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Design of Open to Sky (OTS) Daylighting system for Energy Efficiency in Buildings

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Abstract - ***Methodology for Designing an Open to Sky (OTS) system for daylighting of residential building is presented in this document. Designing involves the steps to determine the light requirement of each unit of building. Two rooms with maximum daylight factor that are placed perpendicular to each other and that are at the lowest floor were considered for designing of OTS system.***

It is also found that the OTS sizes obtained were less than the limiting sizes that are mentioned in building codes. This method can prove to be useful in designing of OTS where it is not economical to leave the spaces unused. Buildings with less height can benefit from this method.

Keywords— *OTS, Daylight factor, window and no skyline angle*

1. INTRODUCTION

Daylighting is the practice of placing windows or other openings and reflective surfaces so that during the day natural light provides effective internal lighting. Particular attention is given to daylighting while designing a building when the aim is to maximize visual comfort or to reduce energy use. When sunlight enters the space through a window or skylight, it brings not only light energy (whether direct or indirect, but preferably indirect light), but also heat energy. With good design, the daylight is not only a good source of light but also the most efficient. Daylight is superior to electric light sources in the measure of light source efficiency.

Open to Sky (OTS) is an enclosed space within the building area which is open to the sky as the name itself suggests. These spaces are called enclosed because it is surrounded by the building units such as living room, kitchen and bedroom from all the sides.Open to Sky (OTS) systems were used preferably for ventilation, Daylighting was the another advantage of the system. Motive of this study was to determine the methodology for designing the OTS system.

2. OPEN TO SKY (OTS) SYSTEM OF DAY LIGHTING

An Open to Sky (OTS) system is similar to Skylights system, the difference between these two systems is that OTS is an open space in between and all the building units are built around it whereas skylights are the openings that allow the natural light to directly enter into the room. Skylights are designed for an individual room. On the other hand OTS provides light to all the rooms if it is designed effectively. The design of OTS systems depend on various factors like required amount of light in a unit or room, daylight factor (DF) required maintain that amount of light, size of window opening that open into the OTS, Visible transmittance of glazing materials and mean reflectance of the surfaces of internal walls and floor material.

Table 1- Recommended daylight factor [10]

Building	Area/Activity	Daylight factor (%)
Dwellings	Kitchen	2.5
	Living room	0.625
	Study room	1.9
	Circulation	0.313
Schools	Class room	1.9 – 3.8
	Laboratory	2.5 - 3.8
Offices	General	1.9
	Drawing, typing	3.75
	Enquiry	0.625 – 1.9
Hospitals	General wards	1.25
	Pathology laboratory	2.5 – 3.75
Libraries	Stack room	0.9 – 1.9
	Reading room	1.9 – 3.75
	Counter area	2.5 – 3.75
	Catalogue room	1.9 – 2.5

3. METHODOLOGY

Design of OTS system is dependent on simple assumptions and calculations. The methodology mentioned in this paper is derived from Design sequence of diffuse daylight by Rules of Thumb [1]. In Design sequence [1], sizing of rooms and area of glazing is achieved by following thumb rules for daylighting. In this paper these design steps are shuffled and arranged to determine the size of OTS. These steps can be used for the rooms which are adjacent to each other and their window openings fall perpendicular to each other.

Thus DF of two rooms needs to be determined which have their window wall perpendicular to each other. While

designing the OTS system it was found that the rooms must be such that their DF must be higher than any other rooms. If it is not so, then OTS will have less size, insufficient to provide the required amount of light.

Steps in Designing of OTS system–

1. Determine the Daylighting Factor (DF) - DF is the ratio of indoor illumination to the corresponding outdoor illumination which can be determined by the requirement of light and the amount of energy received from the Sun.

$$DF = \frac{Ei}{Eo} \times 100$$

Where, *Ei – intensity of light required in the room*
Eo- intensity of light available outside
DF is a ratio but expressed in percentage(%)

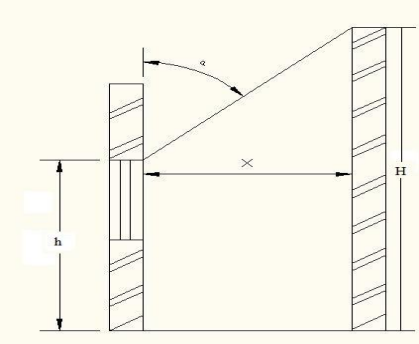
2. Determine the limiting depth up to which the daylight factor is desired i.e. The room width.
3. Calculate the window head height (h), this height is the distance from floor level to the bottom of chajja. For windows with shading device (chajja) it is taken as,
Limiting depth (from step 2) **= 2.0 x h**

and for windows without shading

Limiting depth= 2.5 x h

4. Assume the working plane height (h_w) i.e the height at which maximum activities of the unit or room are to be carried out.
5. Assume the No skyline depth, the horizontal distance from the window (inside the room) at which no sky is visible due to obstruction by the height of the building.
6. Calculate the No skyline angle (α).
$No\ skyline\ depth = (h - h_w) \tan \alpha$

7. Calculate the width of OTS-
Width of OTS (X) is the distance at which the wall, in front window is placed.



$$X = \frac{(H - h)}{\tan(90 - \alpha)}$$

Where, H = height of building

h= window head height

α= No skyline angle

X = width of OTS

8. Check the Daylight feasibility test.
Daylight feasibility test gives the window wall ratio (WWR), which is to check whether it is assumption are required to be made in this step. These include visible transmittance (τ_{vis}) of the glazing material to be used.

$$WWR = \frac{0.088 \times DF(\%)}{\tau} \times \frac{90}{\alpha} \times 100$$

If WWR> 80 %, then it is difficult to daylight the room [1]

If WWR< 80%, then it is feasible to daylight the room

9. Check for daylight uniformity.
Daylight uniformity check gives limiting depth up to which the light of required DF remains constant.

$$limiting\ depth = \frac{\frac{2}{(1-R)}}{(\frac{1}{w} + \frac{1}{h})}$$

Where, R = Mean surface reflectance of the internal surfaces of the room

w = Room width

h = window head height

10. Calculate the area of glazing.
Area of glazing can be obtained to determine the size of opening in the windows

$$Ag = \frac{2 \times (2 \times A) \times (1 - R)}{(\tau \times \alpha)}$$

Where, Ag = Area of glazing

A = total surface area (ceiling, walls and floor)

τ= visible transmittance

α = No skyline angle

R = Mean surface reflectance

4. RECOMMENDATION AND CONCLUSION

1. The proposed design methodology is simple to work out the sizes of OTS.
2. Sufficient DF can be maintained in the building by providing the glazing area as calculated or as per building codes whichever is larger.
3. Sizes of OTS obtained by this method can also prove to be economical for buildings with less height, as there are limitations on sizes as per Energy Conservation Building Codes (ECBC) norms.
4. Less sizes of OTS can be obtained by this method than the least sizes that mentioned by ECBC.
5. This method can be used to determine the height up to which the building can be raised i.e. no. of. Floors for given size of OTS, in order to maintain the DF of the rooms at the bottom.

5. LIMITATIONS

1. The proposed methodology does not take into account the local climate and weather conditions.
2. This method also does not take into account the effect of reflectance due to glazing and reflection component due to wall surface of OTS well. If reflection component is more the light received inside may be more than the desired DF.
3. Performance of OTS designed by this method can be simulated for better results.
4. Designing of shading devices is necessary for buildings with more height, as the rooms at higher level might get direct sunlight inside.

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BIOGRAPHIES

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