Energy Efficiency, Acoustics & Daylighting in building

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Lecture – 50
Daylighting (contd.)

So, we will look into glare further.

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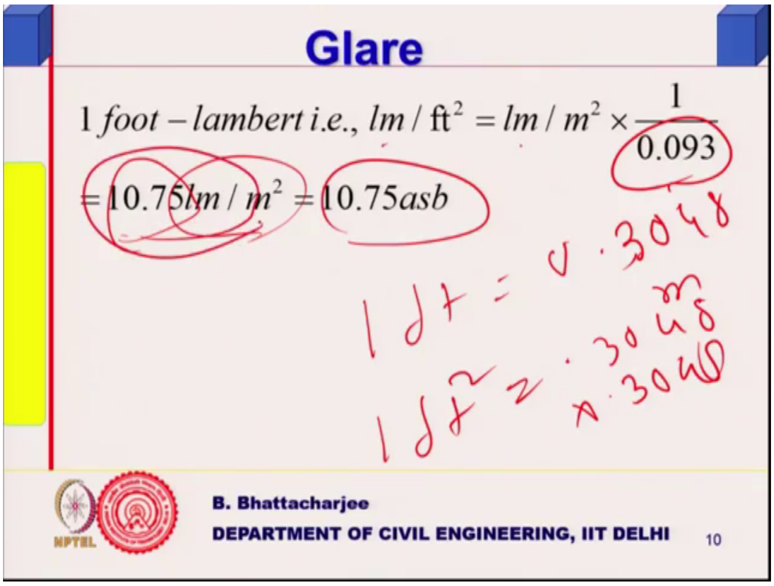

And this is the conversion from 1 foot Lambert to lumen per feet square. So, foot square 2 meter square, point if we remember if I remember correctly then no you know 1 foot was equals to 0.3048 meter right. So, 1 foot square is equals to 0.3048 into 0.3048. So, that gives us 0.09093 right something like this. So, converting the lumen to foot square 1.093 and 1 by pi because 093 is 10.75 right; lumen per meter square.

So, yeah like lux level is lumen per meter square. So, foot Lambert was lumen per feet square, foot Lambert was you know Lambert is the name of the scientist because that Lambert's law I talked about. So, initially they were using because they have not changed anything else if you have seen; 1 by 60 centimetre square right and 680 lumen is equals to 1 watt. So, you know they did not change there, but then feet square 2 meter square; So, therefore, that much lux.

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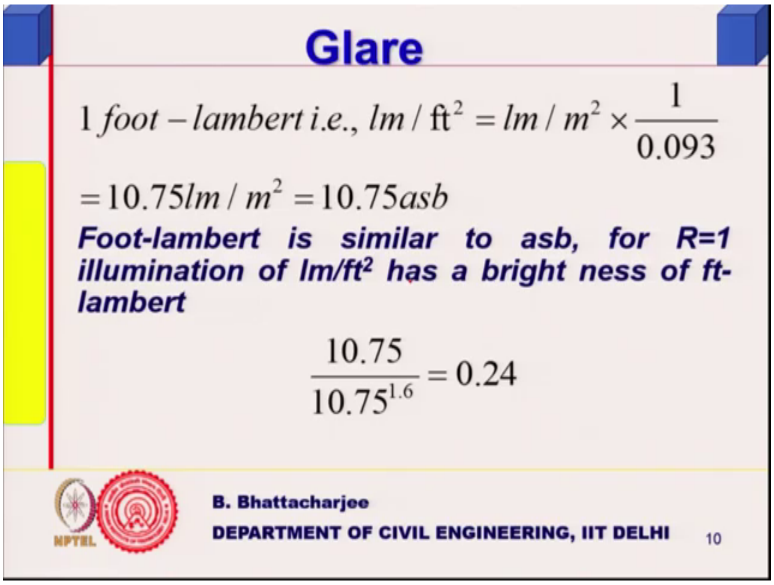

So, 10.75 a s b that is the first step. So, foot Lambert is similar to a s b for r equals to 1 illumination of Lumen per feet square as a brightness of foot Lambert and because in the formula if you have seen the brightness to the power 1.6 was there.

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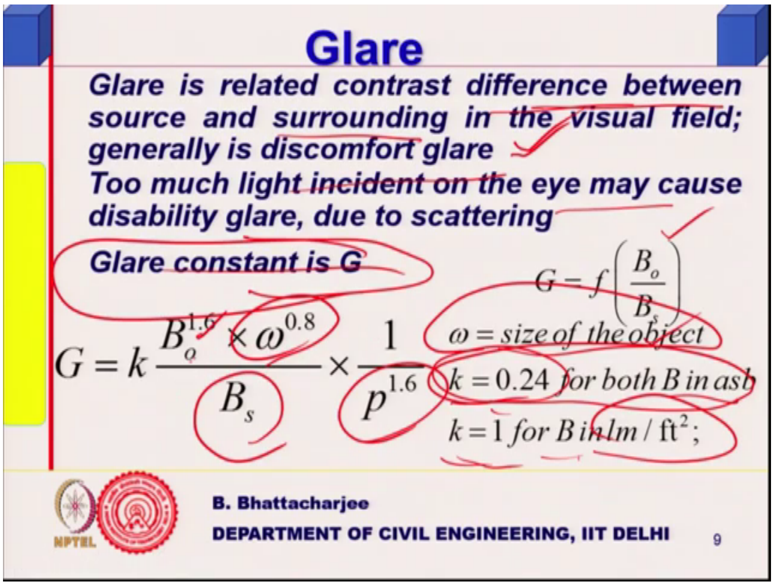

If you see the glare formula B 0 and this was in just there is no power, here there was a power. So, if you take dip this into account, then we get 10 to the power 75 and 10 to the power 75 to the power 1 6 gives you 0.24. So, when you are using because this s p 41 or some codes will straight away right k equals 2.24. If you use earlier formula would have been k k is 1 for lumen per feet square, k is 0.24 for lumen per meter square right. So, that is it apostilb.

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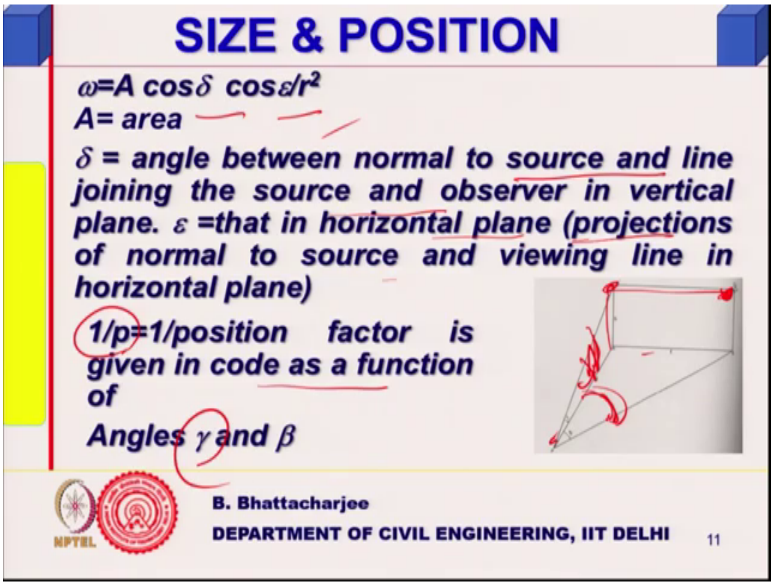

Size is given by A cos delta cos epsilon r square.

Now, what is let us see what is this angle derived do a diagram, yes I think I have a diagram no not I do not have a diagram. So, is it size is written as s cos delta cos epsilon by r square because size of the object size of the you know size of the what was omega? Omega was the omega was the size of the omega was the size the object size of the object size of the object right. So, this might be there may be 2 it may be you know its in 3 D space.

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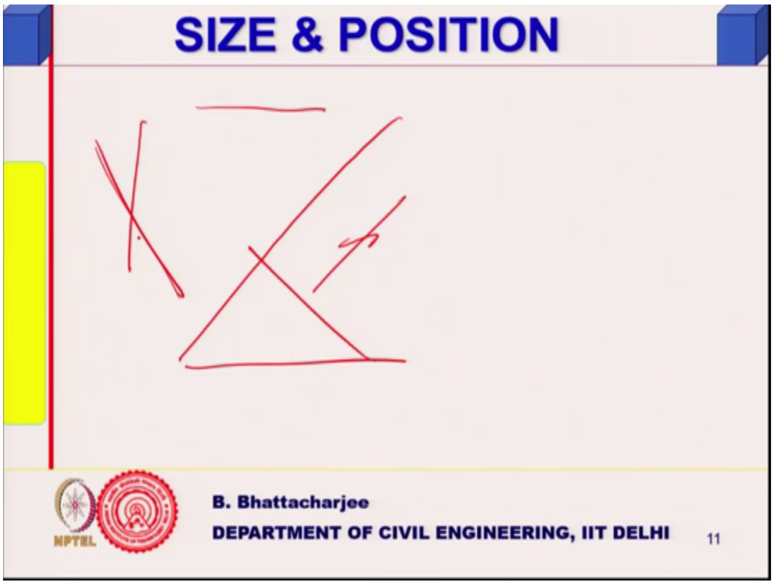

So, earlier you talked of horizontal surface and the projection was normal, but now it is not horizontal surface some other inclined surface somewhere some other inclined surface somewhere. So, I can talk in terms of 2 angles. I can talk in terms of 2 angles and that is what we are doing, that is what we are doing A cos delta and cos epsilon.

So, projection you know 2 project 2 angles are involved in the projection and delta is angle between normal to the source, and line joining the source and observer in vertical plane and epsilon is that in horizontal plane. So, this is your source let us say, this is your source line joining this the angle in there will be 2 angles one in vertical plane, another in horizontal plane. Azimuthal angle as well as a altitude angle reference altitude angle. So, if you take in the vertical plane.

So, these are the two angles through this actually size we are talking of. So, cos delta cos epsilon by r square, a is the actual area. So, delta is angle between normal to source and line joining the source and the observer in vertical plane right. And epsilon is that in horizontal plane right projection of normal to the source and being line in horizontal plane. So, that is what it is an angle between projection of normal to source and viewing line in horizontal plane. So, that is that is how A is found out ok.

Position factor is 1 by p its given in code as a function of gamma and beta. Now this is how gamma is defined. See this angle is in one of them is in beta is in horizontal plane gamma is in. So, this is your lamp the source, this is your objectives or object you know this is this is this is where you are looking at.

So, project position this is the object you know object make this angle in horizontal plane, this angle in vertical plane. So, 2 position factor with respect to with respect to your eye the lamp and object I mean that what you are seeing. So, this is one angle this is another angle. So, gamma this is gamma angle this beta angle and with respect to that it is given. So, maybe if we solve a problem sometime it will be clearer because this angles will become clear right this makes it.

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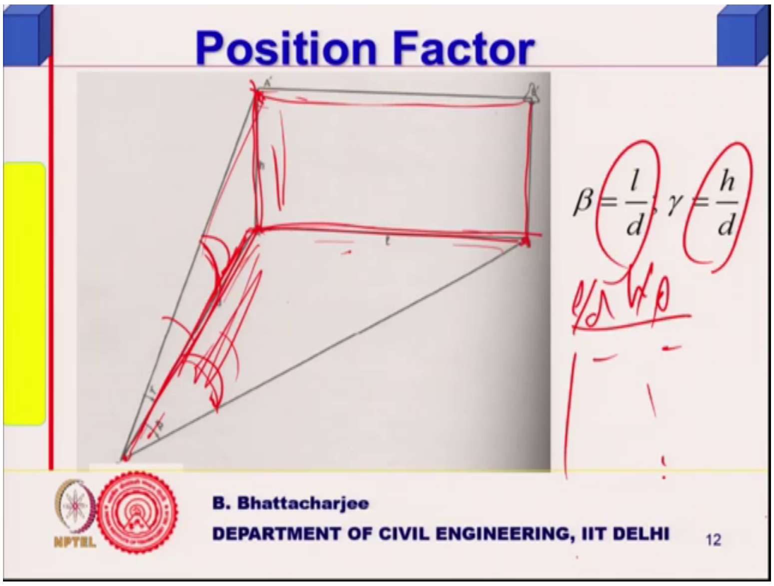

Yeah, this makes this is gamma angle, this is beta angle, this is object and l over l over d at a is object sorry a is object a is the object, address is a line vertical line I have drawn this is. So, this is in horizontal plane. So, the distance is a b divided by d is this angle and h divided by d is again another angle. So, what I do is, I project my object in the vertical plane you know same as say I mean in the same plane as this and this will be the this will be this will be the angle and this will be the other angle. So, something like this beta is equals to l by d and this is h by d.

So, what I do is, this is not this in vertical plane, but this is not horizontal line. So, what I do is, I join my eye to the object. Join my eye to the object draw a horizontal line here, which cuts the projection of the source right somewhere there, and draw a vertical line here which cuts the horizontal line from the source here this is the angle and this the other angle this is the other angle this distance is l, this distance is h and that is how we got it right.

So, position factor is now this is given this is position factor values are given in table in terms of l by d and h by d in terms of l by d and h by d. So, these are given in terms of l by d. So, you have a table where l by d is given, h by d v is given on this side and position factor values are given somewhere in a tabular form this is empirical. So, we cannot do much about it, I cannot derive this for you all right. So, this you have to you know somebody has to give you those values then only you can calculate alright. So, this is what it is, this is what it is.

So, with these fundamental principles now, we can talk in terms of calculating like delight. Fundamental principles we have understood by enlarge right first we talked about what are the units, then requirement of lighting right for task illumination particularly and desirable things like no glare, no flicker quantity of light that we require all right, that is what we have seen. So, now, we can go to daylight.

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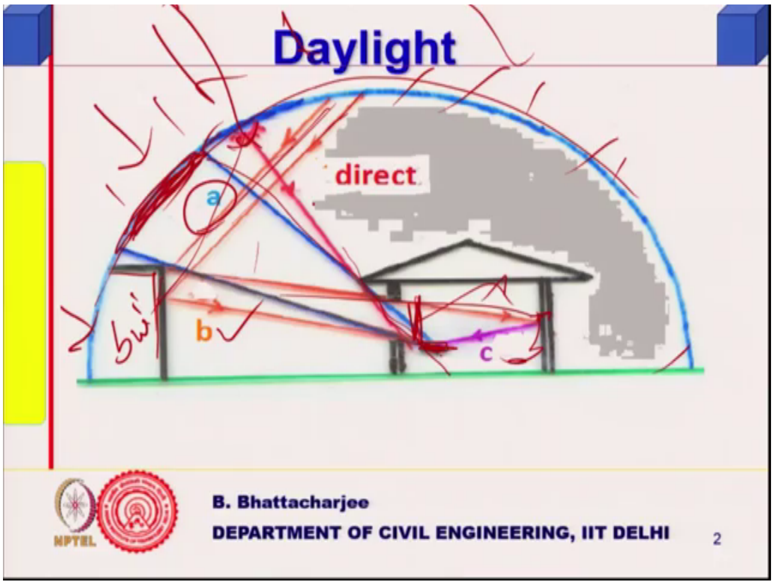

Now, if you see how light does how does light come on to from you know if I have a window something like this. Something like this let us say I have a window somewhere in a house oh somewhere in a house; someone in a house I have a window. So, I have a window somewhere there, and this is the plane where light comes.

Now light can I am talking about daylights. So, from comes from the sky finally, and this is my sky vault sun is somewhere there. So, some direct light will come into the room, but this portion of the sky from where the light can come onto this point, it comes from the diffused sky this portion of the sky because this is illuminated already by the sun rays that not directly, but eliminated. Because sun's rays will come from all the sides is sun is too big only I am viewing it here right.

So, diffuse sky radiation comes from all the places; Even if you do not see towards the direction of the sign you will see the bright sky on the other side right if it is clear sky no cloud or anything of that kind. So, you will see total sky on their side. So, diffuse sky. So, this area which will be an area actually transmits some amount of diffused light to this 1 let me call this as a.

Then some of those from diffused light from some of those places can get reflected in the next building next or sunlight directly can get reflected from the next building and this will also contribute to the light onto my table, where I am interested in finding out what is the light. So, that we call this as b and some light which comes inside here will get all internally reflected and that we could c. So, there are three components of daylight which illuminates the place this you know working plane as we call it.

So, working plane what is working plane? Working plane is something like your table on which I want to find out the desirable level of light or it could be table or if you are reading or a blackboard or whatever it is. So, that is the working plane.

So, working plane on which I am interested in finding out the amount of light. So, daylight contribution to the working plane comes from three sides; it comes from three things, one coming from the directly from the sky vault diffuse radiation from the sky vault. Diffuse sky radiation it can come from reflected from other building right other building trees or anything external objects and third is whatever comes in other points in the room, they will contribute to reflected light to this point you know it comes to some other points.

So, there are three components and the fourth one is a direct light. Now, I do not want direct light because it will bring in heat and it can also cause glare.

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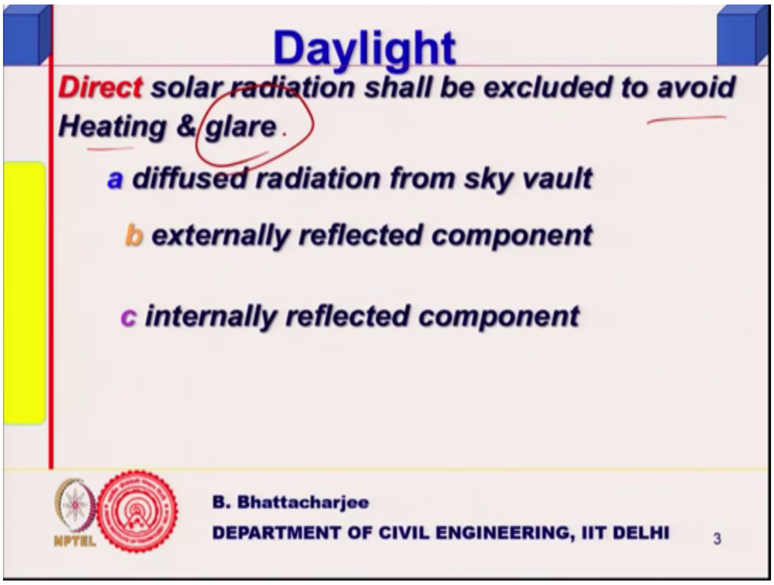

So, direct light is not desirable, its excluded should be avoided for daylight right as much as possible because it will bring in heat in tropical climates and it can also be close up glare because its brightness is too high brightness is too high. At a is diffuse radiation from sky wall, b is externally reflected component and c is internally reflected component like we talked of integrating sphere, c is that internally reflected component which will be diffused light coming from all the walls and ceiling and roof etcetera etcetera because some light is reaching somewhere some diffused light or direct light is reaching direct light.

So, I we will like to avoid some diffused light is reaching somewhere in the room and that is causing that would right so, that will contribute to internally different component.

So, diffused radiation from sky vault, a externally reflected component and internally reflected component. Now this amount which comes in I can calculate out E contribution from each one of them I can contribute illumination contribution from each one of them, but this will vary from time to time day to day right. So, actually this will vary from day to day time to time. So, calculating this I can calculate alright provided I know the sky condition, which will change from time to time because sun's position will change day to time to time in a day and day to day, and then in seasons also the clouds and etcetera will come.

So, this amount if I calculate is too variable too much variable actually; therefore, designing my what I want to do? I want to design my fenestration window areas window location such that I get maximum daylight. My objective is to design the fenestration areas and their location in order to get the maximum amount of light from the sun.

Now, since this will vary from time to time day to day if I select a window location corresponding to our window area, corresponding to one time it may not be satisfactory at other time. So, it becomes a difficult thing, but one thing is interesting.

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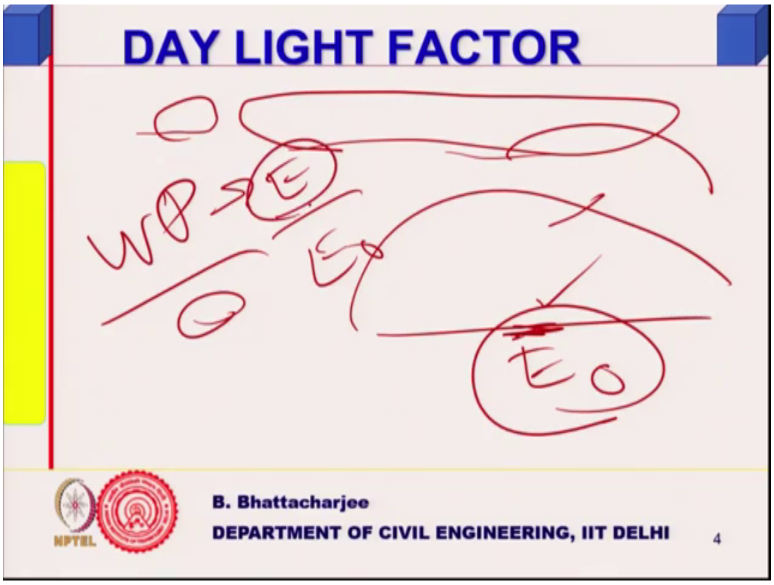

A ratio of daylight you know ratio of outdoor illumination in open to illumination at my point a given point, this ratio tend to remain constant. Because after all it is the daylight, if I find out what is that you know amount of light in open like from the sky volt whatever the light in open area, then the ratio of the illumination on my working plane to this E 0, I call it E 0 the illumination in open unobstructed location unobstructed point this ratio.

So, at working plane let me call it as E divided by E 0 this remains by large constant why? Because this is contributed by the sky, sky condition right and a part of it is coming through the windows here. If this bright this illumination goes down this will also go down. Besides that my I guess adapted depending upon for example, on it you know in a cloudy day, your aperture will change to in a bright if the brightness is too large the I would adjust itself.

So, therefore, this ratio has got a meaning this ratio tells me you know this ratio should be as high as possible for my for the given fenestration that I have provided, that should be as high as possible that will mean that the day light is I am getting right kind of day light. So, people started thinking in terms of something called daylight factor.

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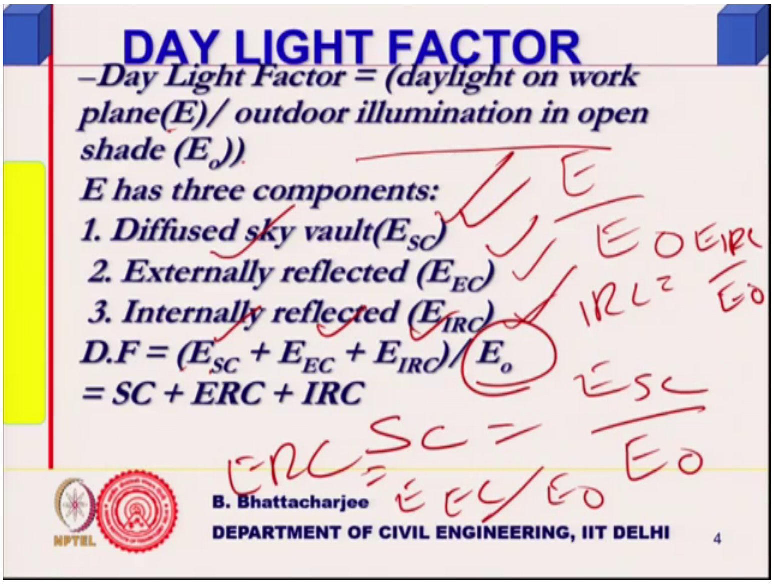

And daylight factor is defined, daylight factor is defined as the ratio of E divided by E 0 E divided by E 0 day light factor is defined as the ratio of E divided by E 0.

So, now then this ratio must have three components, because E had three components right one is due to the diffused sky, another is due to whatever is coming from outside and third is due to internally reflected one. So, we have three components of this illumination, diffused sky vault we call it sky component, externally reflected component coming from that b I was talking about. And internally component is c that I have talked about and; obviously, the direct component d we want to avoid we do give that.

So, daylight factor will have then three components, chi component etcetera etcetera and all divided E zero. So, sky s c sky component is nothing, but E s c divided E 0, E e c E e c divided E 0 is ERC, we call it ERC and I R C is nothing, but E I R C divided E 0. So, these are three components of day light factor and often we actually say in specifications that I must have a minimum 1 percent daylight factor in corridors in nursery school, you know you are combining two things one the lighting level should be good adequate and it should be natural lighting. Like particularly in school this is very important, you should get you know the children should get actually natural light. I am not very sure is it related to issues like vitamin d or something like that kind of thing, but the code specifies because you know the body can absorb vitamin d, only when you get sunlight of a particular time also there says too bright sun does not give you that.

So, therefore, in many of those codes meant for schools, they will specify the daylight factor in this space it should be so, much percentage. So, minimum 1 percent 0.5 percent daylight factor and things like that; which means that you are ensuring that you get adequate light, but that too from the sunlight you know and school is; obviously, daytime generally not supposed to be in the evening for especially for those children right. So, it has got three components. So, therefore, we rather try to maximize a daylight factor often rather than simple daylight.

Now, how do I do that? Sky changes, sky changes you know sky changes and sky keeps on changing from time to time day to day etcetera etcetera. So, we talk in terms of I want to design and windows and fenestration I design only once, I am not going to change it of course, I can put curtains and blinds and things like that, but that is not the best way to do I when after all windows I would not be changing. So, I have to have something called a design sky.

Now, you see the we have calculated out that E 0, if it is uniformly bright sky, then it will be simply pi into b. Remember we calculate how to E 0 will be pi into b and for any window I should be able to find out because integration from 0 to 2 pi and 0 to pi by 2 gave me in open space, for any other space any other opening I can find out because they you know the limits of integration will only change limits of integration will only change, but I got to know the sky brightness which is not uniform.

So, one can think in terms of what is called a design sky. Because design is done once only window areas fenestration areas and fenestration locations they are fixed once, and that I should do corresponding to a given sky right and that sky is nothing, but design sky. So, design sky will be defined in terms of its brightness.

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So, brightness of the sky changes with time, for design it is necessary to use a standard by bright brightness pattern of the sky and such a condition defined by standard sky brightness pattern is known as design sky designs sky right design sky. For example, one can use I mean ideal condition one could have use for subtropical climate overcast sky, but that is not used C I E skies are there. 15 of those are there I will talk of some of them right most time if we is taken to be constant with uniform brightness.

So, supposing I take that as an ideal sky that will be a design space, but that is not the case that is not the k. In fact, as I said that they have actually established 15 different type of sky and more than that in fact, there is a model called Paris model which relates to the radiation received as well. So, we will discuss that sometime later on, but first let us understand what we mean by design sky. So, sky pattern has to be chosen.

Now, its very important from another point of view. You see today you have got all sorts of software's, which can calculate out the which can calculate out the daylight also in addition to doing you know thermal heat transfer calculation and then telling you what will be the cooling load for a given space right like I mentioned might have mentioned like E quest energy plus I think this is echotect there are several of them software's, which actually does some of them does only the energy calculation, some also takes looks into lighting also.

But then you have to choose a particular type of sky for particular location. So, if you choose a wrong type of sky for let us say Delhi or tropical climate as this, you will end up with all sorts of wrong kind of predictions or wrong kind of answer. So, identifying the right kind of case sky is very important out of those 15 skies because it varies right. So, that is design sky concept.

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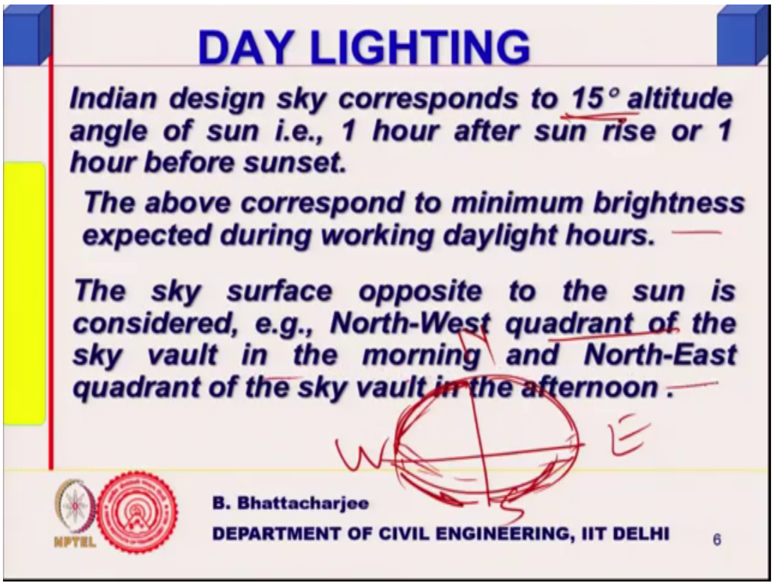

Now I will tell you about the currently existing design sky condition or sky that has been used in Indian condition, in the Indian code s p 41 or the code 2446 or whatever it is 2450 or 245, I do not remember the exact code name, I mean number now, but s p 41 gives you this all detail this was done wrong back in nineteen sixties some research you know some measurements were done at CBR Roorkee.

So, based on that they did came out with this sky and you know limited I would say 1 need not want one may relook into it although the code have not really rule relooked into it, there is a need to relook into it or in fact, there are article stating that there is a need to relook. So, this corresponds to this is very innovative actually.

So, idea was very innovative they correspond it to 15 degree altitude angle of sun. This one corresponds to 15 degree altitude angle of sun by the way this paper was published in French language in illumination journal, somewhere other I had the translation of it, but I do not find this translation neither the paper now, but it does not matter any other essence is with there with me and s p 41 gives it all complete. So, 15 degree altitude angle of the sun, they took for design sky.

Now, 15 degree altitudinal of the sun corresponds to what time of the day? 1 hour after sunrise over 1 hour before sunset right and that is the time when you left the least brightness of the sky because sun is at lower altitude, sun will now rise and brightness will increase. But activity office activity or you know most of your activity human activity related to daylight starts after that time it will be you know; obviously, much later than 1 hour after sunrise and much before 1 hour you know before the sunset.

So, they choose this 1 hour or 15 degree altitude angle of the sun and did some measurement too, and you know this corresponds to minimum brightness expected during working hours, working daylight hours and what they did is, you cannot in tropical climate the direct sunlight is not wanted.

So, they choose the opposite sky vault because sky can be divided into 4 sky vault can be divided into 4 quadrants. So, this is your east, this is north, this south and this west. So, sun rising somewhere from there to going somewhere there in summer or winter going from here. So, what they choose is, see that the sun is either in this quadrant or is in this quadrant.

So, 1 hour after sunrise they took the brightness from this quadrant brightness of this quadrant, opposite to the sun right and 1 hour before sunrise this quadrant. The reason is that, that is what should we use for design purposes and your lighting should be your window should be mostly north side. So, that you get the maximum daylight, but not direct sunlight. Even if you have windows on the you know not north sight, but on the southern side you will have some shades to block the only the oh yeah the you know the direct sunlight during summer, but winter, but in anyway diffuse skylight would be there.

So, therefore, they choose this is for design purposes design purposes they choose this. So, northwest quadrant of the sky vault in the morning and north east quadrant of the sky vault in evening, north is you know that is what they choose. So, this is what it is right.

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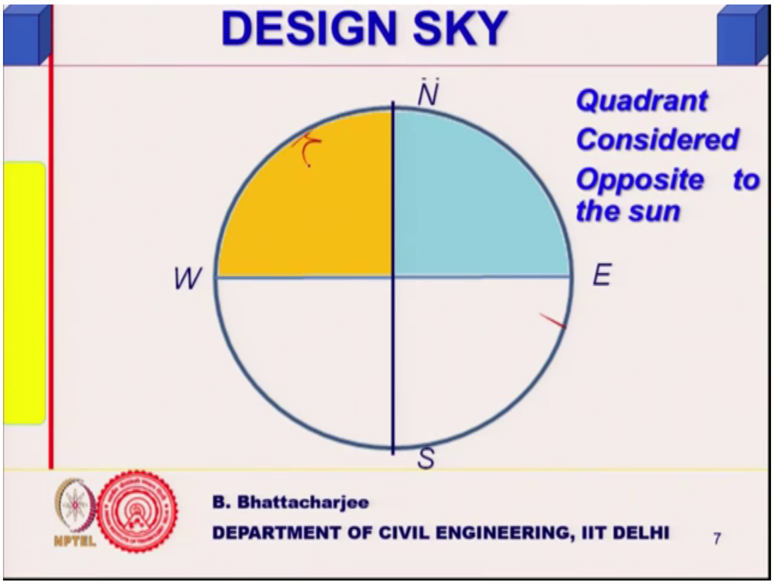

So, this is this is what they choose in the morning and this is in the afternoon this is in the afternoon. So, this is in the afternoon this is in the afternoon opposite to the sun. So, that that is what they choose and so, 15 degree in other words they are choosing some brightness somewhere there all right.

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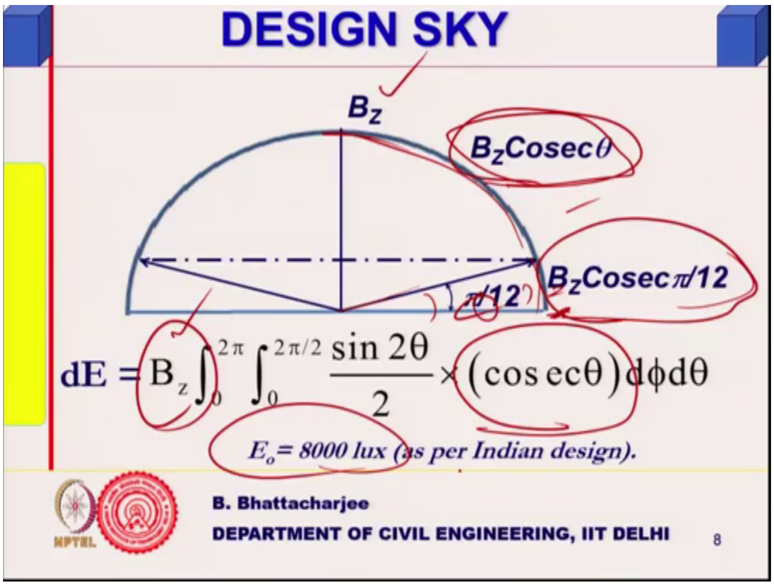

And then they did some measurement and based on this measurement also the conceptual understanding that brightness near the horizon is very high, they simply choose a function in terms of B z cosec theta. What is the this is theta? This angle theta, this angles are theta, these angles are theta. So, this angle is theta this angle is theta.

Now, what is cosec 0 infinity cosec 0 is infinity. So, you cannot use it. So, they choose this, this you know this is actually if you calculate them out or check with currently acceptable in fact, some experiments were done later in CBRI in the last you know 1990s etcetera etcetera. Based on those some articles have come from electrical engineering of Jodhpur University very interesting. But we are not able to lay hand onto the original data that was generated in severe I, by the same gentleman who also worked in the previous one.

That is more realistic measurement because this is a international program from where it came and; obviously, it does not match you this, because that they did at that time, but currently still exists in the code. So, I am talking today of this 1 I will; obviously, give you the other ones as well. So, this is virtues B z cosec theta that to add the near the horizon the brightness is maximum, because we said tropical countries brightness is very high near the maximum. Now, it is in defined it is not defined it is undefined here. So, what that it is, they said that up to pi by 12 that is 15 degree this brightness is constant right, which is given as B z cosec pi by 12 and B z cosec theta in this range B z cosec theta in this range right B z cosec theta in this range.

So, thereby this is how they define this sky and this is at one you know on the quadrant that I talked about at 7 1 hour after the sunrise or 1 hour before the sunset and that is used this design sky, that is not the sky actually will be there. That is the design sky to find out the fenestration and the whole table charts all develop based on this sky, which is there in s p 41 you know just that code that I talked about. So, this is based on this. So, this is the design sky they use.

So, you want to find out d E open in open simply now, use cosec theta instead of B z zenith brightness multiplied by cosec theta, B z is a zenith brightness multiplied by cosec theta d theta d phi you know earlier I had simply b, remember this was b. Now it should be b was constant, now it should be B z cosec theta and tables have been generated based on this, but then they did not have robots computational facilities those days they did it in some intuitive manner, some engineer in genuine you know ingenuity was there I will discuss those, but come to the current scenario how you can do it actually today I let you know later on.

So, right. So, I think that is where we stopped today next class we will look into details of this sky component tables and things like that, and they found out 8000 lux as the by their calculation from 0 to 2 pi, 0 to 2 pi you know they did if you integrate this, this you can integrate anyway easily because this will be 1 by sin theta.

So, this fell easy come integration 1 by sin theta cosec theta is 1 by sine theta sin 2 theta is sin 2 sin theta cos theta sine theta will cancel out cosec. So, that is pretty easy B z were measured somewhere they found it out to be 8000 lux. So, that was that is still being used in the is code I think it needs modifications, somebody should actually press for it and possibly as CBRI is not doing this work anymore because the people who did this work they are not there and even the report is not available.

That is we could not find it so far, but let us see perhaps it will change sooner or later. So, look into the international once in the next class ok. So, that is what we will do.

So, we will do that in the next class.