Window Sizing for Daylighting for Non-Airconditioned Buildings in Andhra Pradesh, India

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Abstract

A window is an opening designed or created in the wall or any surface exposed to external environment to admit daylight, facilitate cross ventilation and contribute to thermal comfort conditions. This paper deals exclusively about drawing adequate daylight to internal spaces from available day light outside. It is analysed and found that the

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is assumed that the ground plane extends away from the vertical plane of the window up to an infinite distance. This simplifies calculations because the configuration factor between a point on a vertical plane and an infinite horizontal plane is 0.5 A poor quality of daylight may result in discomfort and a loss in visibility, which may cause a decrease in human performance and productivity as emphasized by previous research [16,17]. This, in turn, may lead to increased use of the space, resulting in additional energy consumption [18].

Theoretical analysis of day lighting

Day lighting is analysed in terms of the primary parameters such as (a) exterior environment, (b) interior environment, and (c) interface medium (window, skylight, etc.). The analysis of these components should be used to influence design parameters. The primary difficulty is the variability of daylight with respect to the time of day and year, location (longitude and latitude), and environmental conditions. This variation of quality and quantity of daylight (exterior environment) presents domino effect in the interior environment. The exterior environment produces and influences the daylight that becomes the source of light for interior day lighting calculations [19]. The constantly changing exterior environment is the key factor in the analysis of daylight. As per literature dynamic internal light shelves [10], light wells and atrium contributes an effective day lighting in general. The general illumination models [20] and advance fenestration of day lighting [21] emphasized the importance of natural daylight to save energy with regard to climate change and sustainable practices. For developing countries, one has to explore low intensity development aiming clean development mechanism and sustainable practices in we keep climate change as the main paradigm of design. So it is essential appraise the different window sizes that can provide desirable day light illumination levels that can provide scientific information for design of a window with respect to the functional requirement of the interior and for the purpose, the space is to be designed.

Daylight factor (DF)

The daylight intensity at any point inside a room is subject to severe and frequent fluctuations, but it is, however, found to bear a constant ratio for the simultaneous external intensity when the sky is clear or overcast [22]. It is expressed in terms of intensity of day light illumination inside a room at any point in any plane as a ratio or percentage of the simultaneous intensity in a horizontal plane at an outside point open to the entire sky vault. Direct sunlight, if any, is not considered for both interior and exterior values of illumination. This effect can be accommodated by considering the daylight levels in indoor spaces with respect to the light from the sky. This may be quantified in the daylight factor, which is defined as:

$$DF = \frac{illuminance\,in\,room}{horizontal\,illuminance\;from\,an\,unobstructed\;diffuse\,sky} \quad (A1)$$

Recommended lighting luminance values for different functional activities were tabulated by the Bureau of Indian Standards [22], Illuminating Engineering society of North America (IES) [23], as well as by, the Commission International de I' Éclair age (CIE) [24]. Further, the light factor is a measure of all the daylight reaching on an indoor reference point from the direct sky, external surfaces reflecting light directly to the point, and internal surfaces reflecting and inter-reflecting light to the point. Each of three components, when expressed as a ratio or percent of the simultaneous external illumination on the horizontal plane define respectively the sky component (SC), the external reflected component (ERC) and the Internal reflected component (IRC). The daylight factor on horizontal plane only usually taken as the working plane in a room is generally at 0.75 m level from the finished floor level; however the Day light factors in the vertical planes should also be considered when specifying day lighting values for special cases, such as daylight on a class room blackboard, wall hanger pictures or paintings in exhibition halls and sculptures in a museum.

$$DF=(SC+IRC+ERC) \quad (A2)$$

$$\text{Day Light Illumination}=\tau\ MF.\ GBC.\ (SC+IRC+ERC) \times [(DS)/100] \quad (A3)$$

where,

τ: Transmittance of the glazing

MF: Maintenance factor for conditions

GBC: Glazing bar correction

DS: Design sky.

The daylight factor has been calculated at a number of points on a regular grid with in the room of size 4.0 m × 6.0 m, a series of contours has been plotted or drawn which connects together those points which have the same daylight factor/intensity. Such daylight contours analyses how the daylight varies within the room. The quantitative analysis of daylight has been developed in order to investigate the daylight intensity level at different grid point, and further contours of the daylight has been developed to show the qualitative distribution pattern of light. Figure 1 shows the grid points in relation to x and y-axis of working plane and the position of the window opening. The same has been plotted in the form of graphs as per NBC-2005 and generated contours as derived by IES VE-2016 simulation and results have been discussed for appropriateness of a model and qualitative and quantitative analysis of the day light Illumination levels. The Design sky has been considered 10000 lux as per research paper [11], the results have been compared and found that the simulation results are inconformity and there is no variation more than 1%.

Sky component

Sky component is the ratio of that part of the daylight illumination at a point on given plane, which is received directly from the sky as compared to the simultaneous exterior illumination on a horizontal plane from the entire hemisphere of an unobstructed clear design sky. The sky component at different points on working plane is analysed for different sizes of window by using the BIS/NBC 2005 to appreciate the indoor illumination levels. The values obtained are of rectangle

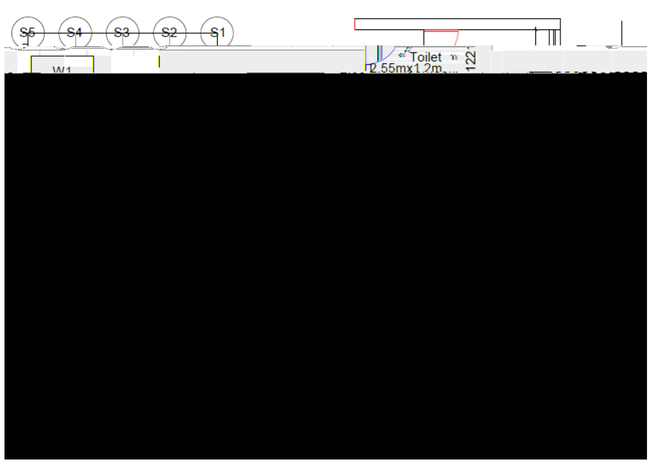

Figure 1: Room Module showing working plane and Day light Illumination grid.

open unglazed windows, with no external obstructions. The values are corrected by considering the window bars, glazing and external obstructions. The correction for window bars is carried by multiplying the values by a factor equal to the ratio of the clear opening to the overall. Where windows are glazed, the arrived sky component is reduced by about 10 to 20% provided the panes are of clear glass.

Internal and external reflected component

The component of day light factor contribute collectively by reflection from the inside surfaces, external obstructions and window area. It varies directly as per window area and inversely to the total area of internal surfaces. It depends on the reflection factors of the floor, wall and roof surfaces insides and of the ground outside. For rooms of white painted surfaces such as walls and ceiling and even for windows of normal sizes, the IRC will have a substantial value at points far away from the window. It was observed that the external obstructions will proportionally reduce the IRC and the same has been considered in the NBC 2005. As per NBC the perfect values of IRC, a specific method of evaluation of the same is given below. The values of the sky component corresponding to the portion of the window obstructed by the external obstruction are to be considered to achieve the ERC. The average IRC can be determined from the BIS internal reflection formula. The simplified form of this is:

$$= \frac{}{AT(\ -R)}(Cfw + \quad cw) \qquad \text{(A4)}$$

where,

0.85=Transmittance value of window glazing

A_w: window area

A_T: total surface area (ceiling + floor +walls including windows)

ρ_{fw}: Average reflection of floor and all the walls excluding the window wall, below the plane at level mid height of the window .

ρ_{cw}: Average reflectance of the upper part and the ceiling of the above three walls.

C: A constant of value 78 when there is no external obstruction [BSI. (1975)]

R: The average reflection factor of all surfaces in the room (ceiling, wall and windows).

IES Simulation and NBC Analysis

The same room size of 4.0 × 6.0 m with the height of 4.0 m have been considered to analyze the different window openings through IES-VE 2016 for uniform overcast sky value of 10000 lux from 8.00 AM to 9.0 AM, luminance at Zenith, etc., the input data has been given below:

Design sky:

1. Uniform (overcast sky): Equivalent horizontal illuminance (design sky) 10000 lux (8:00 am-9:00 am) Luminance at zenith Lz (Cd/sqm)-4337.

2. CIE (overcast sky): Lz(Cd/sqm) obtained from date , longitude and latitude (Table 1)

Reflectance: 70%

Maintenance factor: 0.9

Typology of illuminance: Planar (horizontal)

Materials Reflectance

External Wall (ext) {new concrete (traditional)}: 0.371

Wall (int) {new concrete with white Portland cement}: 0.718

Roof (ext) {aged concrete}: 0.250

Roof (int) {white gypsum}: 0.900.

Results and Discussion

Effect of window area by varying height of a window for a quantitative study of performance of illumination levels for various window areas, computations have been performed corresponding to the window area variations, width variations, height variations and placement of windows for room module of 4.0 m × 6.0 m × 4.0 m with 0.75 m sill height of window. The room module is divided in the grid form to define the various location points to arrive the sky component, % of DF and intensity of illumination at every point of the grid. Figure 1 shows the grid on working plane in relation to the X and Y axis, accordingly the illumination contours and corresponding contour mapping has been plotted. The input parameters are given below:

Design daylight: Uniform Sky=10000 lux (as per perze Model f1f the gr..e

Glazing bar correction GBC=0.9

Sky component=As per NBC-2005.

Figures 2-4 show the variations of illumination levels/contours in

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It has been analysed to assess the illumination level of W1 window splitting is9aevel of W1 window

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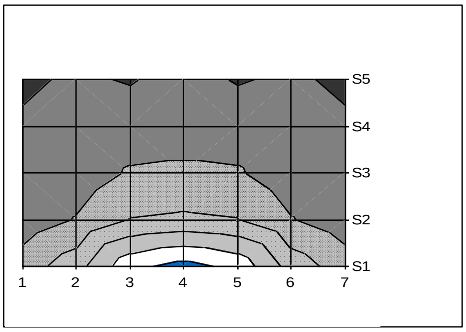
variation of locating a window on vertical plane at the centre as an option-II and locating a window at the opposite plane at diagonal as an option-III shown in (Figure 9). The Illumination contours of Option-III are quite impressive in terms of spread and enhanced illumination levels on working plane hence it an appropriate design configuration for window placement among all. Besides, varying window sizes for the said room size have been analysed along with the daylight illumination levels and the same has been tabulated for middle and corners places of the room to verify the spread and penetration lighting levels as shown in Table 2.

Conclusion

It is essential and crucial to derive the appropriate window sizes for achieving desirable illumination levels required for various functional considerations of a space design. The first of the new computation tools for daylight was developed by Waldram during the 1920's, acknowledged as the 'Waldram diagram'. This allowed the first precise calculation of the amount of light entering a room. The tools extensively developed in due course of time to give accurate results, i.e., the NBC-2005 and IES VE 2016 simulation has shown perfect conformity to each other as elaborated in the paper. The window opening design is a critical component in a building in order to conserve illumination energy with respect to desirable sizes and the functional utility of the space. This has to be dealt with adequate scientific knowledge to save illumination energy by appropriate daylight levels on working plane.



is can be further studied by integrating with thermal comfort and number of required air change per hour.

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