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OPTIMIZING DAYLIGHT IN AN OFFICE BUILDING FOR MODERATE CLIMATE OF PUNE

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ABSTRACT

Daylight has been an immortal source of light. But currently, due to lack of resources this source is supplemented by artificial light. The illumination levels are a big contributing factor towards indoor comfort. To optimize daylight in a building, it must be oriented according to solar design. Shading, orientation, window openings are the major contributors in energy efficient building. This paper deals with the quantitative analysis of daylight through different types of openings and fenestrations used in an office building. The study is for the moderate climate of Pune. The paper also helps to understand passive design strategies like building orientation, building shape, building envelope, shading devices, etc. The analysis is done by generating simulations on software for different WWR (Window Wall Ratio), window sizes and type of glass. The strategies and guidelines for optimizing daylight in an office building are given based on the findings and results generated. Finally which type of office building design and fenestration is best suitable and can give daylight optimization without glare for a given climate is concluded.

Key words: polypropylene fibres, Deformed steel fibres, Catastrophic failure, impact resistance, compressive strength, flexure and tensile strength.

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1. INTRODUCTION

In India among all the building typologies, energy consumption is maximum in commercial buildings. The energy is mainly utilized for lighting the interiors and cooling the building. Lighting and cooling the building again generates heat inside and around the building which in turn increase cooling load. A study shows that about 20-40% energy is consumed for lighting, out of the total electricity required for a building.

Harvesting daylight can significantly reduce electricity consumption in a building. However it also require to counter balance the heat gain or heat loss, glare, variation, etc. Many offices use light photo sensors which take advantage of daylight and dimming light so that no more light is produced than necessary. This can improve productivity of an employee and make him comfortable and efficient.

As the cost of energy increases, efforts are made to minimize energy consumption. This can be done by- utilization of daylight in design practice. It is very comfortable to work in natural light than artificial light but excessive daylight can even create glare problem for users.

Index terms: Daylight, office building, energy efficient, illumination level, shading.

2. LITERATURE REVIEW

A building envelope protects the building from the external environment. This envelope includes roof, external façade, projections, etc which act as thermal shell and decides the temperature intake inside the building. In moderate climate there is not much variation in average yearly temperature as the temperature do not reach the extreme levels. The design in such climatic zone can be flexible enough and efforts should be made to reduce heat gain and maintain thermal comfort level.

Shading, building orientation, windows, openings and their sizes are the major contributors in making the building energy efficient.

The daylight penetration inside the room in a working space is an important factor as it influences users ability to have outdoor view and the design of electrical lighting system. For this the daylight should cover maximum room depth by maintaining required lighting levels. According to one of the developed methods, if the depth of the space increases and is more than three times the ceiling height, the daylight factor (DF) in deeper parts of the room might decrease below 1%.[9]

The recommended illumination levels on a working plane in an office is 300-750 lux.

Illumination levels for different task are recommended to be achieved either by day lighting or artificial lighting or a combination of both. [10]

Table 1 IES standard illumination and MS 1525 recommendation for different office spaces

SPACE	IES STANDARD ILLUMINATION (lux)	MS 1525 RECOMMENDATION (lux)
General offices	500	300-400
Computer room	500	300-400
Conference room	750	300-400
Executive office	500	300-400
Filing room	300	200
Print room	300	300-400

Optimization of daylight mainly depends on passive solar heat gain elements, position and orientation of building and percentage of glazing. Passive building design methods mainly include

- Orientation
- Building shape
- Ratio of wall to window
- Envelopes and Shading devices

All perimeter parts of buildings lying within 6 m of the facade, or twice the ceiling height, are classified as passive, while rest of the other zones are considered non-passive (Fig 1).

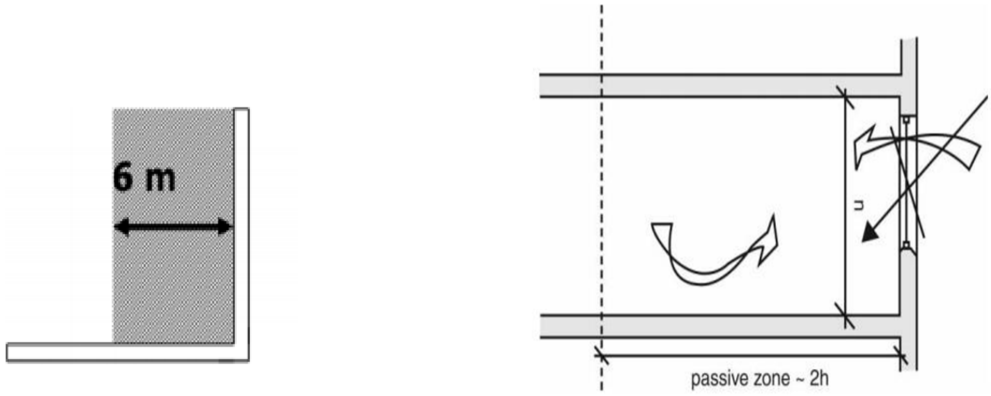


Figure 1 Parts of building that can be naturally lit and ventilated are called passive zones [6]

Strategies for maintaining thermal comfort and energy efficiency in a building have to be incorporated at design stage. One of these could be passively design envelopes which actively meet heating and cooling needs of building. Building envelope provide thermal division between indoor and outdoor as well as play an important role in determining how effectively natural light can be utilized in a building.

The research is about which type of window opening and their percentage are best suitable for office building to achieve optimization of daylight in moderate climate(of Pune).

3. METHODOLOGY

Steps

- Comparison of different types of window openings considering their sizes, projections, shading devices, etc (grid of the building block will be same in each case) in IT office building.
- Designing and orienting them in suitable direction during daytime for two months and analyzing with the help of simulations (May and December)
- Considering WWR same in all the cases maintaining a suitable sill level 0.8m .
- Observing outputs of different simulations
- Concluding the results and observations

Case studies

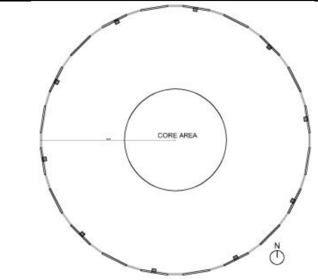
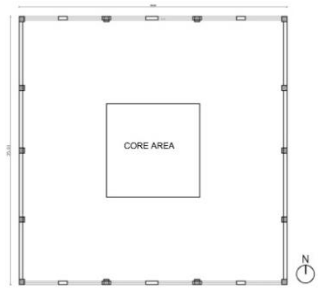
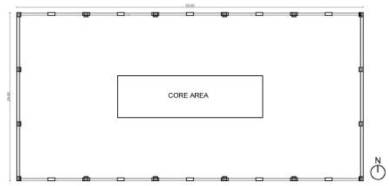
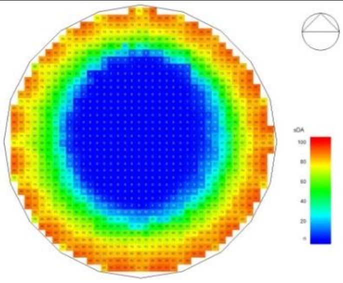
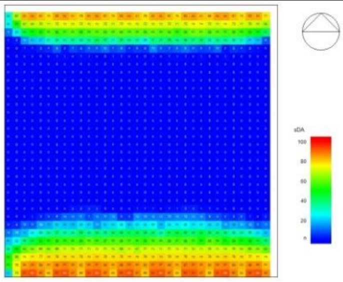
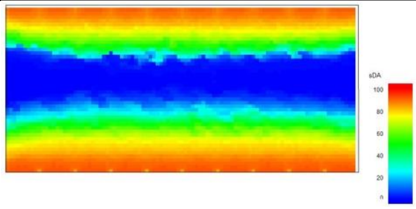
- KPIT, Pune (window with shading fins)
- TCS, Chennai (ribbon window)
- Infosys, Pocheram (window with shading fins and light shelf)

4. UNIT DESIGN FOR SIMULATIONS

4.1. Building Shape

To check which type of shape /form is suitable for office building in moderate climate of Pune, three different forms are considered viz. circle, square and rectangle. The floor plate area is maintained same in all the cases. Daylight simulations are carried out annually orienting the buildings in N-S direction and keeping WWR ratio 40%.

Table 2 Daylight simulations for different building forms

FORM	CIRCULAR	SQUARE	RECTANGLE
PLAN			
DAYLIGHT SIMULATION			

It is found that the illumination level is more in rectangular form than circular or square form.

4.2. Window Openings

An office building of floor plate 50m x 24m and height 4.2m with central core area is considered as a base module. Same grid is maintained to carry out daylight simulations in seven cases for different window openings. The building block is oriented in N-S direction and openings are provided on same faces. The results are analyzed using Design Builder as simulation software. The WWR is same in all the cases i.e 40% (as per ECBC code). The wall, floor and ceiling reflectance is kept constant in all the cases. The sill height is maintained at 0.8m. The cases have been simulated for the month of May (summer) and December (winter) and are generated for clear sky conditions. The target task illuminance is set to 300lux. In simulation model the windows are specified with aluminum framing with a single glazed unit having a glass of transmittance value 0.62 the readings are analyzed for lux level 20 to 1000.

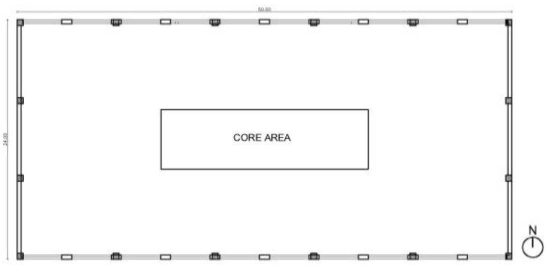


Figure 2 Office building floor plan considered for simulations

Table 3 Types of window considered for simulation

CASES	WINDOW TYPE
Case 1	Box Window
Case 2	Window with overhang

Case 3	Ribbon window with overhang
Case 4	Ribbon window with column spacing
Case 5	Window with light shelf
Case 6	Window with shading fins
Case 7	Window with shading fins and light shelf

4.2.1. CASE 1: Box Window

It is observed that for every 1m distance from window the illumination level gradually decreases. In the month of May and December a sufficient amount of daylight can penetrate only upto 3m from the window line. The rest of the office area will have to depend on artificial light.

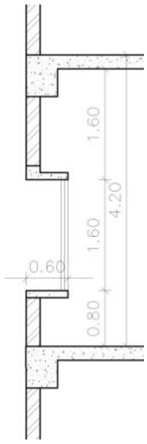


Figure 3 Section of Box window

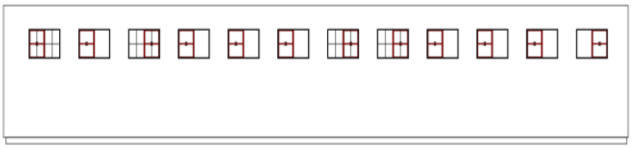
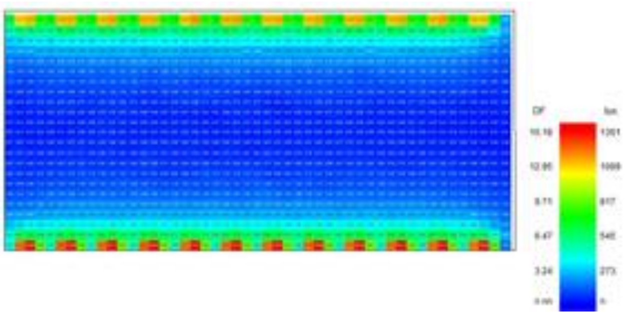
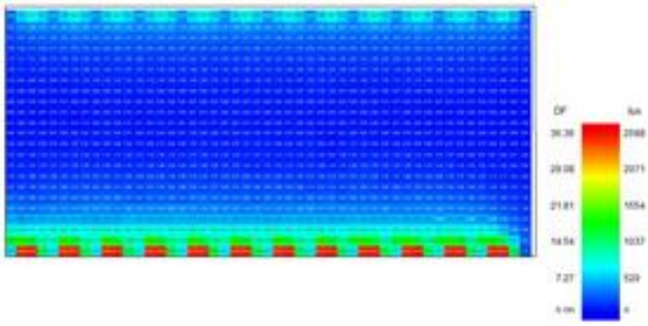


Figure 4 Building elevation with box wind

Table 4 Day light simulation for box window



Day light simulation for month of May



Day light simulation for month of December

4.2.2. CASE 2: Box Window with Overhang

There is a decrease in illumination level for every 1m from the window line. The illumination level is slightly more than case 1. Maximum illumination of 900lux is achieved at 1m distance from the window. In both months about 300lux level is achieved upto 4m distance from the window.

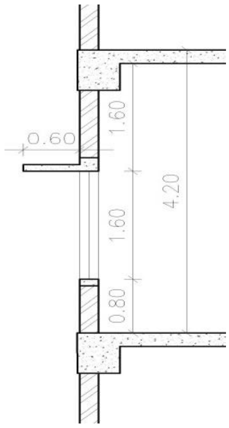


Figure 5 Section of Overhang window

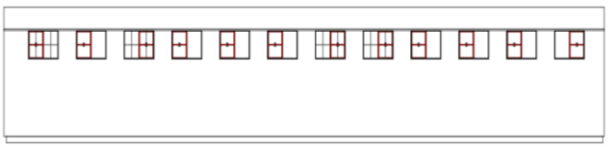
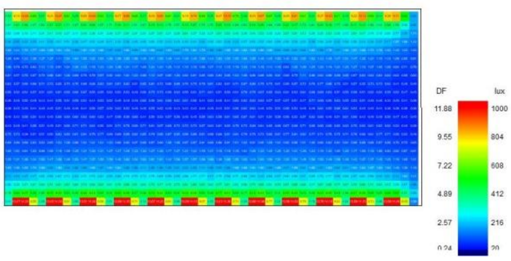


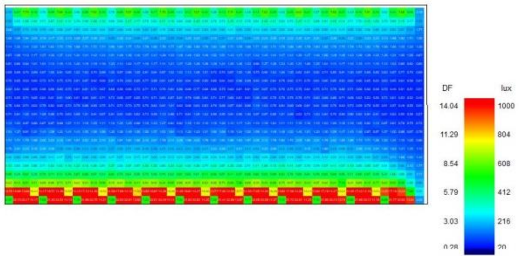
Figure 6 Building elevation with overhang window

Table 5 Day light simulation for box window with overhang

Day light simulation for month of May



Day light simulation for month of December



4.2.3. CASE 3: Ribbon Window with Overhang

In this case it is observed that about 300lux is achieved up to 5m from the window for both the months and gradually decreases at the center. The illumination levels are quite more in this case than Case 2. As the opening size increases the illumination level increases.

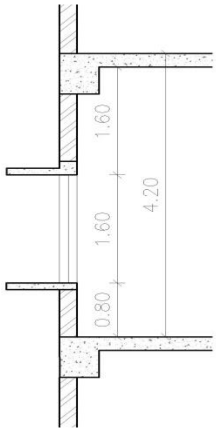
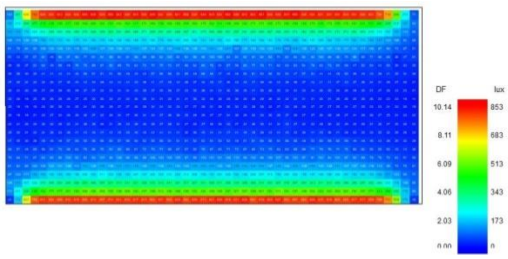


Figure 7 Section of ribbon window with overhang

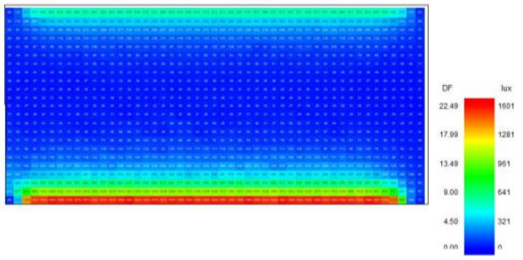
Figure 8 Building elevation with ribbon window

Table 6 Day light simulation for ribbon window with overhang

Day light simulation for month of May



Day light simulation for month of December



4.2.4. CASE 4: Ribbon Window with Column Spacing

In this case it is observed that daylight optimization is more than the earlier cases. Here the columns act as shading device for the ribbon windows and hence more diffused light can penetrate. About 300lux is achieved up to 6m in both months.

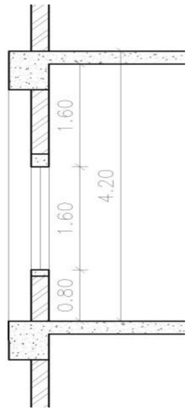


Figure 9 Section of ribbon window with column spacing

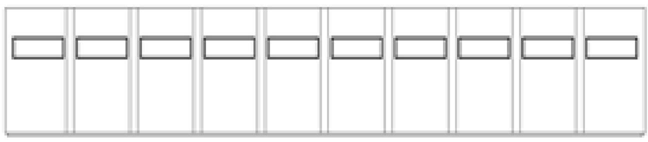
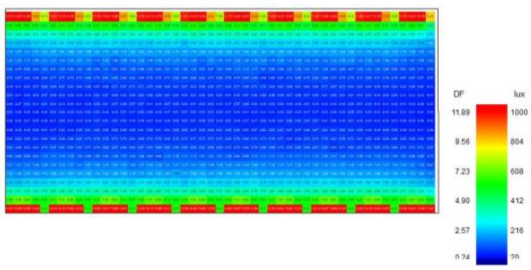


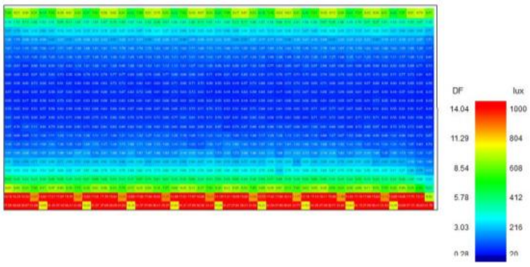
Figure 10 Building elevation with ribbon window and column spacing

Table 7 Day light simulation for ribbon window with column spacing

Day light simulation for month of May



Day light simulation for month of December



4.2.5. CASE 5: Box Window with Light Shelf

In this case the daylight penetration is less than case 4. The use of light shelf do not increase the light levels in this case. Daylight penetration is about 300lux upto 4m in the month of May while it is 400 lux upto 4m only from south side in the month of December.

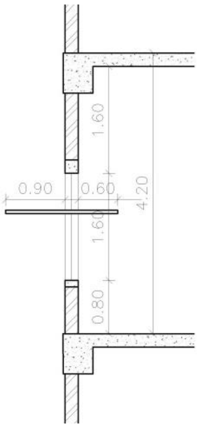


Figure 11 Section of box window with light shelf

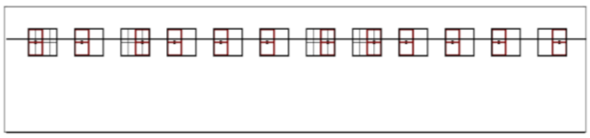
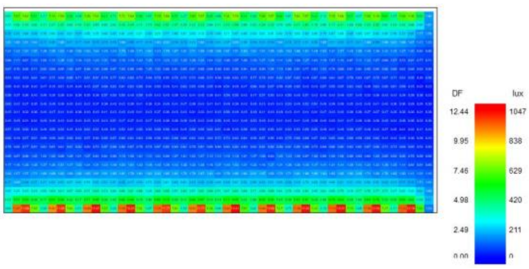


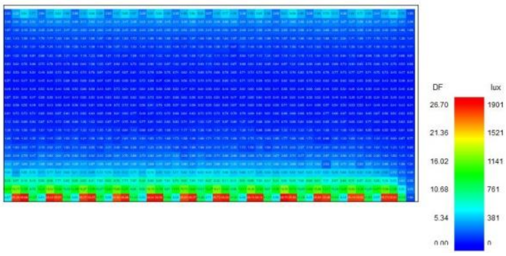
Figure 12 Building elevation with box window and light shelf

Table 8 Day light simulation for box window with light shelf

Day light simulation for month of May



Day light simulation for month of December



4.2.6. CASE 6: Window with Shading Fins

In this case the illumination levels are maximum than the above cases. About 300 lux is achieved up to 6-7m. The shading fins allow more diffused light to penetrate inside the room.

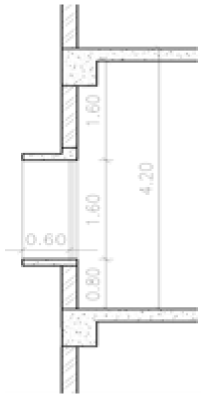


Figure 13 Section of window with shading fin

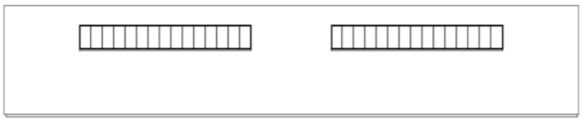
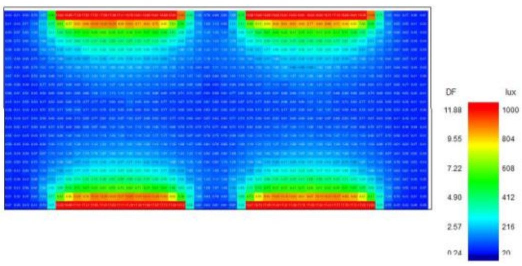


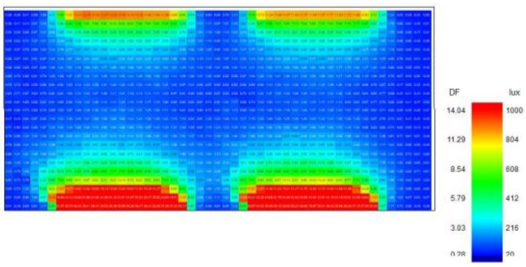
Figure 14 Building elevation with window and shading fins

Table 9 Day light simulation for window with shading fins

Day light simulation for month of May



Day light simulation for month of December



4.2.7. CASE 7: Window with Shading Fins and Light Shelf

In this case the illumination levels are similar to case 6. About 300 lux is achieved up to 6-7m. The addition of light shelf do not increase daylight penetration in the room. It only diffuses the light near window and provides shading in the lower part near the window.

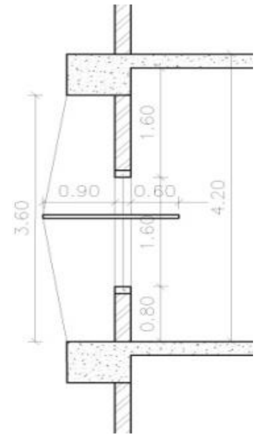


Figure 15 Section of window with shading fins and light shelf

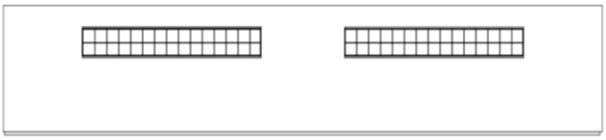
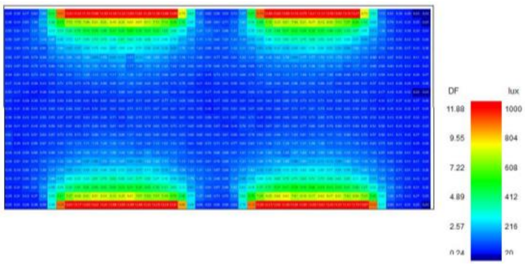


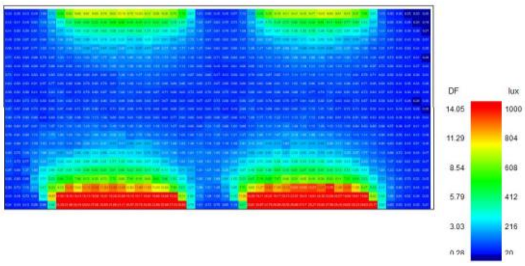
Figure 16 Building elevation with shading fin windows and light shelves

Table 10 Day light simulation for window with shading fins and light shelf

Day light simulation for month of May



Day light simulation for month of December

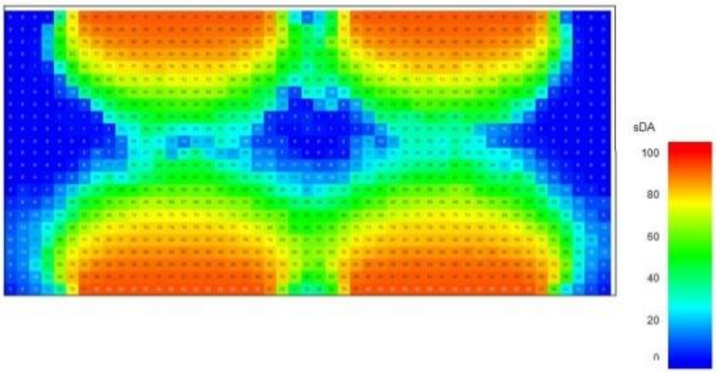


The illumination levels in case 6 and case 7 are maximum than case 1 to case 5, hence annual day light simulations are carried out to find out which case is most appropriate.

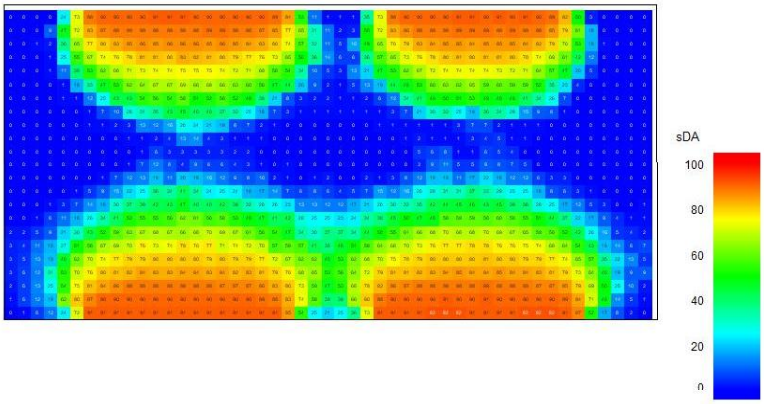
4.2.8. Annual Result for Case 6 and Case 7

Table 11 Annual illuminance for window with shading fins (only) and window with shading fins and light shelf

Case 6: Annual illuminance



Case 7: Annual illuminance



The annual daylight simulations show that in case 6 the daylight penetration is deeper and reaches till the center of the room. About 300lux is achieved at the center

5. RESULTS

Table 12 Illumination in month of May and December for different types of window.

Cases	Window type	Illumination in month of May (>300lux)	Illuminance in month of December (>300lux)
Case 1	Box Window	42%	29%
Case 2	Window with overhang	50%	50%
Case 3	Ribbon window with overhang	50%	29%
Case 4	Ribbon window with column spacing	55%	55%
Case 5	Window with light shelf	45%	33%
Case 6	Window with shading fins	56%	61%
Case 7	Window with shading fins and light shelf	48%	58%

6. MEASURES TO CONTROL GLARE

Following are the measures which can be adopted to control glare in an office building:

- The reflected glare from the extremely bright exterior surfaces like large paving or sand area, parked cars, can be visually uncomfortable. The view of these surfaces must be limited or protected.
- A light-color shade can be used for interiors to minimize heat gain.
- Fine screens which reduce illumination and glare can be used for shading the window to maintain an exterior view without any obstruction. Louvers or screens that operate upward from the window sill can also be used.

7. CONCLUSION

Every building component has potential for saving energy hence it must be chosen properly. The illumination levels are more in rectangular form office building for moderate climate of Pune. The increase in wall window ratio (WWR) increases daylight penetration but also rises the heat levels in the building. Hence low WWR is recommended i.e <40%. Double skin glazing with low U-value should be used. Day light enhancement system such as light shelves do not improve daylight levels (in Pune) significantly but shades the lower part of the window and thereby reducing cooling loads in summer. The shading fins can be used to increase the amount of daylight in an office.

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