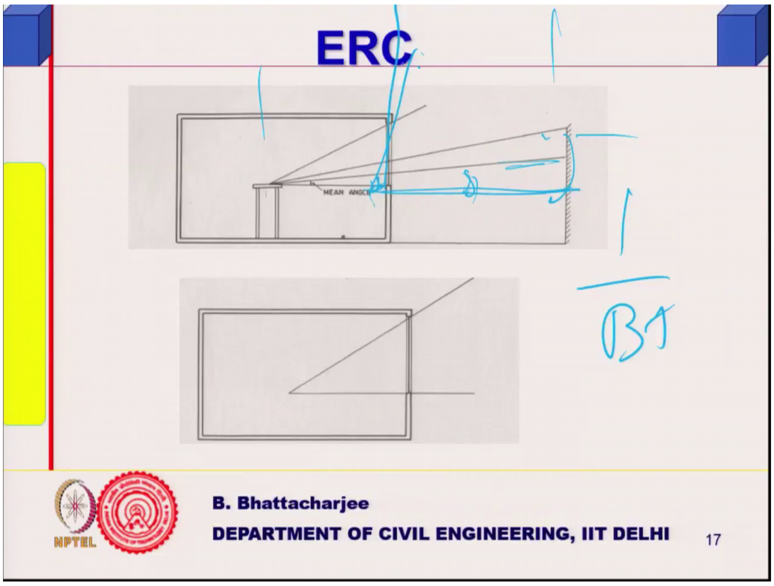

Let me see If I have yeah something like this something like this something like this for example, this is your obstruction. So, mean angle of obstruction is this, this is the total this is this is the overall angle of obstruction mean angle of obstruction is this. So, for this one integral 1 by BF is given so this will vary from 5 degree to 85 degree, 90 degree means its fully blocking everything is blocking you know 90 degree is very unlikely to have something like this. If this is your working plane nearly 90 degree means somewhere here.

But so it is given for 5 degree to 85 degree 1 by BF and what is 1 by BF 1 by BF is nothing, but E 0 by L sky. So, this value multiplied by sky component from the table will give you sky factor sky factor you can obtain use this sky factor together with these values which are given in table. Because E o R E o b s by E 0 is given in the table and R o b s is given for various conditions like sunlit, non sunlit etcetera.

So, from this table one can find out right from the table one can find out and then use them use them in use them for finding with the externally reflected component right, but the principle I have told you principle is what you assume the brightness of the obstruction is constant. And you know the area which will contribute to the E R C area of the obstruction which will contribute and you can then integrate it corresponding theta 1 to theta 2 theta you know etcetera you can actually integrate it accordingly so that that is how it is.

But then this has been done using you know the table have been form for various L by d n h by d using same principle, but today you if you write a program yourself you can actually do it that way so that is the principle. And in order to you know like in order to have the brightness of the brightness of the obstruction again it is given in tabular form whether it is sunlit, non sunlit with obstruction or non sunlit with no obstruction. So, the 3 cases and also I believe is a colour so something is given it with respect to that bright you know something of that kind is given types of surfaces.

So, this values are given in a gross manner and one can calculate this so that is the principle of calculating E R C I will try to solve one problem sometime I think I will try to solve one problem sometime. Now, for I R C I R C it is done in a slightly different manner that is what is I R C internally reflected components.

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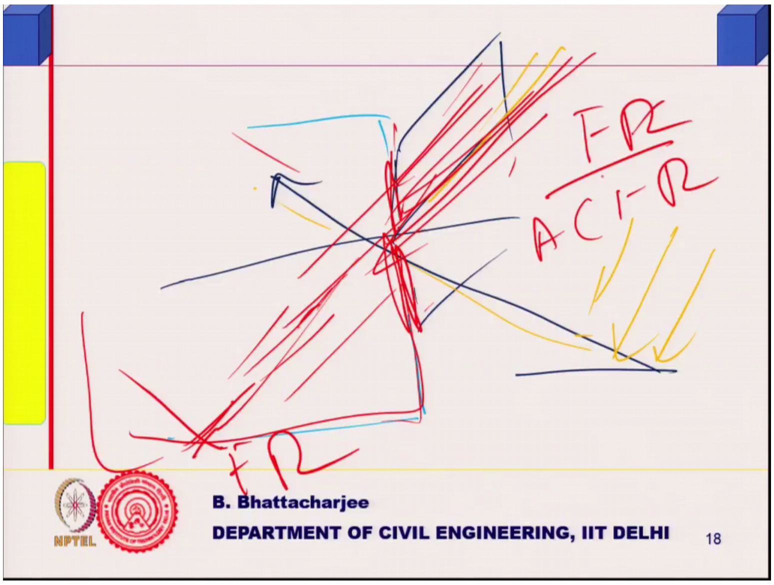

So, what is done is if this is your window if this is your window this is your window, you divide it into 2 parts principle wise you divide it into 2 parts. At the mid height at the mid height this is your window actually this is a, you new window so mid height you divide into 2 parts.

Now lights light through this window will come from the bottom because there will be some ground reflection the sunrays are received sunrays are received you know onto the ground as well and there be ground reflection coming in and then we coming direct you know direct light from the diffused sky; diffuse sky radiation will come here diffused sky radiation will or from obstruction it might come somewhere there some light will come here.

So, what is done is it is assumed that the flux coming here bottom half of the window comes from the ground. Flux coming from top of the window sorry it is other round yeah comes top of the window comes from the sky or obstruction and they are the first reflected from the floor and this walls below the bottom portion.

So, what is assumed is that that light that comes from top half of the window is reflected first reflected from floor and up to the mid height of the window walls up to that mid height of the window you know it is it is assumed that it is actually reflected from all the walls up to the mid of the window, but not this wall because it is coming through that. So, if you are considering one window that wall you live out.

First reflection occurs from here because you are interested in F R and remember principle of integrating sphere it was F R divided by 1 minus R right 1 minus R and divided by area of the internal area of the room. So, this principle we are trying to apply and therefore, first we assume sorry oh everything got cancelled does not matter so, I will redraw it no problem.

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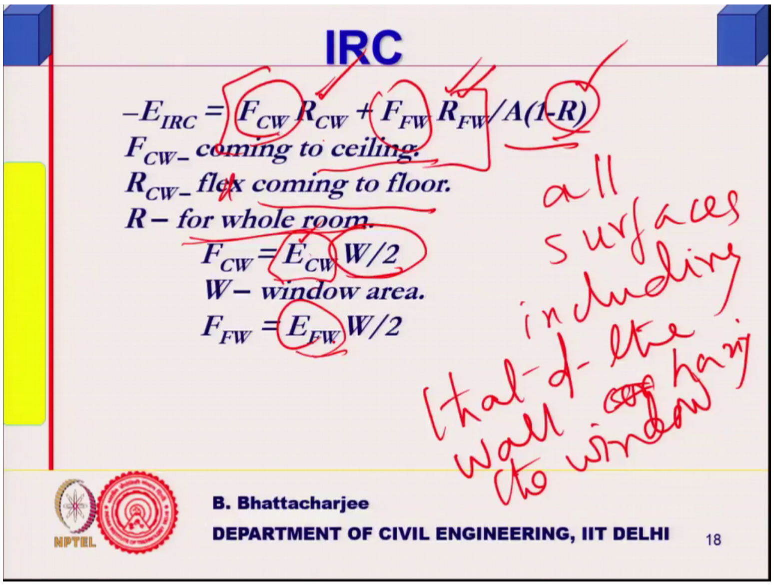

So, I said mid height so this comes guess so I divide the flux into 2 parts F C W and F F W. what are C W and F W F C W or let me write it I think it is it was somewhere here flux is F and the principle I apply is first reflected flux divided by this the integrating spheres principle. So, what we do is we divide into 2 parts F C W and F F W; F F W F F W right so that is C W is the one which goes to the ceiling; that means, it comes from the ground F C W is the one which goes from to the ceiling. So, it comes from that you know mid height is this.

So, the one that is coming from the ground that goes to the ceiling first reflection then reflectivity of this top half of the room I consider x leaving this one reflectivity of that top half above the you know is mid height of the window. So, reflectivity of all the walls ceiling etcetera I calculate up to this wall do not consider this. So, up to this I calculate out reflectivity average reflectivity.

How is this average reflectivity area weighted same way we did it for absorption coefficient of sound. So, it will be actually R 1, A 1 or R i A i sigma this right divided by sigma A i sigma A i so that is weighted average I am calculating. But then this I meant for all the surfaces other than this wall containing the window right and above the mid portion of the window mid height of the window right. So, it goes up and everything.

So, this similarly, as far as this is this comes this flux comes from the top goes to the floor and reflected first reflection goes. So, this R F W is the reflection coefficient of all the surfaces below the mid height of the window that is your floor plus half the, you know up to the mid height of the wall areas up to the mid height living the particular wall on which the window is there.

Now if you have window in many walls you will do for individual one and then sum it up because they are all scalar quantities and you can sum it up. So, this sum this total is summed up, this total is summed up, this total is summed up, divided by when you calculate this R, this R all the surfaces you got to take into them why because second reflection on words everything will take part in reflecting. Second first reflection only first reflection comes either from the bottom up that is including floor or from the ceiling top half, but infinite reflection it will reflect from the same window as well.

If it is open then; obviously, you take the reflectivity equals to 0 reflectivity is if the open window you take reflectivity is equal to 0, if it is a glass then actually you take the reflectivity of the glass actually glass transmits about 0.85 it is it is assumed the glass transmits about 0.85 so, that is multiplied in the formula and 0.15 its reflectivity.

So, you take the glass reflectivity which is a glass window is not open, but closed if it is open then you take it 0, but take this R all surfaces, all surfaces, all surfaces, including those including that of the that of the wall having window itself having window having the window. So, you take this for all you take this for all while this you take leaving the wall on which the window is and only this is for ceiling and this is for floor and this flux are now to be assumed.

So, this is what we are saying is coming to the ceiling the flux this should be flux coming to the floor. So, for whole room R is for whole room that is what I am saying F C W is multiplied by W by 2 window areas into the illumination at the window surface illumination at the window surface that will be the flux illumination of the window surface multiplied by W by 2.

So, illumination at the top half of the window surface ceiling sorry ceiling it goes to the bottom of sorry you know top of the window surface F C W is yeah here. So, the flux that goes up actually in any case that is the illumination and this is that goes to the floor.

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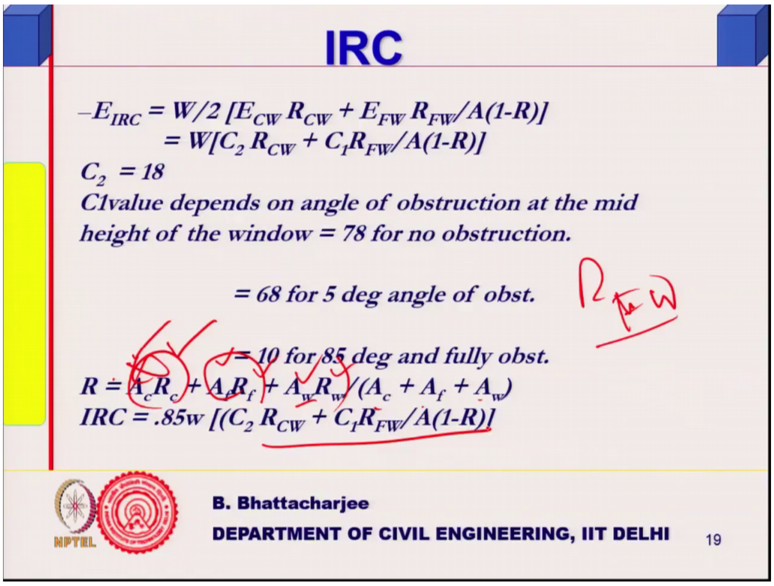

So, elimination of the window surface must be known now this has been simplified further or rather you know what W by 2 area of the window into A divided by R. Now this is written in terms of some constant this is written in terms of some constant C 2 and this is written in terms of some constant C 1 right. Now this values are given in the, this values are given C 2 is going to the ceiling so it comes from the ground right.

So, assuming the ground reflections reflectance to be about 18 percent it will depend upon vegetation type, the location type, for example, if it is subtropical it could be 10 percent in a tropical hot dry desert area could be about 18 percent or 20 percent. So, Indian code takes it to be 20 percent so this is all in percentage. So, this is taken as C 2 is taken as 18 percent reflectance right 18 percent reflectance and C 1 depends upon the if you have an obstruction. If you do not have an obstruction that value would be 78 again everything is in percentage divided by E 0, E 0 has also been taken into account.

Now, 17 is you know 78. So, this value is 78, for 68, for 5 degree angle of obstruction. So, if angle of obstruction is 5 degree for example, in this diagram if you had this angle of obstruction is 5 degree right here it is showing the full obstruction actually if this angle is 5 degree. Then this value is value is taken as 68 because 5 degree means 85 degree most of it is for 10 for 85 degree or fully obstructed.

So, if the obstruction is full, because then the light comes from external obstruction only. So, I R C is contributed by flux coming from the external obstruction so if it is 85 degree or full then this value is much less if the sky is open then you get 78 fully open 68 for 5 degree angle of obstruction little bit is obstructing rest all is free.

So, this is again given in table. So, C 1 value is given C 1 value is nothing, but the one comes to the floor right. So, this divided by E 0 has been already done. So, E you know elements are not ah is yeah this is already done actually E E R C multiplied you know this constant divided by E 0. So, this C 1, C 2 divided by already E 0 is taken into account and this is how we can calculate out.

So, what all that you have to do is first calculate out the R F W R C W and R a stands for total internal area including the window and everything internal surface area and C 1 and C 2 you have to and this is the window area C 1 and C 2 you have to determine C 1 is C 2 you take eighteen straight away because E R C will be I R C will be in terms of percentage 0.85 is taken if its glasses are closed.

So, assuming that transparency of the glass is 0.85 and R is calculated in this manner as explained here area of the ceiling into R of the ceiling area of the floor into R of the floor area of the wall into R of the wall divided by a C a, everything all you know this divided by sum of all this that is what is R as far as R W is you know R R F W is concerned R, F W is concerned F W is concerned this part will be there this will not be there and here it will be half of those area minus area of the wall also.

So, R F W R C W will calculate accordingly and this is the formula for internally reflected conference this is the formula for internally reflected component this is the formula for internally reflected component right. So, that is how you calculate out.

Now, this is this principal only thing which will again matter here is this values that will depend upon sky type, but I believe this numbers have been adopted from international you know research only this values that is given this. Because you find in many of those illumination book daylight you know early daylight books these values are similar this is taken many other places taken as 10 percent for subtropical climate because reflectivity of relatively greener surface you know what you see in cold climate or that would be relatively less for sunlight whenever the sunlight is available.

Here it is taken 18 for you know they take to get 18 or some cases is taken as 20, 20 percent. So, 20 so these are we can calculate out I R C as well right ok.

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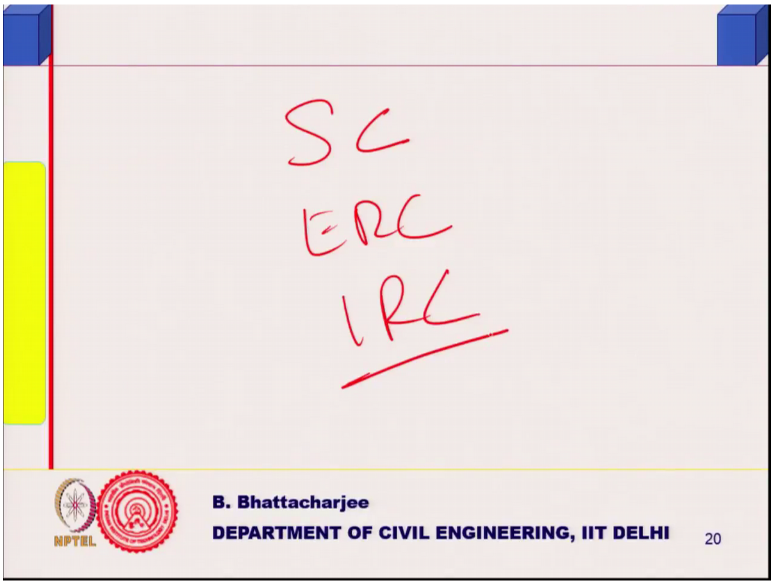

So, this is how you analyze point by point, but some qualitative ideas. So, what we have seen is we can calculate out SC we can calculate out E R C and we can calculate out I R C right. So, these calculations we can do, but then there is some kind of gross understanding.

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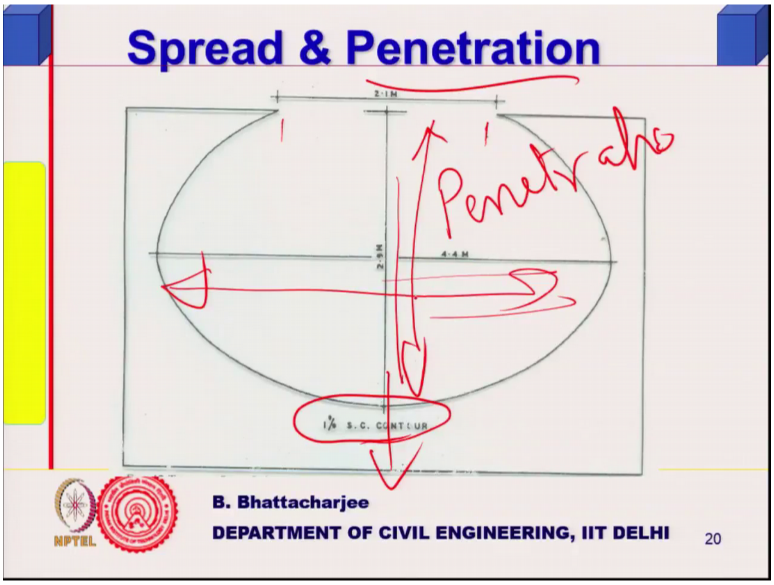

There is something called daylight factor contours sky component contours not daylight factor because I R C will be constant throughout the room including vertical or horizontal surface, because it is a diffused one coming from all points. So, I R C will be constant throughout right E R C will go from point to point again and sky component will go from 0.1.

So, we talk in terms of something called sky component contours because that will depend upon your fenestration area now you see the window idea is coming everywhere and window location is coming everywhere. So, if you want to design its design based on window location and area of the window, height L by d h by d s etcetera.

So, this is this is this is a typical 1 percent sky component contour. This is your window 2.1 meter is shown here and this portion is called spread, this is called spread of the spread of the daylight factor contour and this is called penetration. This is called penetration. And your common sense would tell you if you increase the height of the window the penetration for any person you can take 1 percent sky component or 2 percent sky component contour penetration will increase 1 percent let us say is minimum they are like sky component minimum sky component you want to ensure.

So, you want to find out how much is so penetration will increase as height of the window increases. If width of the width of the window increases then spread will increase so here it is 2.9 meter, 4.4 meter, depending upon the window and you know depending of the window.

So, under design condition or any condition that you can find out so these are called spread and penetration. Spread increases add you as you width of the window increases height increases then penetration will increase, but beyond 5 6 meter you do not find the spread and penetration so much.

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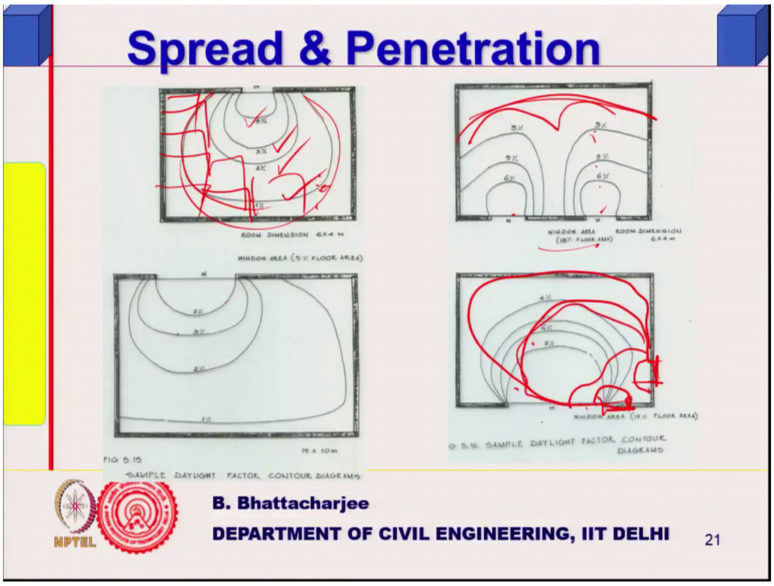

For example this for 1 percent contour sky component compound, this for 2 percent, this for 3 percent, this for 4 percent. So, there are contours you know equal sky component contour. So, there they like a bulb this spread so light 1 percent sky component means E 0 multiplied by 1 percent means 0.01 you will get around 8000 into 0.01 is 80 lakhs am I right so 1 percent of 8000 is 80 lakhs. So, 80 lakhs this is the 80 lakhs line having 80 lakhs.

So, if you have measured them or calculated them making them you know small areas and then you can make a counter plot similarly if you have 2 windows they would be something like this right. So, 1 for 6 percent, 9 percent, 1 percent contour might look somewhere there because they will merge you know it might come something like this or sometimes they will merge also 1 percent can do some merge.

So, spacing of the window is important if the spacing is less then they will merge and overall they will give better one and if it is in one side then you get something like this 1 percent contour is something like this. So, this is 7 percent, 3 percent, 2 percent, and that is how it is if you have more of such diagrams are given more of such diagrams are given.

For example, if you have if you have window here and here then you might get something like this sort of contour you know you might end up getting this sort of contour. So, if 1 window here, 1 window there so first initial 1 will be like this, but beyond that you will have something like this then you might get something of this kind. So, the day light penetration of spread increases in this manner.

What we have seen is in analysis there is some design guidelines available, but they are fairly you know like empirical based on this kind of calculations only. So, point by point analysis is possible you want to find out you know like a qualitatively larger the area more will be the daylight penetration or daylight you know daylight inclusion.

Penetration do you want to increase the height, spread you want to increase you know increase the width then you can do the calculations point by point if you want to do you can do this calculation and find out how is the pattern of your light yeah.

So, this is how one can do some sort of typical design some design charts are also given in S P 41 you know like determining possibly window size, but they are based on similar kind of principles not really much more do you know not further details. So, that is what it is.

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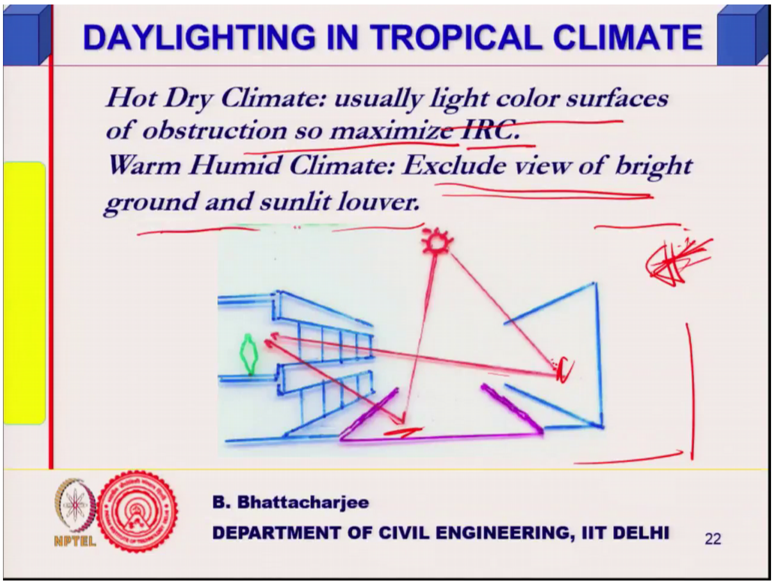

Now, in tropical climate tropical climate usually light colour surfaces of you know we use light colour surfaces for other building. Why we want as much as less absorption as lower alpha value we want alpha value lower for thermal reasons. Now you have high you know whitewash surface which will have high reflectivity so they are sometimes source of glare.

So, hot dry climate light colour surfaces of obstruction and they might be sources of glare actually. So, it is better to increase the I R C and I R C increase means reflectivity of the surfaces inner surfaces should be as high as possible. Because you know if you see it is it was related to I R C 1 minus R is I R C is proportional to 1 minus R right and then R C W n R F W. So, if you reduce the R if you reduce the R this value increases of course, this value increases right, but first reflected component anyway this 7, but overall R having more reflection having sorry if we increase the R what will happen this value will small 1 minus R you increase the R this value will be small I R C will increase I R C increases with increase of R increase of R I R C increases with increase of R right 1 minus R.

So, S R increases 1 minus R will reduce and 1 by 1 minus R will increase. So, I R C will increase if I increase the R value more reflected light more reflected light. So, it is important to have a maintenance of the even you know internal surfaces so that it does not accumulate dust maintenance factor we call something called maintenance factor which varies from 1 to 0.7.

So, more frequently you maintain the inner surfaces and make them you know more reflective better. So, I R C increases besides that I R C also you can increase by putting the fenestration somewhat above the, you know glare the ceiling.

What is the point is then you reduce the glare you know this I mean this kind of concepts one can apply, but then this is not very easy to do for example, you can have you know this reflected from outside or reflected from the ground some of them can result in glare. This can result in glare restriction wall side obstruction sometime in desert area this can be very bright.

So, they can cause glare so exclude view of bright ground and sunlit louver and then what you can do is you know increase this by putting your if possible some daylight, and allowing penetration area at the top because then directly you would not see them, but this one will be feasible all the time, this may not be feasible all the time.

So, usually light colour surfaces I R C you try to maximize and exclude view of bright ground and sunlit louver because that can result in glare. So, maximize the I R C as far as possible that would be the typical idea of you know tropical climate. Anyway north surfaces are better if you are in northern hemisphere southern surface southern we say better because that will not bring in direct sunlight.

But then you should not be seeing sunlit obstruction also that is what is being said that is what being said ok. So, that that actually. So, Indian design methodology I have just covered I have just covered Indian design methodology. So, we can you know it in questions and then next class we will look into something more right.