Assessment of Day Lighting Performance of Institutional Building

***Ganiya Thasneem ** Sangeeth, K.**

*B. Arch Student, **Professor, Department of Architecture, TKM College of Engineering, Kollam.

Abstract

Using natural light to illuminate the interiors of buildings can significantly reduce both lighting electricity consumption and peak demand for electricity. In addition, there are health and color rendering benefits associated with full-spectrum natural light. However, widespread adoption of day lighting techniques has been hampered by the lack of both daylight resource information and simple, reliable methods of testing day lighting designs. The luminous efficacy of daylight is generally superior to that of commercially available electric lamps, which means that sunlight has the potential for reducing building cooling loads by replacing electric light of higher heat content. Natural light is plentiful during the hot summer periods when many utilities experience their peak demand, suggesting that there is a potential for substantially reducing peak electric demand, with consequent demand-charge savings for the building owners and reduced capacity requirements for the utility. Considering the above parameters a study was conducted to assess the daylight performance of a space and to analyze how day lighting and various parameters related to day lighting which affect the visual comfort of a space. Initially a structure of the aim and objectives was formed and a literature study on the topic day lighting was done. Thereafter a space was selected and a detailed live case study was done by measuring the daylight intensity and the data were analysed with respect to various factors affecting the day lighting phenomena and the problems or flaws of the particular space were identified. Attempts have been made to solve the identified problems of each space using different options with the help of a working model, where the issues are replicated and various solution techniques were applied. From the study it could be concluded that the issue of over lighting and glare can be reduced by reducing the width or height of the window openings along with extending the sunshades. Increasing the sill height of the window above the work plane can help in a even distribution of light throughout the room. Curtains and fins can be also provided in case of sunny days with can be removed when not in use which will help to reduce glare. Increasing the width of the window cannot make change in the intensity of the daylight if the surrounding areas have obstructions. Again increasing the length of the sunshade can help in controlling the glare. In addition to this selecting the surface materials with proper reflectance can help in improving the quality of the space.

Introduction

Using natural light to illuminate the interiors of buildings can significantly reduce both lighting electricity consumption and peak demand for electricity. Since electricity consumption and peak electric demand associated with electric lighting constitute the major energy operating cost in many commercial and institutional buildings, the potential cost savings of a well conceived day lighting strategy can be very significant. In addition, there are health and color rendering benefits associated with full-spectrum, natural light. However, widespread adoption of day lighting techniques has been hampered by the lack of both daylight resource information and simple, reliable methods of testing day lighting designs. The natural light resource is substantial during most working hours, the light incident on a building is several times greater than that required to illuminate the building interior, indicating that it should be possible to design solar apertures that provide enough interior illumination to offset most or all of the daytime lighting electricity consumption. The luminous efficacy of daylight is generally superior to that of commercially available electric lamps, which means that sunlight has the potential for reducing building cooling loads by replacing electric light of higher heat content. Natural light is plentiful during the hot summer periods when many utilities experience their peak demand, suggesting that there is a potential for substantially reducing peak electric demand, with consequent demand-charge savings for the building owners and reduced capacity requirements for the utility. Natural light is full-spectrum light with significant health and color-rendering benefits.

Natural light is constantly undergoing changes in intensity and subtle changes in color that enhance the building occupant's sense of connection to the outside environment. Electricity is intrinsically one of the more expensive energy sources that we use in buildings and electric lighting fixtures are quite inefficient in the conversion of that energy to light, as is demonstrated by the graphic presented below showing the conversion and transmission losses in taking raw energy at the power plant to useable illumination on the task surface.

There are many reasons that justify day lighting as a useful light source in almost every type of buildings. Primarily because of the quality of light, importance of daylight as a design element, communication channels to the outside provided by daylight apertures, energy conservation resulting from the use of daylight as a primary or secondary illuminant and the psychological and physiological benefits not obtainable with electric lighting or windowless buildings. Considering the above parameters a study was conducted to assess the daylight performance of a space and to analyze how day lighting and various parameters related to day lighting affect the visual comfort of a space with the following objectives.

- To identify parameters of day lighting of a particular space.
- To evaluate how each parameter affect the daylight performance in a space.
- To compare the intensity of daylight at different times on the climatic conditions to analyze whether the space meet the minimum required light intensity.

Methodology

A detailed case study was conducted to know about the day lighting performance in four different spaces in an institutional building. Using the data obtained from the case study, a detailed analysis was done to identify the problems or flaws of each space. An institutional building is a place which requires adequate and proper lighting facility. TKM College of Engineering, Karicode, Kollam was chosen for the assessment of day lighting performance. The Department of Architecture block was taken for the detailed analysis of each space. Four spaces viz. studio, classroom, staffroom and department library were elected for assessment. The parameters which affect the day lighting performance of a space viz. penetration and spread of sky component, sill height, room dimension, surface reflectance, external obstructions and transmittance of window elements were analysed. Light intensity was measured using lux meter. Several readings were taken at a point and the average was taken as the final value. Light intensity readings were recorded under clear sky and clouded sky conditions..

Studio 4, the studio used for the architectural design by the students was chosen for the study. Detailed study of the studio was conducted for the assessment of day lighting performance. The studio can accommodate almost 50 students at a time. A studio is a space that require adequate day lighting and that is the reason why this space has been selected. Room dimensions were 15 x 12 m with windows of 1.2 x 1.5 m and door of 1 x 2 m. Classroom A307, is a classroom that can accommodate 50 students at a time was chosen for the study. The class room is provided with two door openings and sufficient window openings. Room dimensions were 10 x 7 m with windows of size 1.2 x 1.5 m and 0.6 x 1.5 m and door of size 1 x 2 m. A staff room of size 5.4 x 3 m which can accommodate two persons with window of size 1.2 x 1.5 m and door of size 1 x 2 m. Department library, a space with special arrangements which can accommodate 50 students at a time was chosen for the study. There is a mezzanine floor level in the library. Library is a space that require good amount of high quality light. The dimensions of the library were 15 x 12 m, mezzanine floor: 12 x 7.2 m, windows of 1.2 x 1.5 m and 0.6 x 1.5 m, ventilator 1.2 x 1 m and door 1 x 2 m. The light intensity readings were taken twice daily from all the four spaces. Each space was analyzed based on the identified parameter with respect to the available data of literature study.

Results and Discussion

From the readings of the test conducted with the help of lux meter, it was found that the studio has met the minimum requirement of the necessary day lighting. But it is also found that at many points the day lighting received is much greater than the recommended value. Recommended day light factor per cent for educational building is from 1.9 to 3.8, where 1 percent is taken as 80 lux, which means between 152 lux and 304 lux. Some points in the studio receives 900 lux during clear sky day and 700 lux during cloudy day, both are higher than recommended value, hence there is a chance of glare at that points. During cloudy day the daylight received falls almost within this range for all other points. In the classroom all points meet the minimum required level but some points receive excess amount during clear sky which is near to the door. This makes it uncomfortable for students sitting in that area due to glare. During cloudy day this problem is not much affected. Staffroom seems to be in an ideal position as this space receives correct amount of light in both cases which falls within the mentioned range. Library is a space that should receive apt amount of light. But unfortunately it was observed that this space has very uneven distribution of light. Most of the points did not receive required amount of light even in clear sky condition. The points where the book shelves are positioned received very less light. Under this condition it is impossible to create a comfortable reading atmosphere without the help of strong artificial lighting support.

Penetration and spread of sky component

Generally, penetration is greater with taller windows and spread is better with broader windows. However, a proper distribution of taller windows can provide a good penetration as well as a good spread of sky component on the work plane. Similarly, a suitable sill height above the work plane will enable broader windows to provide a good distribution of light. More windows on the same wall or adjacent and opposite walls give better distribution of light than a single large window. In studio, classroom and staffroom windows are placed in adjacent walls and opposite walls with almost equal number of distribution. No large single window is used in any of the spaces. The windows are 120 x 150 cm which provides a good penetration and spread of sky component. Sill height is also suitable in these cases but in library the presence of mezzanine floor makes the distribution uneven. Also the ventilator in the mezzanine floor is 120 x 100 cm which does not provide proper penetration and spread of sky component.

Sill height

For carrying out a task while standing or squatting on floor, suitable work plane levels are 1.0 and 0.3 m high respectively. Since the part of a window below the work plane does not contribute significantly to the work plane illuminance, a sill height slightly greater than or equal to the height of the work plane above the floor level is desirable. The optimum sill for good illumination as well as good ventilation should be between the illumination work plane and the head level of a person. In studio the work plane is about 100 cm, for classroom, staffroom and library it is taken as 60 cm and. The classroom, staffroom and ground floor of library has desired sill height as mentioned above which is equal or greater than the work plane. But the mezzanine floor and studio has sill height lesser than work plane.

Room dimension

The dimension of a room (for a ceiling height 3.0 m) perpendicular to the window wall should be less than 7.0 m for unilateral lighting from side windows. For a room depth of 7.0 m or more, windows on opposite walls are recommended. As a general rule, unilateral lighting from side windows will be unsatisfactory if the room depth is more than two and a half times the height of the window top above the floor level. The maximum height of the window top and consequently the penetration of sky component is limited by the ceiling height. In general, lighting of smaller rooms from sky and inter-reflection is better than larger rooms. This is the reason why staffroom has ideal amount of day lighting compared to other spaces. Staffroom is a small space compared to others of dimension 5.4 x 3 m. staffroom has two window openings placed in opposite walls. In studio and library windows are provided in the opposite walls, which is a apt method to follow in larger rooms. Here studio and library are quite a large space compared to others with a dimension of 15 x 12 m. Classroom is of a dimension 10 x 7 m .Classroom has window and door openings concentrated on one side only, which is the reason for the excess amount of light and glare in that area.

Surface reflectance

The amount of internal and external reflected components is governed respectively by the reflectance of internal surfaces of a room and external surfaces reflecting light into the room. For any choice of colour scheme, the reflectance of different surfaces can be suitably fixed. The reflectance of common finishes and surfaces are given in Tables 1 and 2.

Table 1. Reflectance of common finishes and surfaces

Typical finish of surface	Reflectance
White wash	0.7-0.8
Cream colour	0.6-0.7
Light green	0.5-0.6
Light blue	0.4-0.5
Light pink	0.6-0.7
Dark red	0.3-0.4

Medium grey	0.3
Cement terrazo	0.25-0.35
Brick	0.4-0.5

Table 2. .Desirable reflectance of room surfaces

Surface	Reflectance
Ceiling	0.7-0.8
Wall	0.5-0.6
Table top	0.35-0.50
Floor	0.15-0.30

Staffroom and library has cream colour for walls and ceiling, which gives reflectance of 0.6 to 0.7, which indicates that for walls desired reflectance is obtained but for ceiling it is not. The floor of these spaces is medium grey which gives a reflectance of 0.3 that meets the desired value. Classroom and studio has white wash for the wall and ceiling which has a reflectance of 0.7 to 0.8 which meets the reflectance value of ceiling but for wall the value is slightly above the desired range. The floor of these spaces is medium grey which gives a reflectance of 0.3 that meets the desired value.

External obstructions

External obstructions like opposite buildings, trees etc. reduce the sky component but add to the external reflected component. The external reflected component varies directly as the reflectance and illuminance of obstruction and also as the solid angle subtended by the obstruction at the given point. The obstructions at a distance of three times their height or more from window façade are not significant and may be ignored. As the separation between a window facade and opposite building is reduced, there is a progressive reduction of daylight. Layout of buildings is significant in determining the daylight availability inside. While continuous rows of parallel buildings result in maximum reduction of daylight, perpendicular staggered blocks cause minimum reduction of daylight for the same spacing to height ratio. In studio, as it is located in the 3rd floor which is above all the adjacent buildings, there are no external obstructions. In classroom also there are no external obstructions in the side of window opening. In staffroom there is a building adjacent to side of one window opening but sufficient amount of light is received. In library along one side of the space there is a building very adjacent that blocks the sunlight and add to the external reflected component which is one reason for the less amount of light received in that space.

Transmittance of window elements

Overall transmission of daylight through windows depends upon dirt collection on window panes, glazing material and shading devices. The decrease in daylight illumination due to accumulation of dirt on window surfaces varies with the location, the angle at which the glass is mounted and the cleaning schedule. The transmittance of a complex louver system is slightly less than the box type of louvers. Sashes, window bars and other window elements occupying a certain area of the window reduce the daylight indoors in proportion of the area so obstructed. In studio some windows and the door have wooden shutters, so that all openings are kept open for daylight to come it. No light can enter in closed state. But windows along the side that faces outside have glass panels in between. In classroom all windows and doors have wooden shutters , so it should be kept open for daylight to enter. But in staffroom one opening had sliding glass window which allows the entry of daylight even in closed state.

Problems identified in each spaces were, excess light received which results in glare, less light received than required amount and uneven distribution of light. Solutions for these problems were attempted by trying out experiments on a working model of space replicating the issues identified. Different options were experimented in this model room of dimension 10 m x 10 m and was analysed on whether these experiment options could do something to the issues and finally a conclusion is drawn.

Experiment 1

In this experiment adjustments of width of windows were done. The experiment was done in an open space with working model of dimension 10 m x 10 m of scale 1:20. Windows of width 60 cm was cut out and sunlight was measured using lux meter. The model is placed and set accordingly so that some points value high than required value. These points would have glare issue also. Window width was reduced to half and t the value was again measured. Thereafter the model was set accordingly so that light received is less than minimum required. Window width was doubled and the value was again measured.

The first measured value was 1801 lux. The second measured value after the width is reduced was 1605 lux. The value measured after the model was set in a place where sunlight was less is 40 lux. The second value measured after the width was doubled is 42 lux. When the width of the window is reduced to half, the light entering got reduced by a considerable amount of average 200 lux. This implies that reducing window width in a situation where daylight is more than enough is applicable solution which could bring a change at least for a small intensity. When the width of the window is doubled, light entered got a little increased by a very small variation of about 2 lux. So in this scenario it can be concluded that in a situation where the daylight is already less than required due to factors like external obstructions, orientation etc just the expansion of width of window may not create an expected change.

Experiment 2

In this experiment adjustments of height of windows were done. The experiment was done in an open space with working model of dimension 10 m x 10 m of scale 1:20. Windows of width 60 cm was cut out at sill height of 60 cm and sunlight was measured using lux meter. Some points value was high than required value. These points have glare issue also, hence window height was reduced to half and the value was again measured.

The first measured value was 1845 lux. The second measured value was 1680 lux. When the height of the window was made to half, the light decreased by a small percent. This can be considered as a good solution as it is suggested that window with sill height greater than work plane helps for an even distribution of light which can be achieved by reducing the height from downwards.

Experiment 3

In this experiment length of sunshade was extended. The experiment was done in an open space with working model of dimension 10m x 10m of scale 1:20. Windows of width 60 cm was cut out at sill height n sunlight was measured using lux meter. Some points value was high than required value. These points have glare issue also, hence, length of sunshade was increased and the value was again measured.

The first measured value was 1054 lux. The second measured value was 900 lux. When the length of sunshade was increased glare was controlled up to a limit. Proper designing of shading devices can help in reducing glare.

Experiment 4

In this experiment external obstructions are considered. The experiment was done in an open space with working model of dimension 10 m x 10 m of scale 1:20. Windows of width 60 cm was cut out at sill height n sunlight was measured using lux meter. Obstruction is placed near the building at cardinals positions and the values are measured at different times at different levels. From this experiment it was observed that presence of obstruction of height double than the height of the building reduces the light intensity considerably in the ground floor, whereas there is no considerable reduction of light intensity in the higher floors.

Conclusion

The primary objective of the study was to assess the day lighting performance of a particular space and to identify the issues related to day lighting and recommending suitable solutions to make the space more efficient in terms of day lighting. Firstly a proper structure of aim and objectives was formed and a literature study on the topic day lighting was done which helped to list out various parameters to keep in mind while doing the live case study. Then a space was selected and a detailed live case study was done by measuring the daylight intensity and the data were analysed with respect to various factors affecting the day lighting phenomena. According to the analysis of all the parameters, the problems or flaws of the particular space were identified. Attempts have been made to solve the identified problems of each space using different options with the help of a working model where the issues are replicated and various solution techniques were applied. The applicable solutions can be thus applied to the respective spaces with flexible changes. After the inference it could be concluded that the issue of over lighting and glare can be reduced by reducing the width or height of the window openings along with extending the sunshades. Increasing the sill height of the window above the work plane can help in a even distribution of light throughout the room. Curtains and fins can be also provided in case of sunny days with can be removed when not in use which will help to reduce glare. Increasing the width of the window cannot make change in the intensity of the daylight if the surrounding areas have obstructions. Again increasing the length of the sunshade can help in controlling the glare. These are the some of the suggestions that can be attempted. In addition to this selecting the surface materials with proper reflectance can help in improving the quality of the space.

References

Hopkins , R. G., (1963). Architectural Physics Lighting. City: London ,Pageno.167- 200.

Richard Sheppard and Hilton Wright, George Allen & Unwin Ltd.,(1948). Building for day light. City: London. Pageno. 11, 29.

SP 41 (1987). Handbook on Functional Requirements of Buildings (Other than Industrial Buildings) [CED 12: Functional Requirements in Buildings]- Pg no : 111 to 165.