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Comparison of Different Lecture Halls with Respect to Visual Comfort

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Abstract—*Daylighting is the use of free, natural light from the sun to illuminate a space. It is an important issue in modern architecture affecting the functional arrangement of space, visual comfort, structure and energy use in buildings. It can improve the health, well-being and productivity of occupants. To visualize the daylight performance, measurement and prediction of daylight illuminance distribution is necessary. There are various methods of measuring daylight viz., calculation methods, graphical methods and simulation methods. In the present work various lecture theatre of NIT Srinagar have been compared in terms of daylight factors.*

1. INTRODUCTION

A significant amount of energy can be saved by using daylight to replace or supplement to electric lighting in commercial buildings. In present times people show increasing interest in using daylight to save energy in buildings [1,2]. A large amount of work has been done to make the buildings more and more energy efficient, but still buildings are not designed to take advantage of daylight. Therefore, daylighting is an important issue in modern architecture. It affects the functional arrangement of space, visual comfort, structure and energy use in buildings [3]. To visualize the daylight performance of a building, measurement and prediction of daylight illuminance distribution on work plane is necessary. Inside a given building and at a given point, the ratio of indoor illumination to the corresponding outdoor illumination is taken to be as constant and is known as daylight factor (DF) [4], given by

$DF = Ei/Eo$

Where Ei = Indoor illumination at station point,

Eo = outdoor illumination from unobstructed sky hemisphere.

The three components contributing to daylight factor are sky component (SC), externally reflected component (ER) and internally reflected component (IRC)

$DF = SC + ERC + IRC$

Knowledge of daylight factor is crucial for artificial lighting design. The extent to which daylight contributes to the illumination of an interior is best described by daylight factor. It has been found that when daylight factor is 5% or more, an interior will generally look well day lit. When the daylight factor is less than 2%, the interior will not be perceived as well day-lit and artificial lighting may be in constant use during the day. When daylight factor is between (2-5) percent, the artificial lighting should be planned to take advantage of available daylight. Localized or local lighting may be advantageous using daylight to provide the general surround lighting. The work plan illumination level (Lux) depends on the type of activity.

In the resent years, it has been studied that daylighting in schools not only save a significant amount of energy but increase students' test scores and promote better health and physical development. Keeping the benefits of daylighting in schools and the resent research trend, the authors, for the first time tried to analyse the daylighting conditions of lecture theaters in NIT Srinagar, Kashmir. Srinagar is situated at 34.08 N latitudes and 74.79 E longitude.

2. METHODOLOGY FOR OBSERVATION AND COMPARISON

In the present study, five lecture theater buildings were selected from National Institute of Technology Srinagar. These lecture theaters were designated as: H1, H2, H3, H4 and H5. All these halls had different characteristics. H1 and H2 were having the same geometry, floor area and window orientation but lie on ground and first floor respectively. H3 and H4 also had the same dimensions but different orientation. H3 had North-South direction where as H4 was in East-West direction. H5 was taken from a two story building for investigation. It had windows in one façade only. For each room, different parameters of daylighting performance were calculated. The same method was used for all the halls. The method was as follows; First a luxmeter was kept outside the building without any obstruction (in some cases on top of the building) to measure the external illuminance. Concurrently, the illuminance of interior spaces was measured. The measured work plan illuminance in interiors at different positions (rows and Columns) compared with each other. For measuring work plan illuminance, the room index was calculated as follows.

Room Index = (lengths × width) / [Mounting height × (length + width)]

The room index was required to know the minimum number of measuring positions from which average illuminance may be calculated. Then according to the room index equation and Table 1, minimum numbers of measuring points were calculated for each lecture hall. An attempt is made to understand the variation of illuminance level from one hall to another. Different parameters responsible for this variation were determined.

Table 1: Room Index and number of Measuring points

Room Index	No of measuring points
Less than 1	4
1 to below 2	9
2 to below 2	16
3 or greater	25

2.1 Building Orientation

Of the various factors influencing the building design, orientation occupy an important position. Orientation refers to the location of a building with respect to the cardinal directions, i.e. North-South and East-West. In cold climate places, like Srinagar, the building needs to be oriented such that solar radiation is admitted to the maximum possible. In the present study, H3 has North-South direction whereas H4 is in East-West direction. As is clear from the figure 1, illuminance is greater in H3 as compared to H4 due to the orientation as all other parameters are same in both the lecture halls. The minimum lux level in lecture hall as per [4] should be 300 lux but from the Figure 1, it is clear that for H4 illuminance level is below 200 lux for all rows and columns which is not sufficient. On the other hand for H4 the lux level can go up to 1100 lux near the window. Therefore the lecture theater having North-South direction has more provision of daylighting as compared to one having East-West direction. But it is not possible to construct a building only in a particular direction due to number of constraints i.e. availability of space etc. The configurations of fenestrations forms an important aspect of climatic design. These are provided for the purpose of daylighting and ventilation. Therefore appropriate design of windows can help to lit the building during daytime. So, for buildings which are oriented East-West, should have appropriate designed windows and suitable number of fenestration. Furthermore, for the existing buildings which are in East-West direction one should use the advanced daylighting systems such as Anidolic Ceiling (AC), Laser-cut panels, Prismatic panels etc which has been reviewed by S. Rayaz and S. Rubab [5] in detail.

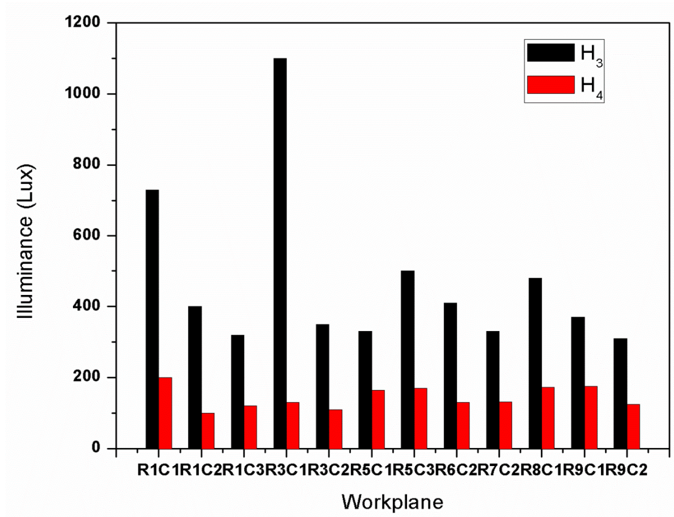

Fig. 1. Illumance level on workplane for H_3 and H_4

The lecture theaters H1 and H2, which are on ground and first floor respectively, were examined for the whole week and average daylight factor was calculated on every day. After analysis figure 2 was plotted. For H1 daylight factor was less than 3% for all the days, which was less than the recommended value. Therefore, H1 is not good for daylighting point of view. On the other hand H2 was found satisfactory. This variation was due to an obstruction building nearby. The ideal window wall ratio for the ground floor hall was estimated so that target illumination level could be achieved. It came out to be 30%. But it will work only for new designed buildings. For already existing buildings one should use External Light Shelves to improve lighting by reflection and provide a virtual sky to spaces during overcast sky and for obstructive building. The lighting level for first floor was sufficient but glare problems were seen. The glare can be reduced by using some shading device without affecting the lighting level.

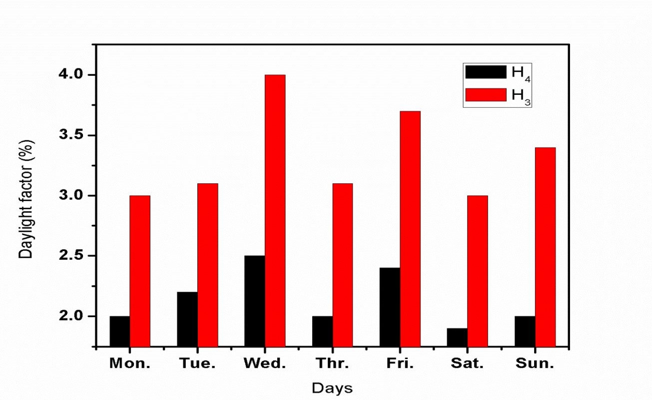

Figure 2. Illumination levels for H_1 and H_2

Figure 3 was obtained for the lecture theater H5 which was taken from the top floor of the institute building. This room was having windows in one side only, so we tried to find the variation of illuminance with distance from the window and came to know that there is no uniformity of illumination throughout the hall. As distance increases lighting levels became worst for sunny days. Since H5 was on top floor so using sky light or light pipes for uniformity of daylight may be the best solution. For already existing buildings it is suggested to use Angular selective Skylight.

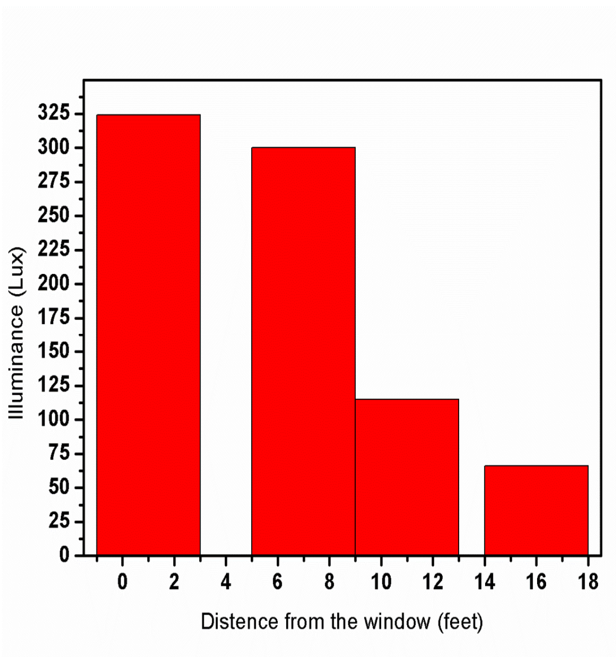

Figure 3 Illumination levels for H_5

2.2 Estimation of lighting energy savings from daylighting

A simplified calculation can be used to estimate the percent savings, Fd, in annual use of artificial lighting due to daylighting implementation using daylighting. The following equation can be used in doing so [6]. Fd = b [1- exp (-aτw Aw/Ap)] Ap/Af (1)

Where τw is the visible transmittance of the window glazing and Aw/Ap the window to perimeter floor area. This parameter provides a good indicator of window size relative to the total building floor area. Ap/Af is perimeter to total floor area. The coefficients a and b depends on building location.

A single lecture room has been considered to calculate the percent lighting energy savings (annual) using simplified method of equation (1) for climatic conditions of Kashmir valley. The different parameters of the theater are:

Aw= 13.9 m^2, τw= 0.72.

Since the parameter Ap/Ap indicates the extent of the daylit area relative to the total building floor area. Therefore, if Ap/Af = 1, there is good provision of daylighting. Also a and b depends on building location and for Jammu and Kashmir,

a =19.63 and b =74.34

Therefore, Ap/Af=1.0 and Daylighting aperture i.e τw Aw/Ap= 0.106

Using all these parameters in above equation

Fd (%) = 74.34[1-exp(-2.08)] = 65%

Therefore, 65% of energy can be saved in a single lecture theatre by using proper daylighting especially for perimeter space fully exposed to natural light. The potential impact of daylighting in reducing annual electrical lighting energy use can be determined in the early phases of the design process. There is no need for detailed computer simulations, control strategies and settings.

2.3 An Ideal Window Wall Ratio (WWR) for good daylighting practices

The main objective of this case study is to identify potentia lly daylit zones in a building, to assign them dimensions and glazing areas and finally finding the required WWR. To accomplish the objective above specified, "Daylighting Rules of Thumb" was used to find out ideal glazing area for windows and ideal window wall ratio for existing or new buildings in Kashmir valley to achieve the target level of daylighting.

The dimensions of the lecture hall are as follows

Height from floor to the ceiling (H) =10′, Height from ground to the middle of window = 6′

Width (W) = 26′, Length (L) = 39′, Work plane height = 3′, Window head height (h) = 9′

Street width (d) =23′

2.3.1Calculation of different daylighting parameters

Sky Angle 'θ'

The sky angle 'θ' determines the amount of daylight, lecture hall is receiving. It can be find out by taking the centre of the window.

$\tan\theta = 23'/26'$ or $\tan\theta = 0.88$ or $\theta \approx 41^0$

Daylight quality and uniformity is also important for visual comfort. Both these parameters depend on the interior space dimensions and surface reflectance. The interior space dimensions include;

Daylight uniformity

It is the distance at which the uniformity of daylighting levels throughout the space drops. It can be approximated by

Limiting depth (L1) = $\frac{2}{1-R} \div \frac{1}{W}+\frac{1}{h}$

Where, R= Mean surface reflectance, W = Width of the hall, h = window head height

or L1= 26′10″

No sky line depth

It is the distance away from the window at which the sky is no longer visible and is defined as

Limiting depth (L2) = (Window head height- work plane height) tan θ

or L2= 5′3″

Depth of daylight area

According to the Harvard University Graduate School of Design

Limiting depth = 2.5xh, when no shading device is used.

When all the three limiting factors were taken into consideration, the room depth is

Room depth < Minimum of L1, L2 or L3 = 5′3″

Therefore, the greatest room depth that can be used for daylighting is the smallest of the three limiting depths.

Area of Glazing

The area of glazing for maximum penetration of daylight inside the hall with dimensions according to the previous steps is determined as,

Aglazing= DF x 2Atotal (1-R)/**τ**w θ

Where Atotal= Total area of all internal surfaces (including windows) in sq. feet

If h= ceiling height, then

Aglazing ≈ 109 sq.feet

Hence, Resulting WWR ≈ 29%

3. CONCLUSIONS

The natural lighting that entered the lecture theaters having East-West direction was very low as compared to North-South oriented buildings. So in order to have a proper natural lighting, orientation plays an important role. For existing buildings one can use "advanced daylighting systems" for daylighting improvement. One has to keep in mind the ideal WWR while designing a new building when there is an obstruction building nearby. It is necessary to design the windows such that there is uniform distribution of daylight in the lecture theater. In order to control the entering of direct sunlight and glare, it is necessary to use some shading elements. About 65% of energy can be saved in a single lecture theatre by using proper daylighting especially for perimeter space fully exposed to natural light. The resulting WWR of the hall lie close to 30%, which is good daylighting practice. Only a WWR of 29% is required to daylit the narrow band of 5 feet. The limitations of this of this study is that direct sunlight, façade orientation and movable shading were not taken into account. One of the important advantages of using this sequence is that it is well suited with climatic conditions of Kashmir valley.

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