Efficiency of Daylighting in a Building -A Case Study

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Abstract— Daylight should be used as primary light source in building in daytime and fulfil both our visual and nonvisual (biological)needs. Sick building syndrome is largely related to air quality and indoor pollution, but also takes into account the availability of natural light, which studies show is vital for people's health and wellbeing. The health effects of natural light and fresh air offered by windows are pivotal to the health of a home and its inhabitants. A lot of the research that relates to the health benefits of natural light relates to night shift workers in particular, because they are working in an environment without natural light, which suppresses their serotonin levels (which affects their happiness), and melatonin levels (which affects their sleeping and relaxation). A lack of exposure to natural light can even lead to seasonal affective disorder, or the 'winter blues', which can then lead to clinical depression. Good lighting will provide a suitable intensity and direction of illumination on the task area, appropriate colour rendering, the absence of discomfort and, in addition, and a satisfying variety in lighting quality and intensity from place to place and over time. The argument for day lighting in buildings therefore has three strands:
• it provides a healthier and more enjoyable indoor climate
• it conserves the earth's resources
• because it saves energy, it saves money. This research work involves checking of lighting efficiency in a building by taking onsite measurements and compare with the protractor method.

Key words: Day Lighting, Protractor Method, Onsite Measurements, Lux Meter, Sick Building Syndrome

I. Introduction

A. General

In the present energy scenario in India where gap between demand and supply of electrical energy is continuously increasing, the escalation in cost of power and associated environmental concerns have created awareness about efficient use of energy in every walk of life. Since, building sector is a major consumer of electricity, it is imperative to envelope building designs that would utilize solar and wind energy to the fullest possible extent for ameliorating thermal environment indoors [1].The focus of these areas is directed towards improving energy efficiency in existing buildings and development of codes so that new buildings to be designed and built with energy efficiency [1]. This is a testimony to the fact that necessity for design of functional and energy efficient buildings has been very well recognized and efforts are needed to design buildings that would function in conformity with climate and not zoning the country into regions in such a way that the difference of climate from region to region are reflected in the building design, warranting some special provision for each region.

There is a still a very slow uptake of energy efficient technology in market place today. Currently there is a little or no legislation governing energy efficient design and there also appears to be very little incentive for buildings to be operate more efficiently.

By adopting more modern and energy efficient technologies and practisers, potential designers, builders and end users in Asian developing countries should gain comparative advantages while avoiding mistakes of the industrialized world [2]. However, there are several barriers hindering them from bracing energy efficiency options in their buildings. Good lighting is necessary for all buildings and has three primary aims:

– To promote the work or other activities carried on within the building
– To promote safety of people using the building
– To enhance the environmental quality and the energy efficiency of the building
– To create, in conjunction with the structure and decoration, a pleasing environment conductive to interest and a sense of well-being.

B. Aim of Research

– To do the energy auditing to determine the lighting deficiency of the building.
– To take onsite measurements to determine the Establish local design sky illumination.
– To determine the necessary daylight factor for the building.
– Compare with the Standards given by BSCP.
– Manipulate the design variables to achieve the required daylight factor.

II. Methodology

A. Case Study

Case study taken for the present work is the Library building of Pondicherry Engineering College which is located nearly 10km from the town and nearer to the seashore. The landform or topography of the case studies is undulating and different conditions prevail over the entire area since slopes and depressions lead to different levels of air temperature and humidity. The Library is located at an altitude of 23.8m and 17.2m from the mean sea level. Orientation of the buildings is South facing and it receives least radiation during morning and evening but still there is some heating problem exists. The plan of the case studies are shown in the Figures and Figures 1,2,3.

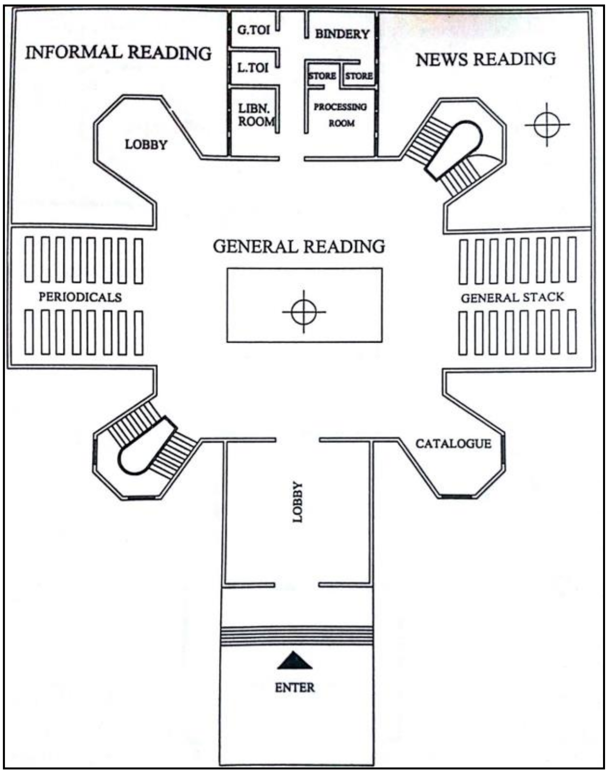


Fig. 1: Ground floor plan of case study

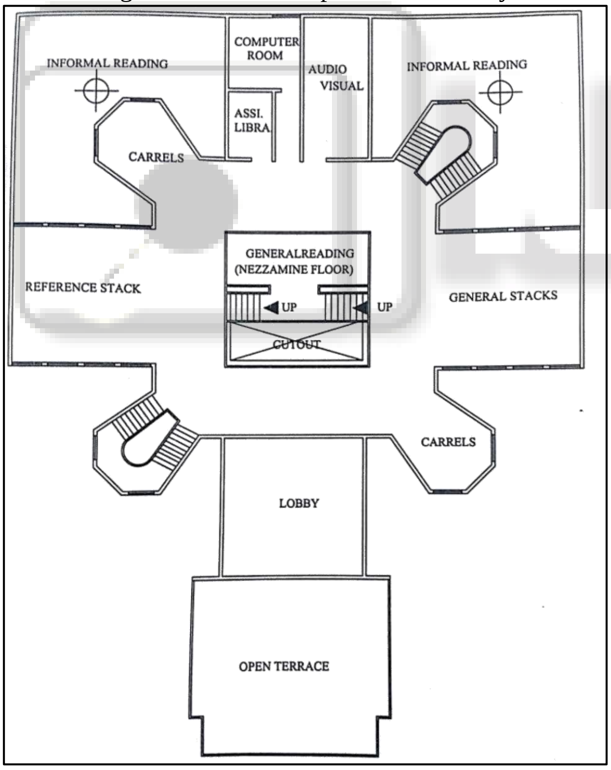


Fig. 2: First floor plan of case study

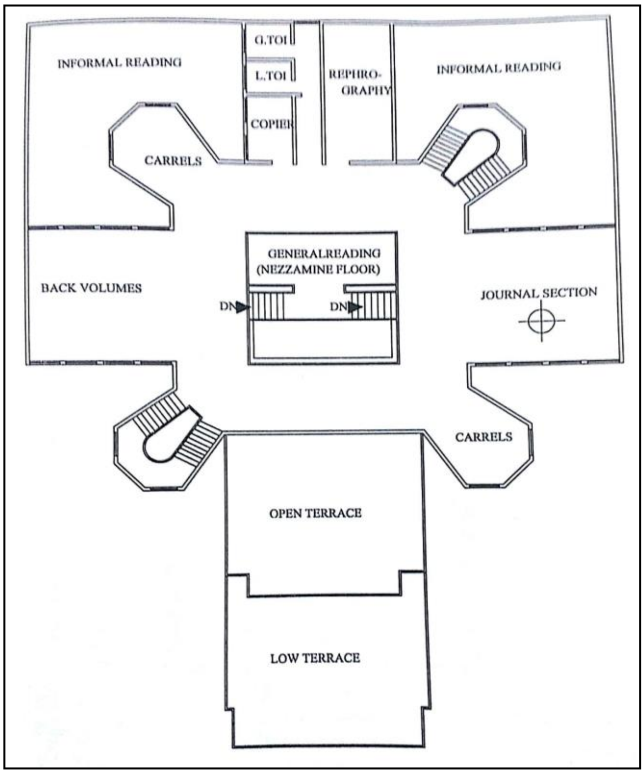


Fig. 3: Second floor plan case study

B. Day lighting Analysis

The daylighting analysis can be carried by any of the following methods:

- On-site measurements (e.g. using lux meter) and calculate DF.
- Nomographs or charts (e.g. daylighting protractors)
- Computer programs (e.g. RADIANCE, Lumen Micro, Lightscape, LightCAD)

The method taken in the present study in on site measurement using Luxmeter and the Nomographs and daylighting protractor.

C. On-site measurements

Procedure for analysis

- Take on site measurements using Luxmeter as shown in Figure
- Establish the minimum illumination level (Ei)
- Establish local design sky illumination (E0)
- Calculate the necessary daylight factor using the formula [4] given below

$$DF = E_i / E_0 \times 100$$

Where

E_i is the minimum illumination level in Lux

E_0 is the local design sky illumination in Lux (E_i = 8000 Lux for Warm – Humid climate)

- Compare with the Standards.
- Manipulate the design variables to achieve the required daylight factor.

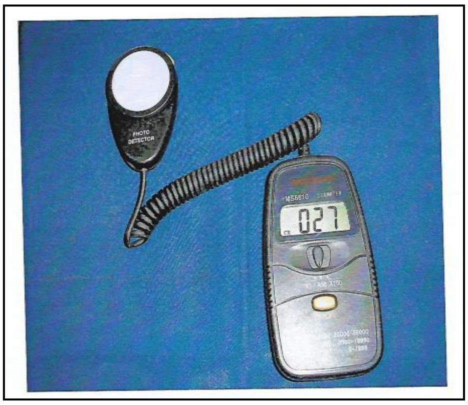


Fig. 4: Lux meter

D. Determination of Daylight factors:

Day lighting analysis using Lux meter has been carried out for four months from the month of September. Minimum illumination level for the four months have been measured and presented in the Table 1 below. Minimum of four months is taken as the E_i value. The local sky illumination E_0 is taken as 8000 Lux for Warm-humid climate. The day light factor is determined, compared with recommended value and the deviations are found out and reported in the table. Minimum Daylight factor goes up to 0.3% and maximum reaches to 2.8%. The standard used for comparison is given by "British Standard code of Practice"

Location	Sep	Oct	Nov	Dec	E_i Lux	E_0 Lux	DF %	Req. value	Deviation
Ground floor	130	100	90	120	90	8000	1.1	2	0.9
First floor	90	70	30	50	30	8000	0.3	2	1.7
Second floor	160	110	100	120	110	8000	1.3	2	0.7
News reading section	260	220	210	230	210	8000	2.6	2	0.6

Table 1: Values of Day light factor by Site measurements for case study

E. Protractor method

In the case of light falling on to a point, it can be broken down into three components

- Sky component
- Externally reflected component
- Internally reflected component

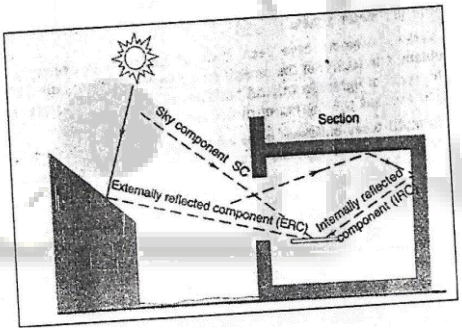


Fig 5: Components of Diffuse Light Falling on work Plane in a room

The component usually falls as shown in Figure 5.14 [1]. Daylight factor is nothing but the sum of these components and can be expressed as follows.

$$DF = SC + IRC + ERC$$

F. Determination of Sky Component

- Take the section of the room, draw the working plane and on it the point to be considered (O) as in Figure 5[1].
- Connect the limits of aperture to point o i.e., the lines PO and RO.
- Place the protractor with a scale a uppermost, baseline on the working plane with the centre on point O.
- R3ead the values where lines PO and RO intersect the perimeter scale: the difference of the two values is the initial SC.
- Read the altitude angles where lines OP and RO intersect the angle of elevation scale and take the average of the two readings.
- Take the room plan and mark the position of the point to be considered (O).

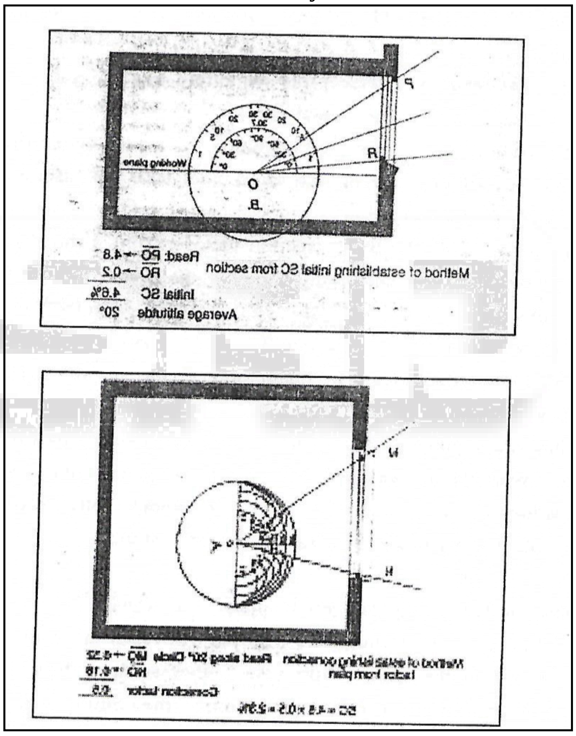


Fig 6: Use of Daylight protractor to evaluate the Sky Component

- Connect the limits of aperture with point O, i.e., MO and NO.
- Place the protractor with scale B towards the window, base line parallel to the window with the centre on point O.
- Four concentric circles are marked on the protractor 0^0, 30^0, 60^0 and 90^0. Select the one according to the corresponding elevation angle obtained in step 5, if necessary interpolating an imaginary semi-circle. Unless the reference point is very close to the window, this will normally be well below 300 and will not have much effect.
- Where lines MO and NO intersect this semi-circle read and values along the short curves on the scale of the inner semicircle.

- If the two intersection points are on the either side of the centre line, add the two values obtained: if they are on the same side, take the difference of the two values. This will be a correction factor.
- Multiply the initial SC by the correction factor to obtain the sky component. If there are no obstructions outside the window, there will be no ERC. If however, there are objects will reach the point considered, and will contribute to the day lighting, particularly in crowded urban situations. The magnitude of this contribution is expressed by the ERC, which can be found as follows.
- Find the equivalent SC, which would be obtained from the same area of sky were it not obstructed, following the steps described above.
- Multiply this value by 0.5 times the average reflectance of obstructing surfaces, or if this is unknown, by a factor of 0.2.

G. Determination of Internally Reflected Components (IRC)

Much of light entering through the window will reach the point considered only after reflection from walls, ceiling and other surface inside the room. The magnitude of the contribution to the day lighting of the point considered is expressed by the IRC. This will normally be fairly uniform throughout the room, thus it is sufficient to find the average IRC value. The simplest, method uses the nomogram given n Figure 6[1]. Steps to be taken in with nomogram are as follows:

- Find the window area and find the total room surface area (floor, ceiling and walls, including windows) and calculate the ratio of window to total surface area. Locate this value on scale A of the nomogram.
- Find the area of all the walls and calculate the ratio of wall to total surface. Locate this value in the first column of the small table (alongside the nomogram).
- Locate the wall reflectance value across the top of the table and read the average reflectance at the intersection of column on line. Or calculate an area – weighted mean reflectance (assume glass reflectance is 20%).
- Locate the average reflectance value on scale B and lay a straight – edge from this point across to scale A (to value obtained in Step 1).
- Where this intersects scale, read the value which gives the average IRC if there is no external obstruction.
- If there is an external obstruction, locate its angle from the horizontal, measured at the centre of window, on scale D,
- Lay the straight – edge from this point on scale D through the point on scale C snd read the average IRC value on scale E.

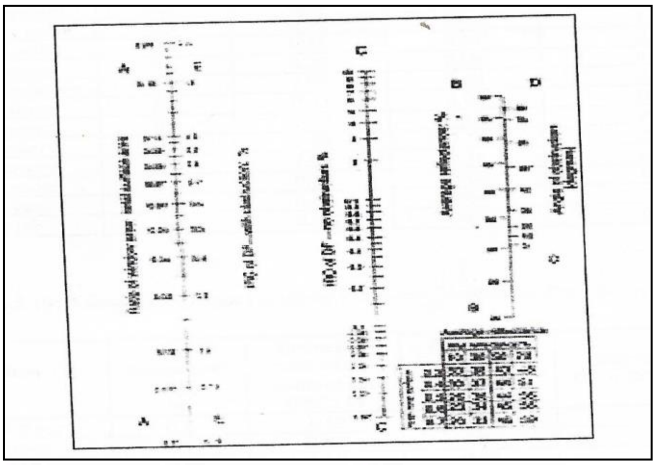


Fig. 7: Nomogram for the Internally Reflected Component of the Daylight Factor

H. Determination of Daylight Factor

The magnitude of the three components such as Sky component, Internally Reflected component and Externally Reflected component are determined for all the locations of the Case Studies and Daylight Factor is determined by taking the sum of these components and are reported in the Table 5and Table 6.

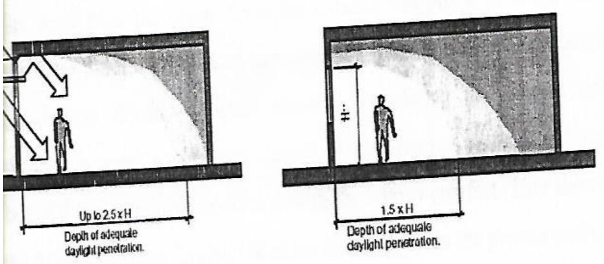
Location	Sky component (SC) %	Internally Reflected component (IRC) %	Externally Reflected component (ERC) %	Day light factor DF=SC+IRC+ERC
Ground floor	0.2	1.19	0.04	1.43
First floor	0.1	0.52	0.02	0.64
Second floor	0.1	1.29	0.06	1.65
News reading section	0.3	1.74	0.18	2.82

Table 2: Values of Daylight Factor by Protractor Method for Case Study

III. RESULTS & CONCLUSIONS

1) Building health survey explains that most of the people suffer problems like eye irritation, throat infection, headaches, lack of concentration, fatigue, skin dryness etc due to improper lighting, poor ventilation and excess heat in summer in both the Case Studies. 80% of people participated in the survey reported at least one of these symptoms.
2) Temperature control (78 percent) and ventilation (66 percent) were the most common problems ever noticed by respondents.
3) Drafty conditions were reported by 75% of the respondents, 14 of whom (70 percent) noted that the conditions still exist. It shows that it is necessary for evaluating the building for comfort.
4) The minimum daylight factor for all the locations is determined by both the methods and compared with the standards.
5) In most of the classrooms daylight factor is found to be less than the recommended value.
6) Minimum Daylight factor goes up to 0.3%. Day light could be adopting the following systems.
7) Daylight penetration into a space can be increased by using light shelves. This is a horizontal element with a high reflectance upper surface that reflects light onto

the ceiling and deeper into a space. Matte finishes are better than specular surfaces for good distribution of daylight because they reduce reflected glare (hot spots).



8) Interior windows, transoms, and translucent or transparent interior partitions allow daylight to pass through to other spaces.
9) Blinds that rise from sill level, rather than drop down from above can be used to reduce backlighting and glare on work surfaces while still allowing daylight to penetrate deeply into the room through the unshaded upper part of windows.
10) Desirable reflectance's such as ceilings>80 percent; walls 50-70 percent; floors 20-40 percent; furniture 25-45 percent should be given.
11) Generally avoid dark colors except as accents, and keep them away from windows. Dark surfaces impede daylight penetration and causes glare when seen besides bright surfaces. For good distribution throughout the room, it is especially important that the wall facing the window be light-colored.
12) From the Energy Auditing the approximate consumption of electrical energy is determined and are as follows for case study = 77.2 KW
13) This could be effectively reduced by adopting the climatic design principles improving the energy efficiency.

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