Analysis of Daylighting in Educational Building of Composite Climate

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Abstract: ***Daylight is a resource for natural space-illumination. It is highly desirable to provide more usable daylight in buildings, not only for energy efficiency but also to increase the performance and well-being of the inhabitants. Daylight through the window is a popular solution for lighting indoor space. Using daylighting in educational buildings has many advantages and increases building's and occupant's efficiency. The application of daylighting strategies can minimize electrical energy for lighting and maintain a well-lit atmosphere in the educational building. Autodesk Ecotect 2011 is used to evaluate the daylight-related performance of illuminance and daylight factor. It is used for the simulation of design models to obtain daylight factor information and distribution of illuminance. Daylight factor and illuminance distribution are evaluated according to various room scenarios and different window configurations. Simulation studies conducted in this paper show that the openings in different orientations, windows with and without shading devices, the color of interior walls have different impacts on the daylight distribution inside the room in composite climate.***

Keywords: Daylighting; Daylight analysis; Autodesk Ecotect 2011; Orientation; Shading devices; Interior reflection of daylight

1. Introduction

Daylighting can be described as the controlled use of natural light in and around the buildings (Reinhart, 2014). It is the practice of placing windows or other openings and reflective surfaces so that natural light can provide effective internal lighting during daytime (Lam, 1977). Daylight is the combination of all direct and indirect light originating from the sun during day time which varies with the seasons of the year, the time of the day and the weather conditions (Mardaljevic, 2012). Daylight offers high illuminance and allows for excellent color discrimination and color rendering providing the basis for good vision (Ruck, et al., 2000).

The daylight availability in indoors is affected by the interaction of the following:

a) The source (sky and sun);
b) The receptor (indoor characteristics);
c) The mediator (characteristics of external items such as surrounding buildings, vegetation, architectural components) (Santos, n.d.).

Daylighting in Educational Building

Daylight quantity and quality are critical in educational buildings, so it is very important to ensure that daylight plays an important role in the design and construction of buildings for any purpose, especially educational buildings as daylight has an effect on efficiency as proper attendance and decreased absenteeism of students are promoted by the better-illuminated school (Ander, 2003; Robbins, 1986).

Benefits of Daylighting

- Higher illumination levels increase the visibility, speed, and accuracy of people performing tasks (James, Ito, Dorne, Wright, 2017; Treado, 1989).
- Better health in the long term, Improved occupational performance (Ullah, 2014).
- Minimize the amount of artificial light and reduce electricity costs, buildings with daylighting can save 15-40% of the overall energy (Rana, 2018).
- Improved mood, enhanced morale, less fatigue, and reduced eye strain (Heschong, 1999).

Daylighting in Composite Climate

Composite climate displays the characteristics of hot & dry, warm & humid as well as cold climates and the design considerations depend upon the dominating climate of the region (Koenigsberger, Ingersoll, Mathew, Szokolay, 1973). Composite climate has Intensive Solar Radiation, 10-45° Temperature, Strong wind in monsoon, Hot and dusty wind in summer.

The abundance of daylight in the composite climate is due to the high intensity of the sun and the longer period of its illumination in the tropical composite climate. The design sky illumination can reach about 12,000 lux considering the sky to be overcast (Roshan, 2014).

Studies performed by scholars, on the other hand, indicate that high daylight in a tropical area has not been used to the full (Ahmad, 1996).

In the tropical composite climate, the solar radiation, intensity, and hours of radiation are high and uniform throughout the year, which is considered to be a benefit for daylighting. This climate allows greater flexibility in design due to seasonal changes between long hot, dry periods to shorter periods of concentrated rainfall & high humidity.

Indirect light on south elevations, Larger glass areas on the north, Enclosed courtyard spaces are some design strategies for daylighting in composite climate.

Windows on the vertical facades in the design of buildings offer an opportunity for the penetration of daylight into the building but can only reach a limited depth through the window, even though the sky is not obstructed (Tregenza, 1980).

The tropical skies are not consistent and therefore allows for more sunlight which also, in turn, generates more heat gain and glare, therefore daylight penetration in the tropics must be treated with regard to these factors and it was revealed that the use of light guiding shades, angle selective glazing, light shelves, horizontal and vertical light tubes, switchable glazing and active solar regulation is a way to utilize tropical daylight whilst controlling heat gain and glare in buildings (Pela, n.d.).

Interior spaces need high ceilings and highly reflective room surfaces for the best light distribution. Daylighting considerations affect the architecture of the building exterior, determining the amount of fenestration and its appearance on the building facade. (DESIGNING FOR DAYLIGHTING, n.d.).

The building orientation and shape should be designed with daylighting in mind. To take advantage of sunlight without an excess of heat or glare, the building should be oriented so that windows are on the north and south sides (DESIGNING FOR DAYLIGHTING, n.d.).

South-facing windows give strong illumination, north-facing windows give quality consistent daylight with minimum heat gains, whereas in east and west-facing windows, shading is difficult, north or south-facing windows are suitable (Mohapatra, Kumar, Mandal, 2018).

The use of overhangs and solar shading devices are the most common strategies for daylight design that can provide a comfortable visual indoor classroom atmosphere in tropical climates without raising the building's construction, operation, and energy costs (Ackley, 2017).

Openings excluding doors should be
≥20% of the floor area (openings located in one wall) and
≥ 15% of the floor area (openings located on both side walls at the same sill level)
(IS: 7942-1976, IS: 8827-1978).

Daylighting Considerations from IS: 7942-1976, IS: 8827-1978

- Working plane is assumed to be 0.85m high, whereas in educational buildings it is considered to be 0.6-0.9m, according to age and type of task.
- Only windows on external walls are considered for daylighting, excluding the windows on corridors.
- Light from tall windows reaches the rear portion of the room whereas the wider window provides a light parallel to the window plane with reduced depth in the room.
- Sill height should be between 0.9-1.05m for the ceiling of 3-3.5m.
- The chalkboard should be placed adjacent to the window walls to achieve minimum glare.
- It is desirable to have a white-washed ceiling, off-white wall, terrazzo finished floor which will have reflection factors as 0.8-0.7, 0.7-0.5, 0.35-0.25 respectively.
- A row of trees 6m tall as an external obstruction which are at a distance of 6m from the window may reduce daylight factor by half, whereas if it is at a distance of 15m can reduce 10% of daylight factor.

Table 1: Recommended illumination levels on work areas for educational buildings

S. No.	Visual Task	Illumination Level (lux)	Daylight Factor
1	Classroom desktop chalkboards	150-300	1.9-3.8
2	Laboratories	200-300	2.5-3.8
3	Library-reading tables	150-300	1.9-3.8
4	Drawing, typing, sewing	300	3.8
5	Toilets	150	1.9
6	Manual training	150	1.9
7	Children with defective vision	(Special lighting to be provided)	

2. Methodology

Considering the size of the classroom ($6\,m \times 9\,m$ as the breadth and length ratio should not exceed 1:1.5), size of openings (20% opening) from IS: 8827-1978. The area of the classroom is $54m^2$ therefore the openings provided are $12m^2$ with a total 4 number of windows sizing 2m x 1.5m (approximately 20% opening). The working plane is considered to be at 0.8m from finished floor level and shading device of width 0.6m. The location is considered to be Raipur, Chhattisgarh (composite climate) with latitudes and longitudes as 21.25°N, 81.62°E respectively. The design sky illumination is considered as 12,000 lux with an overcast sky condition. A typical model of the room in different conditions is prepared and analyzed by using Autodesk Ecotect 2011. April (summer), December (winter), August (monsoon) are considered for the analysis.

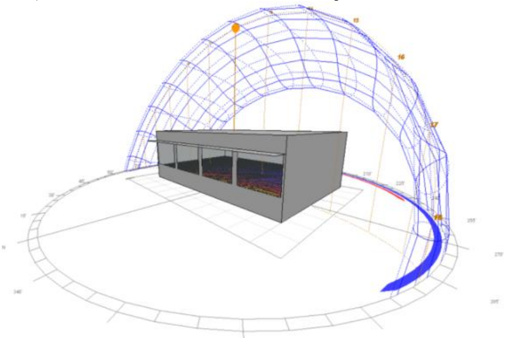

Figure 1: North opening

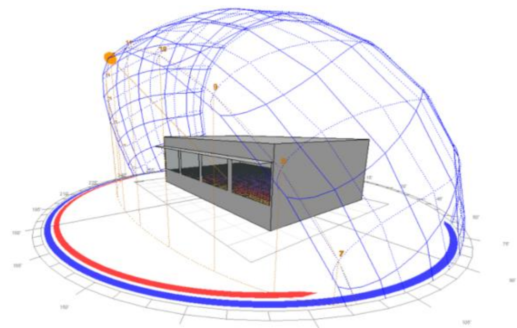

Figure 2: South opening

Figure 1, 2: Orientation of openings in a classroom

3. Analysis

Figure 3, 4 shows the effect of shading devices on the north facade in the month of April. The windows on the South facade receive most daylight but also receive more heat in April. Figure 5, 6 shows the effect of shading devices on the south facade in the month of April. April receives maximum solar radiation when the school is open.

Figure 7, 8 shows the effect of using a dark and light color of interior surface finishes with varying reflection factors.

Figure 9, 10 shows the effect of shading devices on the south facade in the month of December. December is a month in the winter season when the school is open.

Figure 11, 12 shows the effect of shading devices on the south facade in the month of August. August is a month in monsoon when the school is open.

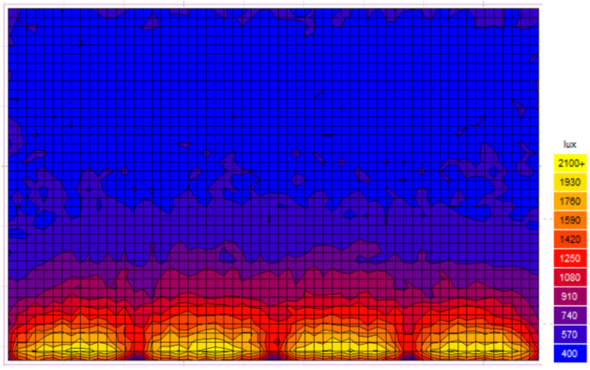

Figure 3: With shading

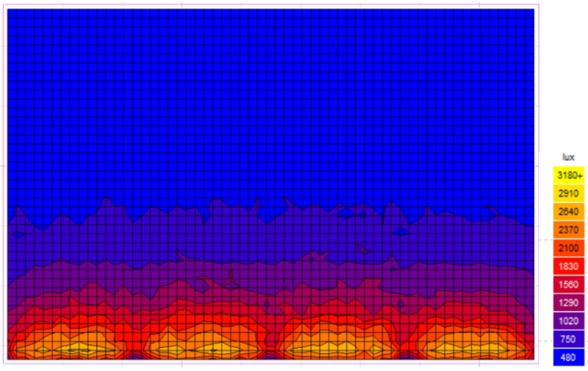

Figure 4: Without shading

Figure 3, 4: Analysis of opening in north facade in April

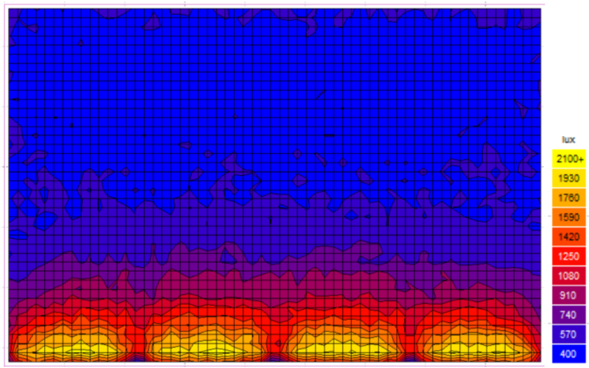

Figure 5: With shading

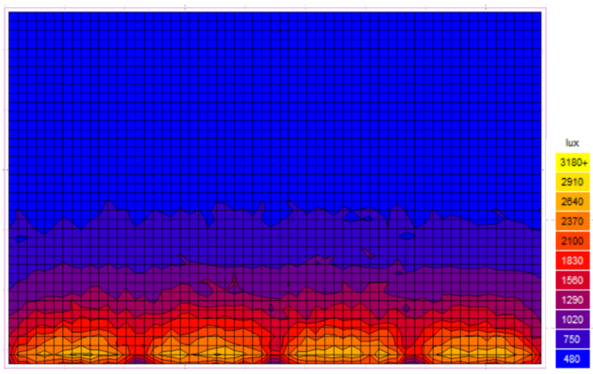

Figure 6: Without shading

Figure 5, 6: Analysis of opening in south facade in April

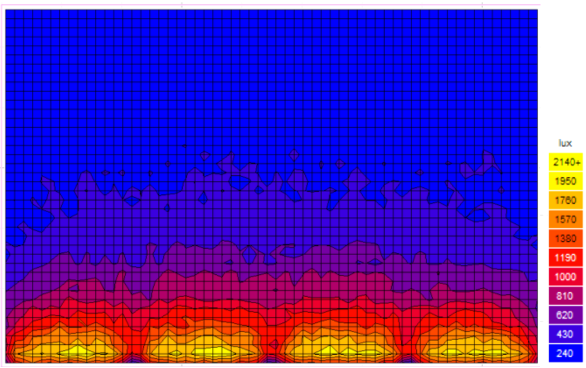

Figure 7: Dark color interior walls

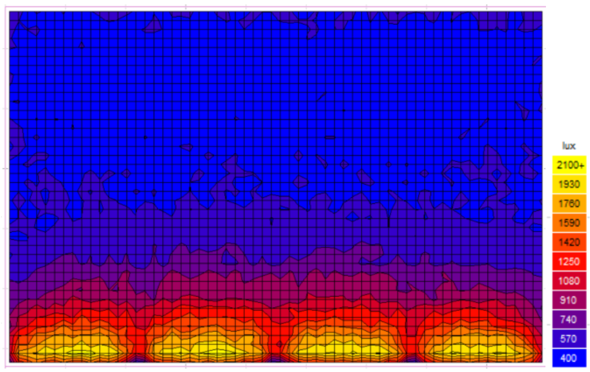

Figure 8: Light color interior walls

Figure 7, 8: Analysis of interior wall reflections in south facade in April

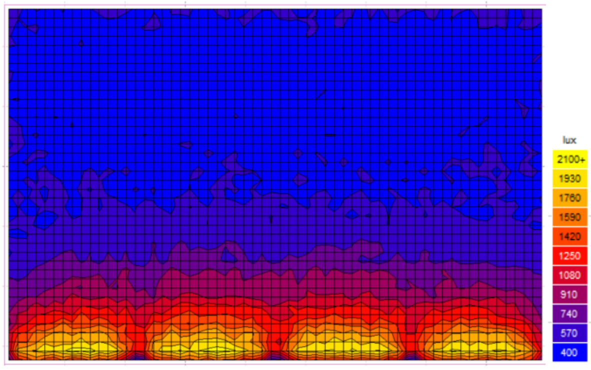

Figure 9: With shading

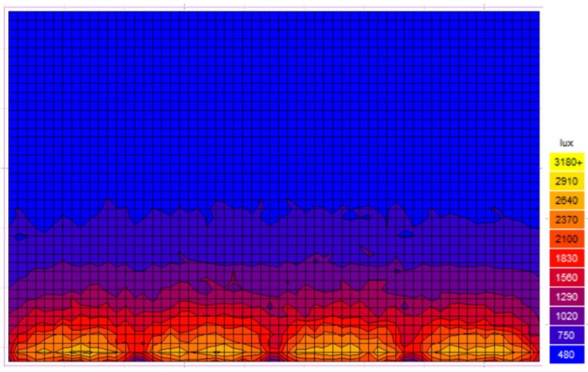

Figure 10: Without shading

Figure 9, 10: Analysis of opening in south facade in December

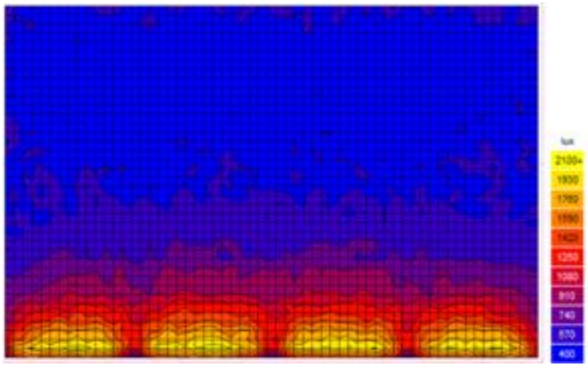

Figure 11: With shading

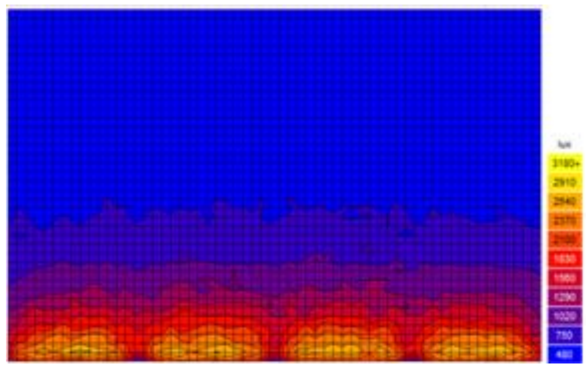

Figure 12: Without shading

Figure 11, 12: Analysis of opening in south facade in August

4. Results

The results are drawn from the standards given and the simulation from the software. The windows on the North and South facades are best suited for receiving daylighting but at the same time, south facade openings receive heat and glare from the sun in a composite climate. Shading devices affect the distribution of daylighting inside the room and also hinder the excessive amount of daylight penetration. By providing shading devices the optimum daylight is better distributed and glare is also cut down. The horizontal shading devices are best for shading north and south facades of composite climate as it cuts the summer sunlight and brings in the winter sunlight. The daylight is better distributed inside the room if the walls' color is light with reflection factors as 0.7 - 0.5.

5. Conclusion

From the results of analysis it can be concluded that the daylight penetration inside a room is different in different orientation. North and South facades receive most daylight throughout the day in composite climate therefore larger openings are provided in North and South orientation and smaller openings are provided in East and West orientation. Considering the heat and glare from the openings in the south facade, horizontal shading devices are best suited. Horizontal shading devices are used in the North and South facade to reduce the heat gain and glare and allow the winter sun to penetrate inside. Shading devices help in better distribution of optimum daylight inside the room by hindering unnecessary daylight penetration which can result in heat gain. Here, the results are by using the same size of shading devices. Further, shading devices can be designed according to the orientation. It is desirable to provide minimum openings in West orientation as it becomes difficult to shade them. If openings are provided in East and West orientation then landscape elements can be used as better vertical shading devices. The color of interior walls also affects the distribution of daylight. Lighter color walls reflect daylight more and hence the distribution is more optimum. It is desirable to have a white-washed ceiling, off-white wall, terrazzo finished floor which will have reflection factors as 0.8-0.7, 0.7-0.5, 0.35-0.25 respectively.

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