Sustainable Architecture
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Lecture - 44
Indoor Environmental Quality- IV

Good morning, welcome to the 4th lecture of this week as part of this ongoing online course on Sustainable Architecture and we have been discussing about indoor air quality in this week. So, in the previous lecture, we discussed about the VOC compounds and towards the end of previous lecture we discussed about the controllability of lighting and thermal comfort systems.

So, today we will start with how to design the Indoor Environment for thermal comfort and visual comfort which is appropriate thermal environment and optimally lit indoor environment. Now, when we talk about lighting the emphasis here is to have as much daylight as possible and totally cut off the need for artificial lighting especially in the daytime.

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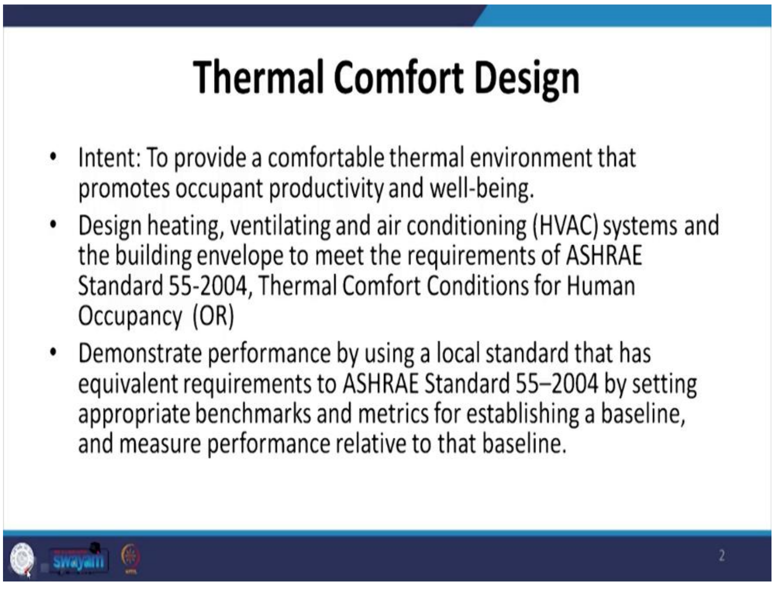

So, we start with thermal comfort design, now when we have to design building interiors for thermal comfort, we would take help or we would take the benchmark as the code which is ASHRAE Standard 55. So, the intent is to provide a comfortable thermal environment and it is required in order to promote the occupant productivity and overall well being. How do we do that?.

We design the indoor environment, indoor space to meet the requirements which are given as part of ASHRAE Standard 55, those are the conditions which are required; which are specified as thermal comfort conditions for human occupancy. To ensure that, the design of HVAC Heating, Ventilation and Air Conditioning systems plus the building envelope will be done in order to meet with the requirements.

One option is that which is the prescriptive approach, if we are not doing that the other way is to demonstrate this performance by using the local standard also. So, instead of ASHRAE 55 we could go ahead and use an equivalent standard, local standard. For example, in our case also we go back to ASHRAE Standard 55. So, for us it does not make much of the difference; however, in several other countries especially Europe where they have their own thermal comfort requirements and these standards they may be used.

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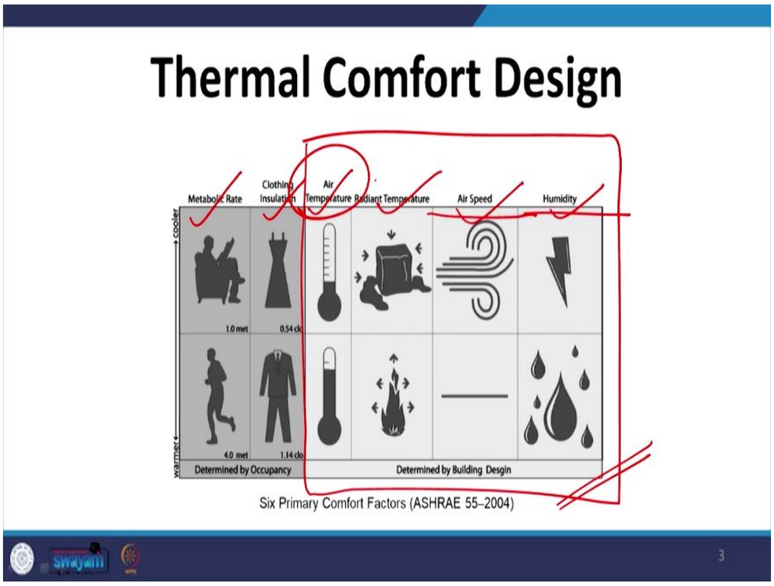

So, when we are talking about the thermal comfort design and we have already seen these different parameters which affect the thermal comfort. So, we know that, there are environmental parameters and then there are personal parameters. So, we have to take care of all these parameters. We have to take care of the air temperature, the radiant temperature, the air speed and the humidity. As part of the environmental parameters and as personal parameters we have to take care of the clothing insulation and the metabolic rate.

Now, metabolic rate and; metabolic rate will be dependent upon the activity or the purpose of the space. So, if it is an office space certain metabolic rate will be assumed and also the clothing will be assumed because, when people go to office, they are clad in a particular kind of attire. So, these two will be assumed while the rest of these environmental parameters they will be designed for thermal comfort using HVAC.

Now, we can design the system in such a manner that these environmental parameters are met. We have desired amount of humidity, we have ample amount of air speed and we are also able to manage the air temperature and the radiant temperature. But how do we know whether the system is performing as it was designed? So, is there a way to understand whether building occupants are comfortable with the given design?

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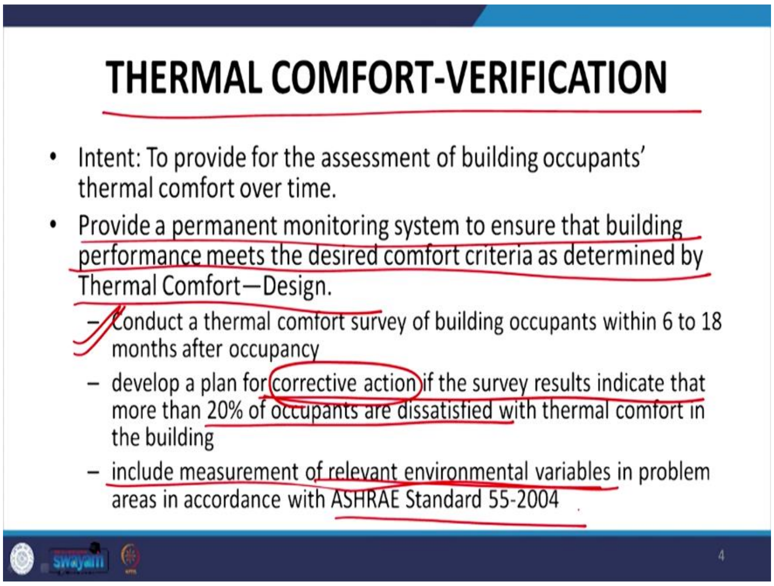

So, the next very important criteria is the thermal comfort verification; so, the next very important criteria is thermal comfort verification. Now, the intent here is to provide for the assessment of building occupants thermal comfort over time. As a design intent we have already designed the HVAC system and the building considering that thermal comfort will be ensured for all the buildings occupants; however, it may not really be delivered as it was intended.

So, what needs to be done is we would provide a permanent monitoring system to ensure that the building performance meets the desired comfort criteria as determined by the Thermal Comfort-Design which we just saw as the previous slide. How that would be done? One, conducting the thermal comfort surveys with building occupants within a period of 6 to 18 months after occupancy.

So, as soon as the building has been put up for use it is occupied, it is up and running the building occupants will be surveyed for thermal comfort. From the thermal comfort survey, the results will indicate whether thermal comfort is being achieved or not, whether what was intended through the design has been implemented on ground. So, we would really verify whether thermal comfort has been achieved or not.

If not, then once the survey has been conducted we would identify the corrective course of action which would be indicated by the survey results. So, whatever the survey results indicate if more than 20 percent of the occupants are dissatisfied, then a corrective course of action needs to be taken and it needs to be implemented. Also we have to include the measurement of relevant environmental variables in problem areas in accordance with ASHRAE Standard 55.

So, it is not just thermal comfort, but we would also be monitoring a couple of other environment variables besides those for thermal comfort for example, carbon dioxide. So, all of this would form a part of thermal comfort design and verification and after verification the corrective course of action will be taken. So, this was about thermal comfort and its design, the next very-very important part is daylighting.

Now, the intent here is to bring in daylight to maximum floor area of the building. The intent is to provide the connectivity between the interior and the exterior spaces to achieve visual delights to occupant. So, it is not just about bringing in light, but it is also about the visual comfort.

Because, when we are connected to outdoors human beings inherently they feel more comfortable when they are directly connected to the outside. Even when there is sufficient artificial light which is provided inside the building a connection with outdoors greenery, plants is always going to bring in a greater sense of visual comfort.

So, not only does bringing in daylight results, in energy savings and demand reduction because then the need for artificial lighting is offset. It also reduces the cooling load because; the efficacy of daylight is significantly higher than any other form of electrical lighting. So, it produces less heat as compared to the amount of light. So, more daylight inside implies less requirement for artificial lighting.

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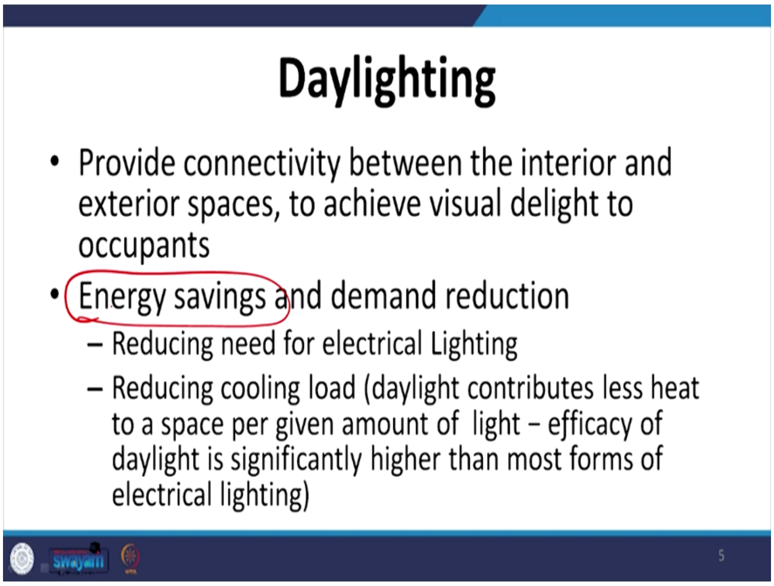

So, not only does it reduce the energy consumption besides that it is also required for building occupants, visual comfort and well being.

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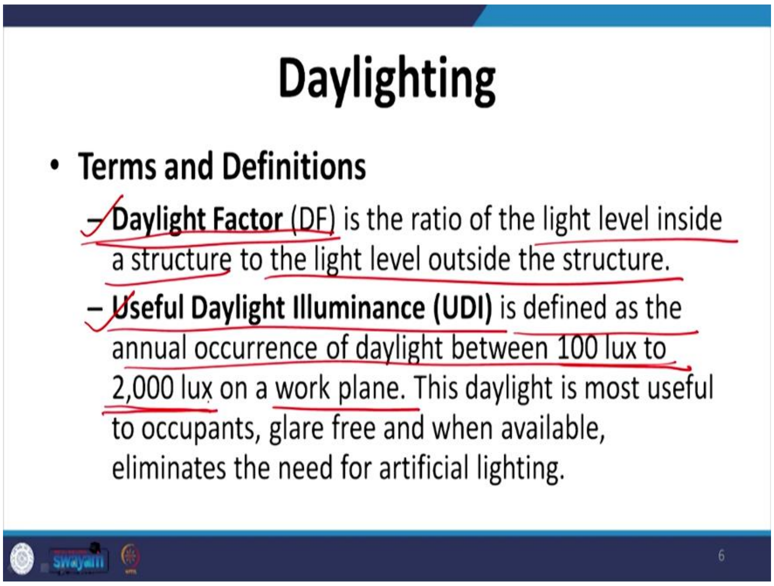

The occupants feel better and their productivity increases when they work in daylight areas. So, this is proven by the research and that is what is intended in sustainable buildings and green buildings. Now, how do we ensure that there is sufficient daylight and how much is enough. So, to define that several terminologies have been used and there are several definitions which are available, the 2 most common which are used in green buildings are; one, is daylight factor and the other one is UDI which is called the Useful Daylight Illuminance.

Couple of years back, daylight factor was the most commonly used terminology; however, gradually UDI is becoming more popular. So, Daylight Factor is actually the ratio of the light level inside a structure indoors to the light level outside the structure that is outdoors. So, daylight factor is just a ratio while UDI is defined as the annual occurrence of daylight between 100 lux to 200 lux on a work plane. Now, whenever we are talking about the daylight design, we are looking at the amount of illuminance the daylight present on a work plane height.

It is not on the floor, it is not on the ceiling, but it is on the working plane at the height of the working plane. So, UDI is the annual occurrence of daylight between 100 lux to 2,000 lux and this range is actually the most useful for the occupants, it is glare free most of the time. Of course, glare depends upon a lot of other parameters as well, but between this range it is mostly the glare free light and it totally eliminates the need for artificial lighting.

So, how can we bring in daylighting? If we look at the architectural design approaches, the passive design approaches there are several, features several features of architecture which can be incorporated.

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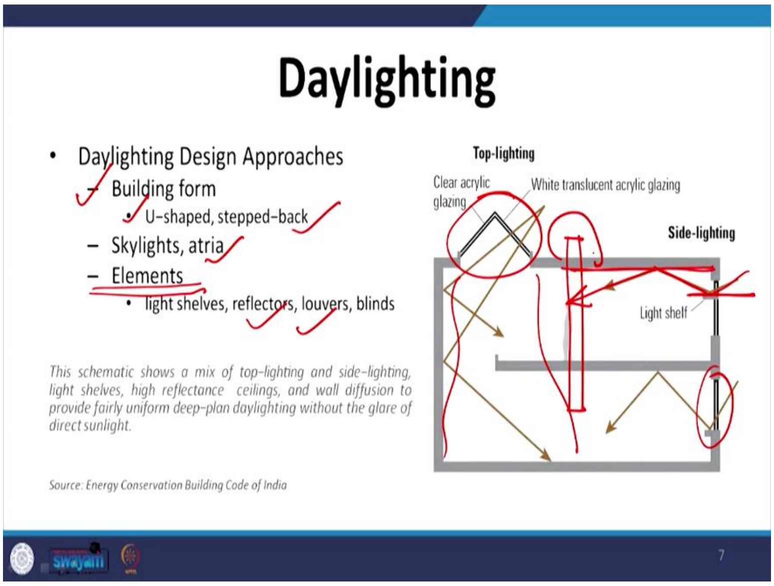

First of all, the building form itself so, certain building forms encourage bringing in of daylight for example, U shaped or stepped back or courtyard for that matter. So, wherever we have atriums or courtyards which are open to sky they bring in a lot of light to the building interiors.

So, that is through building form itself. In addition to that we can bring in we can incorporate several elements for example, the skylight. The skylight would light up a lot of interior area directly, we have windows, we have light shelves which is a very interesting concept which is being used these days. So, light shelf we will allow reflection of the light the daylight to the ceiling which we will be painted light and with a reflective color or material. So, that it penetrates the light deeper into the interior space.

So, in addition to that we might also use reflectors, there are louvers and blinds which can be used to direct the daylight capture. There are special types of glasses also where they have within the glass itself they have inbuilt prisms to diffuse the light. We also have the artificial light wells where in deeper areas the light from the roof can actually be brought in by the light tubes.

So, such elements are available in plenty and they can be made use of while designing green buildings or sustainable buildings. In addition to daylight factor and UDI we have to consider several other parameters as well.

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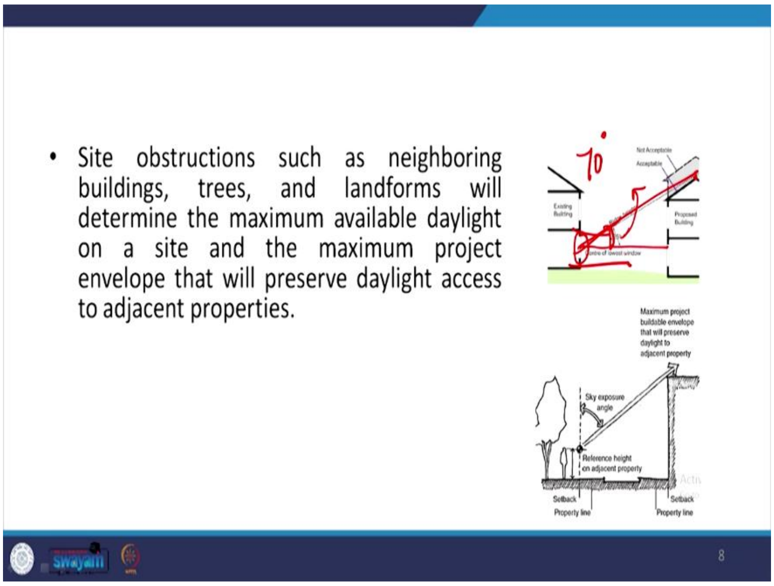

One very important is the angle of obstruction. What is the angle of obstruction? So, from a window at the center of this window if we make an angle with the nearest obstruction, the maximum height of the obstruction. So, this angle which is formed is called the angle of obstruction.

Some green building rating systems also talked about the upper limits of this obstruction. In case the obstruction is greater than a certain number the window is not considered for daylighting calculations or for bringing in the outdoor views outside views. So, in IGBC this limit has been set as 70 degrees. So, if it is higher than 70 degrees, then this window will not be considered for bringing in the daylight or to offer the views.

So, it is not just the daylight or the amount of daylight, but it is also the amount of views which are available which needs to be considered, which will be considered with the help of angle of obstruction.

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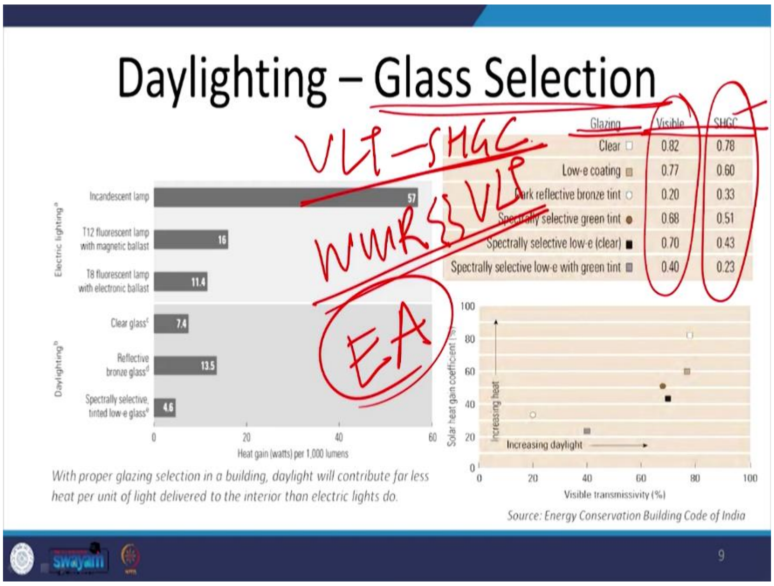

Now, when we are designing the windows for bringing in daylight besides the design of windows one very important criteria is the selection of glass. So, which glass will be selected? Now, there is a kind of balance which needs to be stricken for heat ingress for controlling the amount of heat which is coming in through the windows, we suggest that the U value of the glass should be lower and the SHGC of the glass should also be lower.

Now, if you look at the kind of glasses which are available in the market which have a low U value and a lower SHGC for one climate we are discussing, most of such glasses would be coated with metallic coating they would either be hard coat or soft coat, but they will often have coating. Now, this coating reduces the amount of visible light which is penetrated through the glass. So, while we are reducing the amount of heat gained through the building, at the same time we are also reducing the amount of daylight which will be penetrated through the glass window.

So, when we are selecting the glass we would be talking about a comparison of both the VLT and SHGC for different types of glazings. And select the one which will balance the heat ingress and also the daylight penetration simultaneously. Besides this comparison between the visible component and the SHGC we will also take into account the window wall ratio. So, if it is a smaller window maybe a clearer glass can be provided, while if it is a large window, a glass with low VLT may also bring in sufficient amount of light.

So, there are two things to be compared VLT with SHGC and WWR in combination with VLT, a product of WWR and VLT is called effective aperture. So, we have to look at effective aperture, what is the window wall ratio and we have to look at the combination of VLT and SHGC and choose the glass appropriately, that determines to a large extent the design of daylighting in building. Once we have done that we will calculate the daylight factor.

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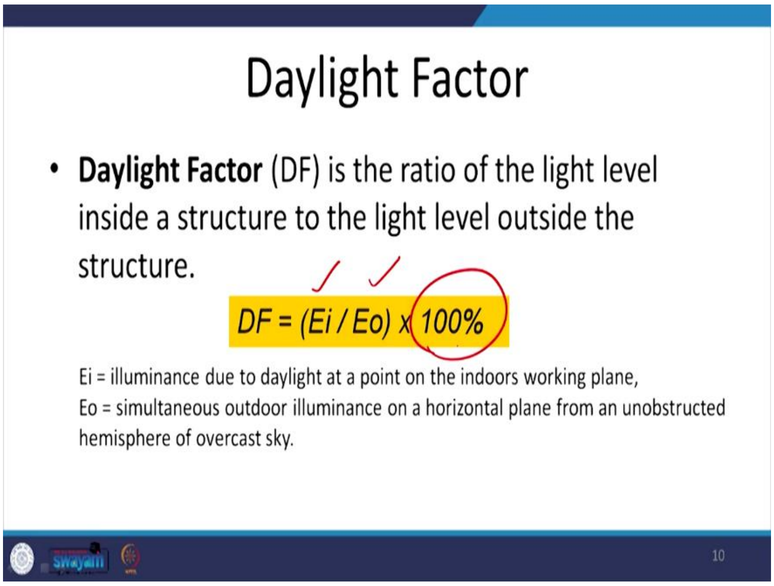

So, daylight factor as we have already discussed is the ratio of light level inside a structure to the light level outside the structure. Simply Ei divided by Eo which is outside and taking in as a percentage.

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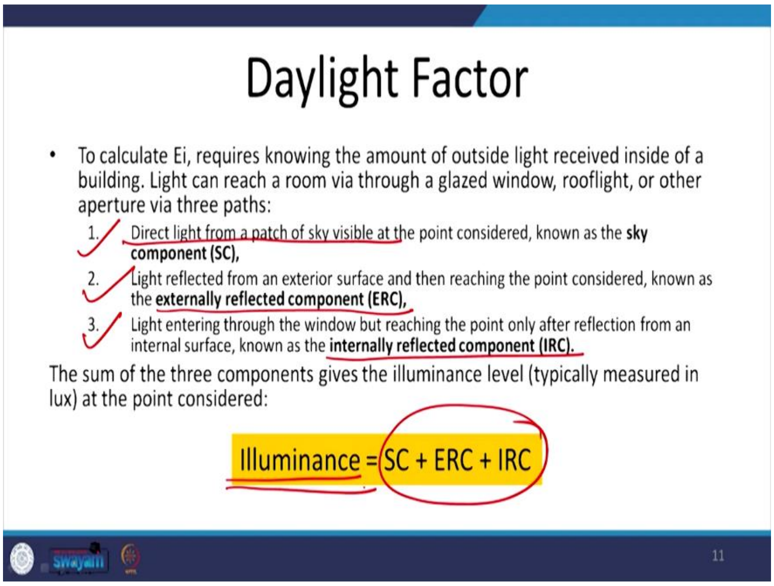

Now, the Ei when we are talking the amount of luminance amount of light which is available inside has multiple components. So, it has 3 distinct components; one is the, direct light from a patch of the sky which is visible at a point considered. So, it is known as the sky component of the light which is going to come indoors that is one.

Second is the, externally reflected component. So, suppose we have a building right opposite our window which is painted in light colors. So, the sunlight might actually be falling onto that window and the reflected component might be received inside the building which is being considered, which is being studied, this is called the externally reflected component.

So, we have to take into account that also. So, at times there may not be sufficient amount of sky component available, but there might be a lot of externally reflected component which might be available. The 3rd very important significant component is IRC or internally reflected component. Now, this internally reflected component is because of the reflections from the indoor surfaces, the interior surfaces.

So, the light may be entering only through the window, but then it gets reflected to the ceiling and it further penetrates inside which is what we were just seeing when we discuss about the concept of light shelf. So, when we have a light shelf and it is painted with a reflective coating on the top the light is then reflected to the ceiling and then coming in this is going to be considered as internally reflected component. A combination of all these 3 will give us the illuminance inside.

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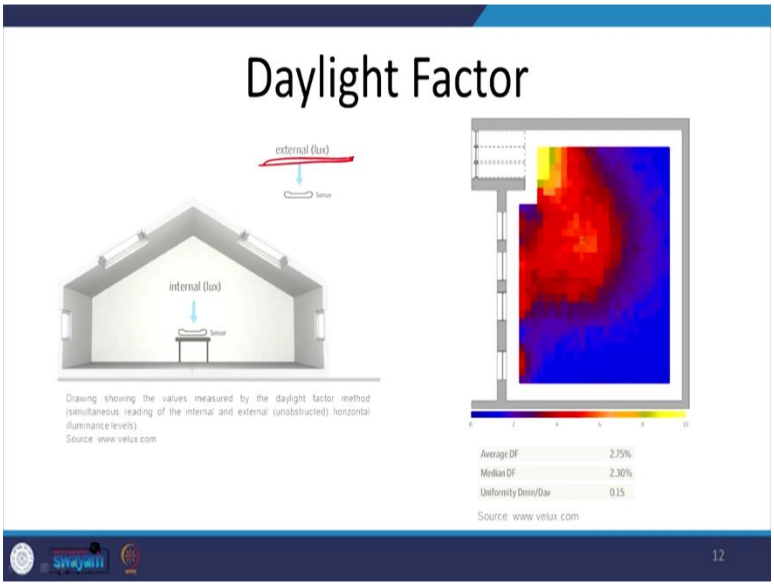

So, when we are talking about the daylight factor we would be talking about the amount of illuminance which is available inside versus the amount of light which is available outside both being considered in lux here. On an average 2 percent daylight factor is considered reasonable, it is the threshold, minimum threshold and if we have a 2 percent daylight factor the space is considered to be reasonably daylight.

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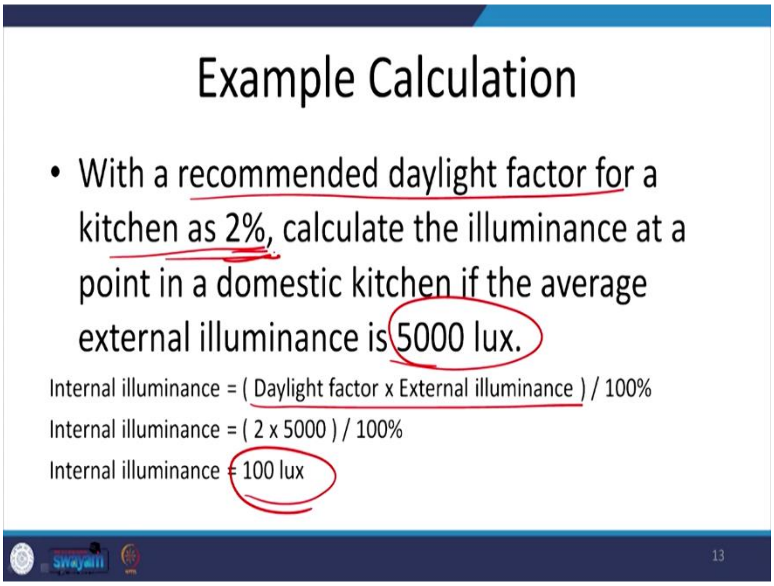

Let us quickly look at an example calculation here. So, if we have to calculate the amount of light which is available in a kitchen considering that there is recommended daylight factor of 2 percent for a kitchen, and if we have to calculate the illuminance given that there is 5,000 lux available outside as the external illuminance.

So, if we consider 2 percent daylight factor and we take taking it as a percentage we just multiply the daylight factor with external illuminance. And since it is a percentage we divided by 100 and we get the internal illuminance which is being targeted here. However, this 2 percent daylight factor has to be achieved with the help of window design the selection of glass, the selection, the design of the window, the size of the window.

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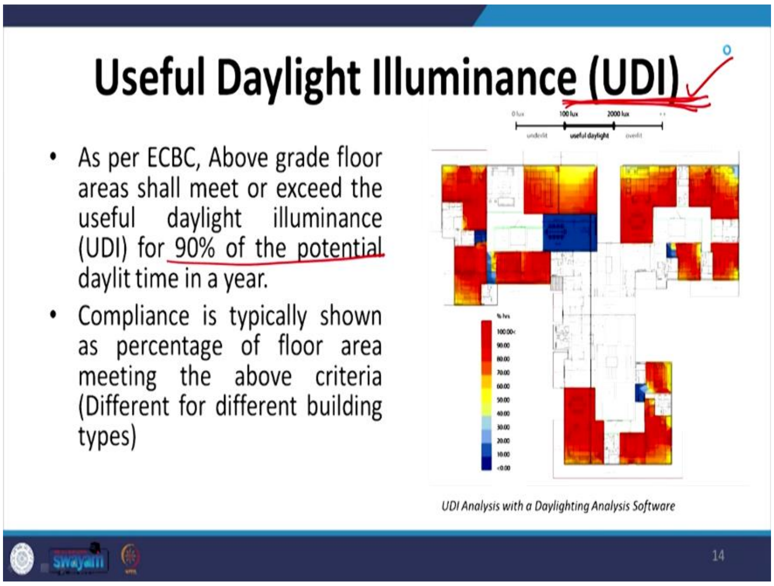

So, when we are talking about compliance as per ECBC, UDI has now replaced the daylight factor and in UDI as for ECBC 90 percent of the areas must be potentially daylit. Currently daylight factor has been replaced by UDI, Useful Daylight Illuminance and the criteria varies.

So, the minimum compliance is for majority of the course, if you are talking about ECBC here, at least 40 percent of the area should be daylit for 90 percent of the time in an year, with the minimum prescribed UDI. So, if we are looking at the minimum mandatory requirement 40 percent to 50 percent of the area should be daylit. If we are looking at securing credits or earning points on the basis of the green building rating systems for example, IGBC or lead then it goes on to say that at least 75 percent of the floor area for any given space must be sufficiently daylit as per the UDI requirement or higher.

So, we have to look at how much of the area is being sufficiently daylit not just at a particular moment in time, but throughout the year at least 90 percent of the times in a year. To calculate that as per ECBC now to show the compliance there are 2 ways in which the compliance for daylight can be shown. One is we can show it show the compliance manually or we can go for daylighting simulation tools. So, if we are going ahead with the daylighting simulation method, we have to follow certain guidelines.

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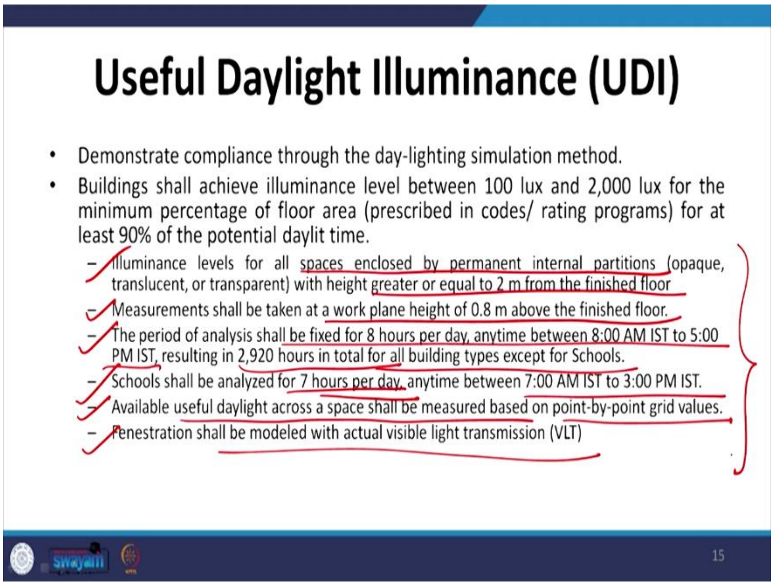

First the measurements whatever we are taking should be measured at a work plane height of 0.8 meter above the finished floor which is what we have already discussed. Also the daylight should be calculated only for the spaces enclosed by permanent internal partitions, they may be opaque, translucent, or transparent ,whatever which have a height greater than or equal to 2 meter from the finished floor.

The third is the period of analysis it shall be fixed for 8 hours per day, anytime between 8AM to 5PM, a total of resulting in 2,920 hours for all buildings except for schools. For schools it should be analyzed for 7 hours per day, anytime between 7AM to 3PM also the useful daylight shall be measured on a point-by-point grid values. It should not be only one point in a space, but it should be point-by-point grid values and that will be then averaged out.

And then the fenestration shall be modeled with actual VLT, which is being considered in the building. Considering all these the simulation daylighting simulation may be carried out.

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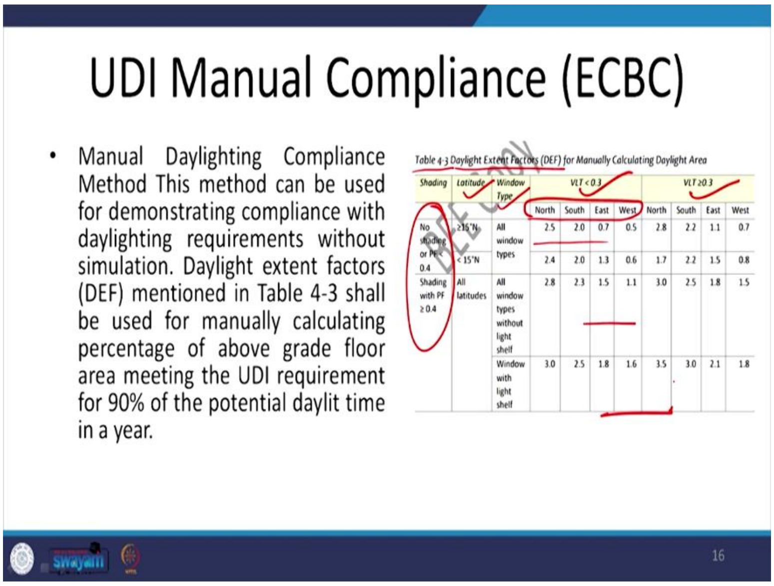

Shading	Latitude	Window Type	VLT < 0.3				VLT ≥0.3			
			North	South	East	West	North	South	East	West
No shading or PF < 0.4	≥15°N	All window types	2.5	2.0	0.7	0.5	2.8	2.2	1.1	0.7
	< 15°N		2.4	2.0	1.3	0.6	1.7	2.2	1.5	0.8
Shading with PF ≥ 0.4	All latitudes	All window types without light shelf	2.8	2.3	1.5	1.1	3.0	2.5	1.8	1.5
		Window with light shelf	3.0	2.5	1.8	1.6	3.5	3.0	2.1	1.8

If you look at, the ECBC requirement which are given for manual calculations you would find the stable 4-3 which gives us the DEF values or daylight extent factors for the daylit area. Now, depending upon the type of the window the latitude of the place where these windows are being designed and for different orientations, along with the projection factors of the shading which has been provided.

And also the selection of glass, depending upon the VLT less than 0.3 and greater than 0.3, the DEF values are given in this table. So, for each window separately the DEF will be calculated or found out from this table as per ECBC.

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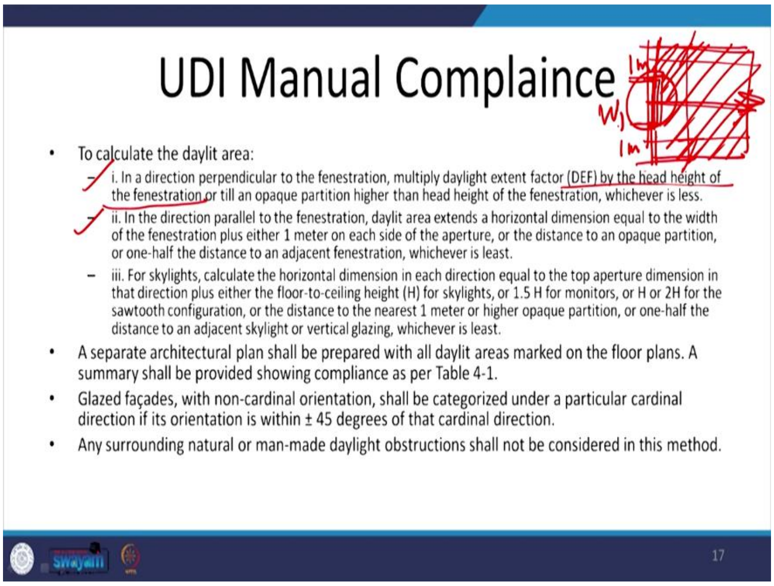

Once we have found out the DEF we will then go on to calculate the amount of daylight which will be available in an area, now this has to be calculated in to both the dimensions. So, we will calculate the amount of floor area will be daylit, first for perpendicular directions. So, for example, we have a room where the window is available.

So, in the direction which is perpendicular to the fenestration here, the length of this area which will be daylit is calculated by multiplying the DEF by the head height of the fenestration or till and opaque partition is present, whichever comes earlier. So, multiplying the DEF with the head of the window we can calculate the perpendicular distance up to which the daylight will be available.

The second is in the direction which is parallel to the window at least 1 meter on both the sides of the window the horizontal expands of the window, daylit area will be calculated or it will be determined in case there is a partition available within this distance. So, whatever is less will be considered. Now, this area is the daylit area because of this window.

So, for any given plan this daylit area will can be manually calculated and the compliance criteria remains the same that at least 40 percent of the floor area should daylit for 90 percent times of the year.

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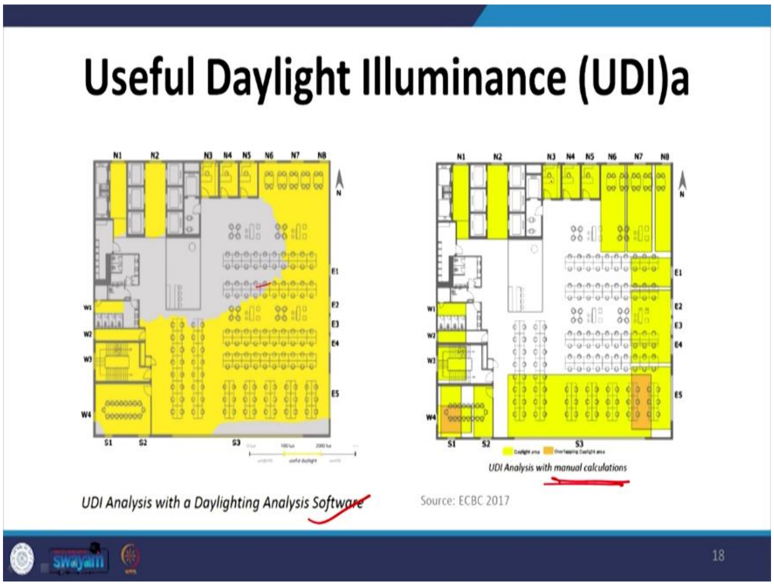

So, if you look at these 2 plans the same plan has been analyzed for daylighting; one with us with the help of a software and the other one with manual calculations. So, here this is the plan this is an open plan and based upon the amount of windows which are available the daylit area with the help of software has been calculated shown here, while with the help of manual calculations following the DEF and the procedure given in ECBC, this is the amount of daylit area.

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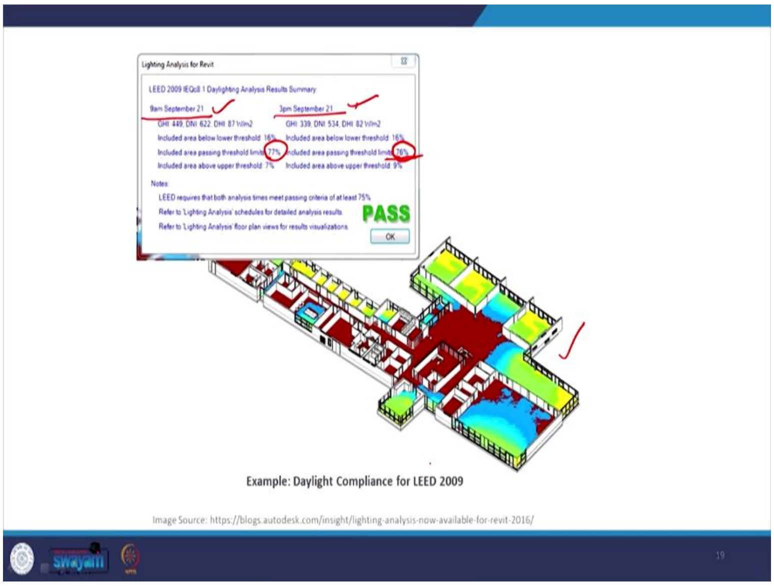

Now, the percentage of this area will be calculated and the compliance be shown. So, with the help of the daylight simulation software which is embedded as part of revit here. The compliance has been shown, for 2 times on September 21 so for 9AM and 3PM and then we can see that, the area which is passing the threshold limit is exceeding 75 percent which is the minimum requirement if you want to comply with lead.

So, if it has cross 75 percent this building design is eligible for earning a credit for daylight compliance. So, when we have to show the daylight compliance each window in the building will be considered and the floor area which will be sufficiently daylit will be calculated and the compliance be shown.

So, we will stop here; here we have completed our discussions about, how to design a building and interior space for thermal comfort as well as daylight. And we have also seen the compliance approaches, how to show the compliance and how to earn credits for this given criteria.

Thank you so much for being with us today, we will go on and discuss about certain other aspects of indoor environment quality for interiors as with regards to interiors in the last lecture of this week tomorrow. So, see you then.

Thank you for being with us.