Energy Efficient Architecture
Lecture 7

Daylight Factor

Daylight or the light of the day, is the combination of all direct and indirect sunlight during the daytime. In simple words, whatever you see, whatever gives the ability to see objects without any external, mechanical systems is known as daylight. When you come out, you see everything that's present. The secret behind this capability is 'daylight'. This includes direct sunlight, diffuse sky radiation and often both of these reflected from the Earth and terrestrial objects. It includes not only direct sunlight radiation but also the reflected sunlight radiation that has been falling on buildings and reflected back to you. Sunlight scattered or reflected from objects in outer space that is beyond the Earth's atmosphere is not generally considered daylight.

What is the importance of daylight? Why do we need it ?

Windows that admit daylight in buildings are important for the view and connection they provide with the outdoors. If you are sitting in a closed room without the presence of natural light, you will see stressed since you are isolated from outdoor space and the building is completely being shut inside and creates some of the phobia for the users. Daylight is also important for its quality, composition and variability. Even though we have a wide range of artificial systems that's present right now, the clarity and the range of spectrum that daylight can give cannot be compensated by any type of artificial lighting system that has been innovated. A review of people's reactions to indoor environments suggests that daylight is desired because it fulfils two very basic human requirements; to be able to see both a taks and the space well, to experience some environmental stimulation. The presence of daylight is not only important to see what are we doing or what is present around us but to also keep us connected between indoors and outdoors or for us to be connected with the environment that is present around us. You might observe sitting in a closed room, you might feel really stressed, depressed or you might even feel completely let down because there is no sunlight. If you have to be in a good mood, you need to have a lot of daylight present in your design.

What is daylight factor?
The ratio in percent of work plane illuminance at a given point to the outdoor illuminance on a horizontal plane. Evaluated under cloudy sky conditions only, (no direct solar beam) is called a daylight factor. Daylight factor is a proportion of how much light you have on a table or a working plane and compare it in relevance to the amount of light present outside on a cloudy

day. The proportion between these two is called the daylight factor. The daylight factor is defined as -

DF = (Ei/Eo) x 100%

Where, Ei is illuminance due to daylight at a point on the indoor's working plane i.e usually on a table surface, how much light we have is called Ei. It is usually kept around 800mm from the ground plane and Eo is simultaneous outdoor illuminance on a horizontal plane from an unobstructed hemisphere of overcast sky. It is in relevance with how much light you have on your working plane. At the same time, how much light is present on the outside without the obstructions due to buildings around it, vegetation, without any obstruction how much light the environment has on a cloudy sky day. That is called Overcast sky day. There are three possible paths along which light can reach a point inside a room through glazed windows.

Light from the patch of sky visible at the point considered, expressed as the sky component (SC). When you come outside and when you see the sky, without any obstruction, how much light you can see is called the sky component. Light reflected from opposing exterior surfaces and then reached the point, expressed as the externally reflected component (ERC). As we saw earlier, daylight is a combination of three factors. These are the three factors that also contribute to the daylight factor; the direct patch of sunlight that we see on an open hemisphere. Also, due to the obstruction that is present around the building, whatever light hits the exterior surface of obstruction, it's being reflected to a point is also added to the daylight factor. Light entering through the window but reaching the point only after reflection from internal surfaces, expressed as the internally reflected component (IRC). If there is a window very close to you, there is sunlight coming through the window, it doesn't directly hit your works plane, it usually reaches your sill, gets reflected onto your ceiling and from the ceiling it again bounces back to the working table in which we are considering. These are internally reflected components called IRC.

The sum of the three components give the daylight factor. The daylight factor is SC which is the unobstructed sky patch + ERC which is the externally reflected component + IRC which is the internal reflected component. Why do we need to calculate this Daylight factor? Let us see its purposes and uses.

It helps as a guideline for determining the quantitative characteristics of daylight in a particular work space. How much light we have in relevance to outdoors? How design can be made to improve its quality or improve its luxe level? To understand this better, we need to know more about Daylight Factor. Based on these guidelines, it can be determined whether a room has

sufficient daylight. Depending on all the analysis we are going to make, it will tell us which room will have more daylight and which will have less daylight, which area of the building. According to that, you can place your study rooms, your bedrooms; depending on the daylight levels, how much you might need according to your activity pattern on everyday basis. In certain cases, you may even dictate a change in the design. For instance, if you have already designed a space where the living room has less daylight factor, this means that for a long period over years is going to be very dark. Living room is an area in which people are going to use the space more often when compared to the other spaces during daytime. Hence, we need to have good daylight in a living room. This can dictate even your design to be changed and can contribute to very positive changes in your design.

Daylight Analysis

Let's move on to Daylight Analysis. Why Daylight Analysis? When doing daylighting analysis, you're typically trying to answer some fundamental questions that include - Can you improve the form of the building or room to get more natural daylight? Since the daylight factor is a combination of sky component, external reflectance component, internal reflectance component. You can even articulate your building forms in such a way that high forms of daylight can be diverted outside or made into certain forms by reflecting the daylight onto your workstation. Can you get enough light for specific tasks? If it is a task oriented design, if you need almost very good daylights say 1500 lux levels, if you doing some intricate work on work planes, you might need high levels of illuminance. To understand which points will need this high levels of illuminance, you need to undergo this analysis to understand this better. How much can you offset artificial lights with daylight? If you're making all this effort it must eventually contribute to reducing your energy bills or usage of your artificial lights. It has to be restricted only during the night hours when there is no sun and you have no other choice but to use artificial light. To understand how beneficial it is to use this technique is what we are going to learn further by understanding Daylight analysis. Is light well distributed and not causing glare? By this we can understand how the light is being shattered in space if the light is reaching from one end of the source say windows present on one wall. If the light that is entering through the window can reach the end of the room or if we need extra additional windows as openings to let in more natural daylight, to fill the entire room with natural daylight is what we can understand from this type of analysis. If there is excessive daylight causing glare, we have a living room in which we have a huge TV and there is a lot of sunlight causing glare on the TV screen, there is no point in having windows. You need to make sensible choices to cut down extra daylight which is causing the glare or the occupant discomfort.

Let's see what are Sky Conditions and what are the different types of sky conditions that are usually and predominantly used?

Sky Conditions are usually daylight varies depending on sky conditions. They are usually 6 different types of Sky conditions, one is completely with the sun, one is completely coudly. Whatever different ranges in between represent different proportions of daylight and cloudy conditions. Sun is the main source of light. The entire sky dome emits light blue to an atmospheric scattering and a reflection of clouds. This also contributes to Daylight Factor which scatter from the atmosphere and also the clouds, the reflection happens due to the presence of clouds.

Standard types of Sky are Clear Sky and an Intermediate sky. Clear sky is the sky that we usually experience during summer days in which there is no cloud at all. The intermediate sky is the one we experience usually during spring months in which there are partial clouds present and also there is direct daylight that we can also experience. This is date dependent. Depending on which period it is going to come. Overcast sky is usually the sky condition that is completely cloudy and you cannot spot the presence of the sun. The Uniform sky is the one that usually has the presence of daylight, through the whole day it is the same. Catering of clouds is completely uniform throughout the atmosphere. This one is not day dependent because even for one hour we can experience an overcast sky condition or uniform sky condition. The other two are usually day dependent or seasonal dependent. The overcast sky is the most widely used, representing the worst case scenario. When you are looking at these four sky conditions, what you might observe is, the one that has clear skies is the one that is going to give out high amount of daylight. The one that has uniform skies is the one that is going to be covered completely with cloud and the daylight which is going to come in is going to be very less. We usually choose the uniform sky condition to evaluate the daylight factor in order to satisfy for other sky conditions as well. When you are designing something for a worst case scenario, obviously even the condition gets better. You are benefitted more out of it, this is why we usually use Overcast sky condition.

Daylight Simulation/ Calculation Methods - there are usually two main calculation methods to understand daylight analysis. One is BRE Split-Flux Method - simplified method used by Ecotect internal engine. Takes into account;

SC - sky component
ERC - externally reflected component
IRC - internally reflected component

This method is the one that is already present in ecotect which is an environmental awareness software. In which it takes into account all the three components that contribute to daylight

factors - Sky component, External reflectance component, Internal reflectance component. Ecotects allows for 'increased accuracy' considering factors such as colour of external obstructions, etc.

Raytracing/ Radiosity - more accurate calculation method used by Radiance. This also works in ecotech, but this is a plugin that has to be installed in ecotect to understand the daylight analysis in much more accuracy compared to the BRE split flex method that is already being built-in. It is better to use radiance which is a plug in, in ecotect to analyze the daylight. In simple terms it traces 'each' ray of light to determine the light incident in a given point/plane. Comparatively, Radiance is advantageous because it traces each ray of light that has been entering in your space in which surface it falls, it is being reflected, where it's being reflected and how it is getting distributed. Everything is being calculated for each and every ray of light that falls on your building.

Understanding Split Flux - Usually, this is how the split flux method works. As you can see, this is the window and this is being taken as the selected window, the light source from which the exterior light is going to fall and is going to get scattered. This is the one method which is built in with ecotect.

Ecotect Vs Radiance

This is daylight analysis using radiant analysis and as you can see, this is a skylight where that is a source of light through which light is going to come into the building. The light is getting distributed. This area is going to have 20% of light when compared to the exterior. Outside is 100%, only 20% light is coming inside and its being distributed because of your internal reflectance factors and as light enters, it is going to hit this surface and get reflected here. It's going to hit back and bounce back. All this internal reflection is being traced out. Next is Daylight analysis by Daylight Factor. This image is derived from Ecotect which uses daylight analysis already built in. As you can see here, the light enters but the light is scattered only where there is skyline but this is not the true scenario which you will observe in day to day life. So, even if you have a window at one point, you won't see the light falling only that lane plane, plane of line in which the light is going to fall just below the window. Usually it gets scattered but there is a lot of internal reflection and refraction that happens, which makes the light scatter in your room. As per the results produced in radiance analysis shown in the first image, this is much more accurate because it traces each and every ray of light. Let us have a closer look as to how radiance works. These are some of the images on outputs that ecotect can produce. By the usage of radiance for daylight analysis.

as you can see, this is a picture of an interior where we have a lot of reflection happening on the ceiling, floor, shining materials, etc. All these are being taken into account when we use radiance. It also traces how the reflection happens. As you can see, in the next image, this is considered as the light source. There is the skyline here. As you can see, there is gradual difference in the flux levels. The ones that are present here, the orange ones, as you can see in the image on the left hand side, it has 3,750 lux. When compared to outdoors, it has a very good amount of lux because it is very close to the window. As one moves a little farther away, this is how the lux level reduces and can be observed everyday in real life scenarios as well. This is one more image that traces the sunlight that was let inside because of the presence of this window. This lets you make decisions with regard to placing your furniture.

Radiance through Ecotect - this can be made even for the entire floor plan. As you can see in this image, these spaces are going to have very good amount of daylight. These are spaces that have almost no daylight at all. When you have some such type of results, you will know at which place should you increase the presence of of windows. Some places, you don't need that much light. Let's say if this is the bedroom, you don't need that much of daylight present because you are going to use this space only at night. Presence of a lot of windows at your bedroom might invade your privacy. Considering both, to achieve a balance, we can reduce the number of windows to cut down the view to the exteriors during the daytime. This external room is like a study room, the daylight comes through very small openings here. The daylight isn't reaching until the end of the room. So you might want to keep more windows at the other end of the wall. Let more daylight come inside your space and reduce the usage of artificial daylighting. These type of design decisions you can make with the help of daylight analysis by radiance.

Radiance advanced can help you produce such images. This makes use of different textures, materials, colours, reflectance of those materials and colours is also being calculated and taken into account to give much accurate results. As you can see, these are some of the image outputs that are being produced by radiants.

Radiants flow from daylight SIMS - In ecotect you need to export a scene with a geometry and you need to specify the materials where your sky or light source is. What type of sky condition are you using? Which climatic condition are you going to choose for your site? All this falls under that. If you are going to do a radiant analysis for a room like this, you need to make another room just like this, in your ecotect model and you need to set a camera to know where the daylight analysis should take place and in which area. Point and Grid, you need to divide your building plane into smaller grids to trace the daylight that has been falling from the external source. This is how the input parameters run because of the inputs. It produces

pictures like how we saw earlier. Those are some of the results produced by this method. It also makes traces of values and datas, this is the one that shows how much lux level is present at each point after we divided our view to grid systems after this point and grid method.

First, when you are making a scene, you need to a make a building that is almost similar to how you are planning to design and then you need to give materials. For each and every wall, you can choose which material are you going to choose. Colour of which, you can see here along with the reflectance material. For each material, the reflectance value changes. You can write down all the surfaces and finishes you are going to use. Say for metal surfaces, the reflectance value is very high compared to normal surfaces being painted with a dull colour. You can track down all these different reflectance for the different materials you are going to use. You have to give input in this section, to render much more accurate results.

Next is daylight source. In daylight source, usually here in output generation, you need to give which sky definition intermediates with the sun. Usually the one that we use overcasts the sky's condition because that is a worse case scenario. If we can satisfy our design for the waste case scenario, throughout the year we are covered. We need to make all this other arrangements; if its an interior view, if you are going to turn off other daylights and such, this is the sky condition we have to define. What type designs skies? Usually in European countries, we have design skies at 3000 lux, which means on a completely cloudy day, the lux level present on the exterior is usually maximum 3000 lux. .In reference to the 3,000 lux, this is what you are going to get your results from.

We need to create a view of the building in which you need to make your daylight analysis in. You can cut sections and make views like this. Point and grid is where you need to make a space in grid pattern in order to understand much accurate results for daylight analysis. Here, you can choose according to which type of form you have. The offset can be adjusted. As you make this point grid, this is how your plane is. Your work plane is being divided into different grids and the height can't be adjusted. Usually for a work plane, you need to height at 800mm from the ground place, which means at a table height how much light is going to fall is what you will be looking at. You don't need as much as daylight on the working plane on your ground as well. Since it is not going to be used much.

After giving and incorporating all of your inputs, you need to export your model from ecotect to radiance. Here you have one option called export manager under which there is a tab called 'Radiance/ Daysim'. We need to click on Export model data to export it and then we usually get our raises. This is the standard types of skies in ecotect and radiance. Sunny without sun, Intermediate no sun, Overcast sky and Uniform sky. These are the sky conditions that we

already discussed earlier. Skies 'with sun' add a source description for the sun on the current position in the sky. Depending on where the sky is located in relevance to your ground plan, has to be specified when you are choosing the ones with sun.

Design Sky Illuminance -Overcast sky. Latitude based - based on statistical analysis of the sky illuminance. Tregenza Formula - based on hourly sun altitudes for the site. Depending on where your design is located, you can choose your design skylight condition, these are some of the examples for that. Moving on to Shading devices, good day light design, especially in climates with a strongly over-period such as as in North India, must address this problem in an integrated way. So if there is a presence immense daylight on the outside, you need to control it from entering the interior space via shading devices and the number of window openings. The window opening plus shading device must be seen as a daylighting system i.e a system which regulates the proportion of light entering the room, the part of the sky visible from the room to avoid direct sun and the distribution of light within the room. It cannot be separated from daylight, it has to be seen as an integral part with daylight and shading has to be made as a daylight system to control the presence of excessive daylight. The devices can be classified into; moveable opaque - this can be highly effective in reducing solar gains but eliminates views and impedes air movement. Eg; roller blinds, curtains, etc. Louvres - may be removable, adjustable or fixed-affect view and air movement to some degree. Can also provide security. Fixed overhangs - easy to provide with an overhanging roof or balcony. Also gives protection to walls and openings from rain. Little or no effect on view and air movement. These are the three types of shading devices that we predominantly use. If there is more sunlight, there is high temperature, we need shading. So more light means more shading and we need to have shade in such a way that you cut down more light.

To carry out the shading function one or more of a number of shading devices can be employed. The devices can be classified into three types; moveable opaque - this can be highly effective in reducing solar gains but eliminates views and impedes air movement. Eg; roller blinds, curtains, etc. In climatic conditions that have blazing hot summers and extremely cold winter periods, you can have systems in which they are 100% shut and 100% open. As you observe in this picture, this is an example of a shading device that's present in a building in an Arab country in which it can be completely closed or the percentage of opening can be adjusted according to seasonal variation. Louvers may be removable, adjustable or fixed. This can affect view and air movement to some degree but it helps provide security. This is how a louvre system is usually present. Fixed overhang - easy to provide with an overhanging roof or balcony. Also gives protection to walls and openings from rain. Little or no effect on view and air movement. In practice, shading devices are very varied in form and sometimes consist of

combinations of the above types. This is a fixed form, you can combine both louvre system, moveable and fixed overhangs.