A STUDY OF DAYLIGHTING TECHNIQUES AND THEIR ENERGY IMPLICATIONS USING A DESIGNER FRIENDLY SIMULATION SOFTWARE

Amarpreet Sethi
College of Architecture and Environmental Design
Arizona State University, PO Box 871905
Tempe, AZ 85287-1905
e-mail: sethi@asu.edu

ABSTRACT

This paper outlines an approach to daylighting design by studying the relationship of the solar exposure as a result of the daylighting techniques used and the resulting daylight distribution in the space and resultant glare. The study shows the need for daylighting strategies to be a part of the design process, such that they may be used to determine the possibilities of providing for passive solar gain or aim to reduce solar and interior loads with appropriate daylighting techniques.

Daylighting techniques in terms of light shelves, with varying reflectivity, louvers, have been analyzed using Ecotect, to predict the light distribution, external and internal reflected component. This demonstrates the use of the analysis software during the design process to predict the better performance of one feature over the other.

1. INTRODUCTION

The most important benefit of the application of daylighting in a commercial building is not energy conservation, but increased occupant satisfaction. Role of daylighting in providing comfort has been discussed by a large number of people and a large amount of research has been done in this area.

The main problem faced in daylighting is that of unequal distribution of daylight in rooms, which can also cause a problem of glare. This can be overcome by breaking up sunlight either by reflecting it on to the ceiling or by diffusing it through baffles. One of the strategies used to overcome or react to this problem is the use of lightshelves. These lighting techniques are utilized, with no determination of its impact on the heat gains due to their reflective property. Depending on the reflectivity and surface characteristics of the light shelf, the quality and amount of illuminance varies. Another thing that varies would be the amount of infrared that is reflected into the space. The knowledge of this relationship would help in the use of the strategy in climates where it is most suited. Certain techniques used may be more appropriate for cold climates, where passive gain may in fact be required.

Most simulation softwares, model the benefits of the use of daylighting by the use of sensors in terms if (1) reduction of the use of artificial lights and (2) the reduction in the heat gain due to the reduction in artificial lighting. The relationship between the daylighting technique used and the relative heat gain due to the property of the light shelf is assumed to negate itself, but since this is something we would easily have a control over, it should be kept in mind. It is important to differentiate between the daylighting strategies that may be used also to achieve solar gain and strategies by which this may be avoided for warmer climates.

The openings however, should not be considered as only daylight strategies, but it provides the ability to see out. Even though the presence of daylight helps to satisfy some biological needs with regard to the changing nature for the weather, certain needs are directly associated with a view-activity participation, relaxation and the need for information about the environment. [1]

2. THEORY

2.1 Heat Gain

The energy flow through a fenestration system is divided into the following components:

a. Conductive and convective heat transfer caused by the temperature difference between outside and inside air. Net long-wave (above 2500nm) radiative exchange between the fenestration and its surrounding (includes the shading devices) and between glazing layers.
b. Short-wave (below 2500nm) solar radiation incident on the fenestration, either directly from the sun or reflected from ground or adjacent objects (such as lightshelves).

Though it is a fact that, along with light comes heat, the energy radiation (visible portion) that produces light overlaps considerably with the radiation (near and far infrared) that produces warmth. The overlap however is also seen in the artificial light products, though their efficacy is being progressively improved over time.

The aim is to maximize the natural light keeping the heat gain to the minimum or to the maximum depending on what is desired at the particular climate or time of the year.

2.2 Daylighting strategies

2.2.1 Light Shelves

Lightshelves are flat or curved elements inside or outside the window façade aperture, above eye level. They redirect the incoming light or solar radiation by reflection, and can at the same time also shade the glass below it, reducing the sun penetration into the space. They may be placed in the middle of the fenestration dividing the window into a view window, below the shelf and a clerestory window above the shelf.

Thus the lightshelves may beam sunlight into the interior of the space, at the same time shading the lower window and diffusing light into the space.

A patch of sunlight is between 5-10 times brighter than the same surface illuminated from the diffuse sky, and special elements have to be used to re-distribute and use this light.[2]

2.2.2 Prismatic Glazing

Prismatic glazing uses the principal of refraction to redirect the sun's rays to the ceiling to improve daylighting conditions in the space. Using a material with molded prisms, prismatic glazing works best at certain solar angles, but as the rays move beyond the critical angles direct sunlight can cause glare. [3]

2.2.3 Louvers

Both sloped louvers and translucent glazing are effective in diffusing direct sunlight. However, louvers tend to direct a large amount of sunlight toward the ceiling. Thus the light colored ceiling becomes an important part of the louver fenestration system.[4]

3 EXPERIMENTAL METHODS

Types of daylighting Modeling techniques used:

3.1 Simplified manual tools:

Protractors and diagrams BRE Daylight factor protractor, Waldram Diagram, could be used to do a quick daylighting analysis.

3.2 Physical modeling

Using scaled physical models for daylighting analysis. This is made possible due to the short wavelength of light, which means that the behavior of light is accurately reproduced at scales down to those likely to be used for architectural models.

3.3 Computer-based models

There are tools with quantitative output, usually using simple algorithms to predict daylight factor or light transmittance, eg. DAYLIGHT, MICROLITE, ECOTECT etc and Simulation models that use ray-tracing techniques to model the behavior of light, they can produce highly realistic images as well as quantitative data. eg. RADIANCE etc.

4. APPROACH

ECOTECT, Building Analysis Software is used to do a Solar Analysis and a daylighting calculation. A wide range of display options are provided for the analysis grid. These range from 3D mesh plots to fully colored contour maps. It features a designer-friendly 3D modeling interface fully integrated with acoustic, thermal, lighting, solar and cost analysis functions.

4.1 Daylighting Analysis

ECOTECT uses the BRE Daylight Factor method for daylighting calculation and the Point-to-Point method for electric lighting. For more detailed analysis, it can both export to and invoke the Radiance Lighting Simulation software developed by the Lawrence Berkeley National Laboratory.

4.2 Solar Analysis

Excessive solar exposure is one of the main causes of thermal discomfort in buildings, even in relatively cold climates (due to high internal gains). The amount of solar radiation falling on an object is simulated also providing shading and reflection percentage information.

5. CASE STUDY CALCULATIONS AND DISCUSSIONS

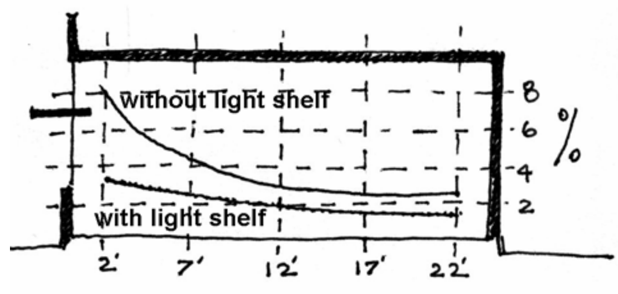
A room of specifications mentioned below was modeled in ECOTECT and daylighting and solar exposure calculations were done to determine the daylight distribution and resulting solar exposure in the various cases. Further the External Reflected Component and Internal Reflected Component as a function of the reflectivity or specularity of the lightshelf were observed along with the reflective solar gain.

Standard room taken for the research
Room = 35ft x 24ft x 10ft (L x W x H)
Work Plane Height = 2.5ft
Sill ht = Variable
Orientation = Variable
Wall and Ceiling Color = light grey
Specularity of light shelf = 0.2 (white) - 0.95 (mirror)
Location = Phoenix
Day = 23rd June and 24th September
Glazing = lintel at ceiling height, sill varies

The following models were set up to compare the daylighting distribution achieved by each case. These diagrams were compared with Fullers Moore's analysis in *Concepts and Practice of Architectural Daylighting*, though in some cases, Fuller Moore's study was under overcast conditions.

5.1. Case study 1

Room with a glazing, 7'0" high, sill height = 3'-0" was modeled. These simulations have been done for 23rd June, with the glazing facing south.



After Moore

Fig 1. Daylight factor illuminances with (w) and without (wo) an intermediate light shelf (overcast sky)[3], from model studies done by Fuller Moore.

Both cases, with and without intermediate lightshelf and a case with lovers in the lower view glazing were modeled in ECOTECT to compare light distribution, and further solar exposure in the three cases.

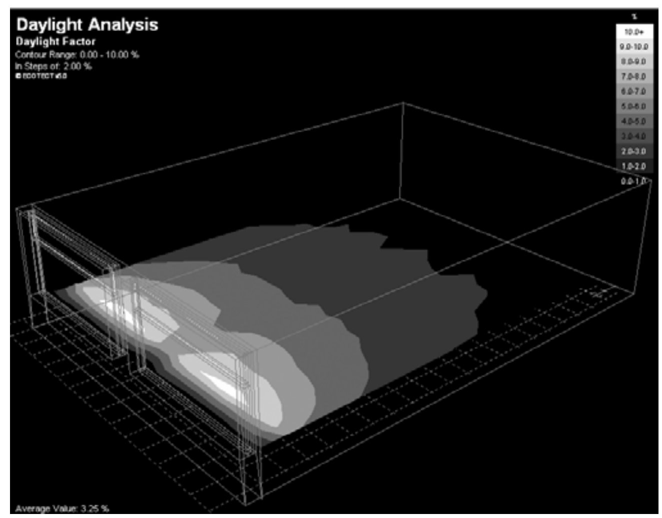


Fig 2. Shows the contours of the Daylight Factor for a glazing without Light shelf.

The change in the distribution of natural light is clearly seen with the addition of the reflective light shelf, and further with the addition of Lovers at the lower glass.

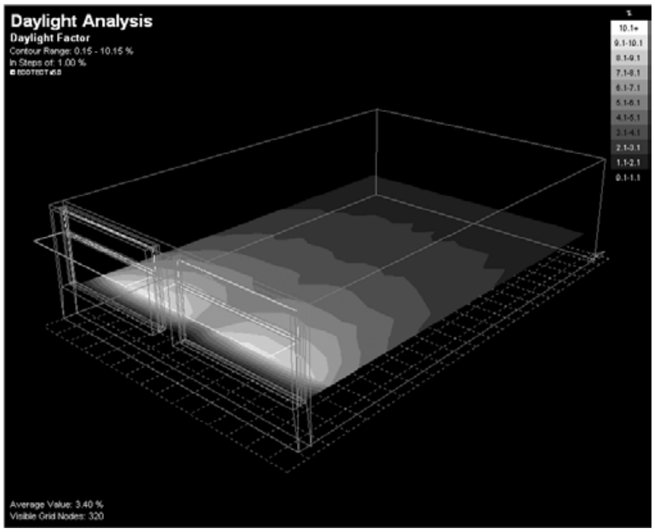


Fig 3. Shows the contours of the Daylight Factor for a glazing with an intermediate Light shelf.

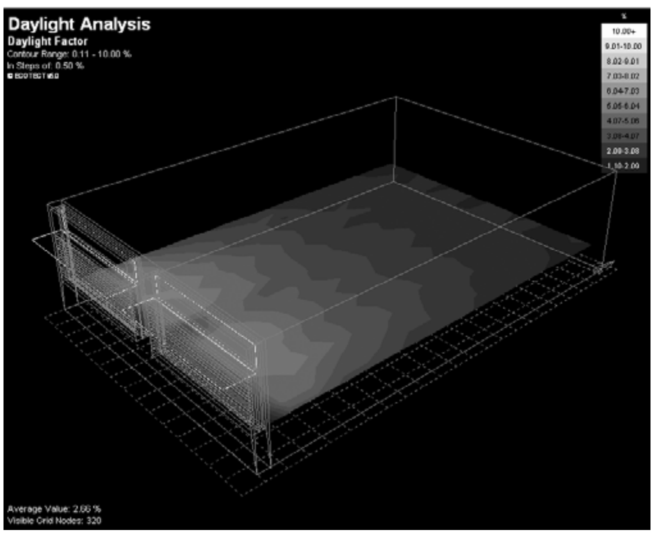
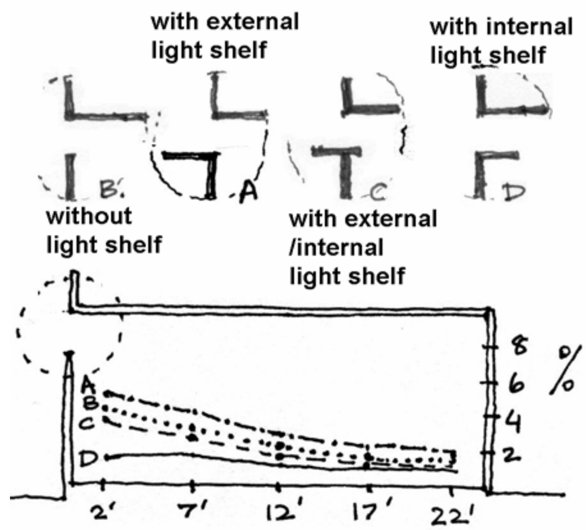


Fig 4. Shows the contours of the Daylight Factor. Here the view glass or lower glass has horizontal 3” Louvers with a 3” spacing between them.

5.2. <u>Case Study 2</u>

Room with only a clerestory window was analyzed with changing location of the light shelf, and further solar exposure has been shown.



After Moore

Fig 5. Comparison of effect of white light shelf position on interior illuminance (clear glazing, overcast sky); (a) no shelf; (b) white shelf outside; (c) white shelf half out/half in; (d) interior white shelf[3], from model studies done by Fuller Moore.

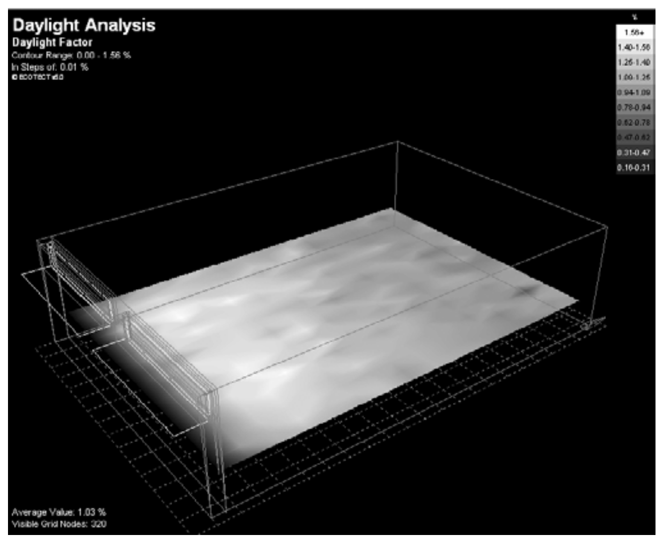


Fig 6. Above figure shows the contours of the Daylight Factor for the room with the reflective light shelf.

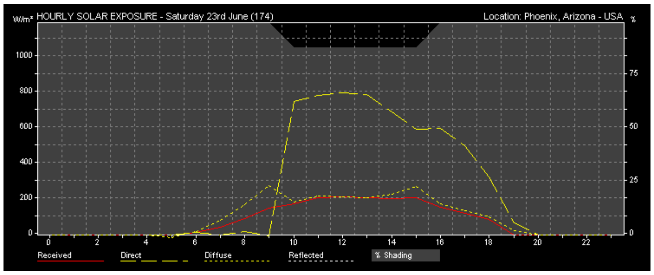


Fig 7. Shows the solar gain within the space, reflective component is negligible in this case due to the high altitude angle in June. It can also be seen the window is completely shaded, and hence the only solar gain is through diffuse.

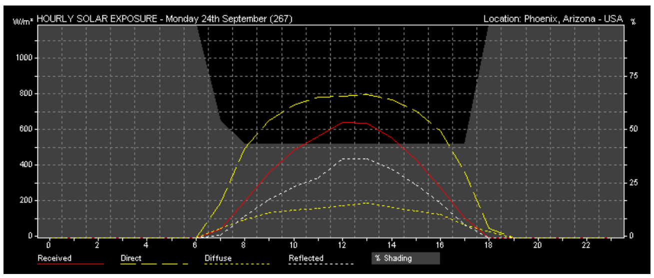


Fig 8. Solar Exposure (24th Sept – hottest day as analyzed by Ecotect) is seen,it is also seen that the window is not completely shaded and also the reflected solar gain is observed. With the change in the Altitude angle the window is seen to be unshaded for a small period of time and there is reflective gain as well.

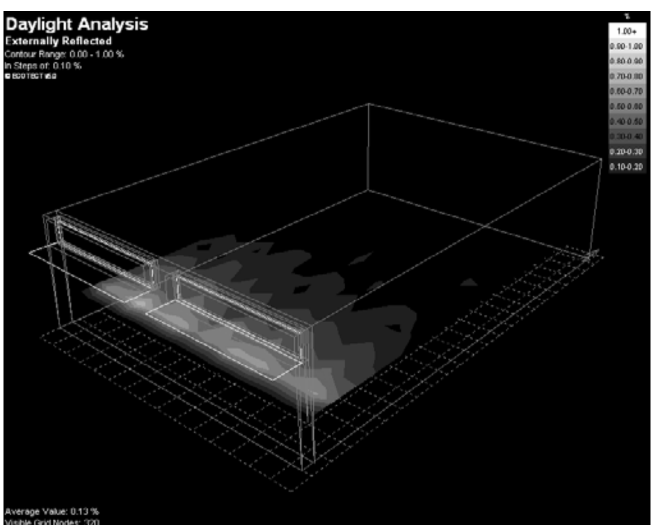


Fig 9. Above figure shows the contours of the external reflected component. Because this is for June the reflected component reaches only half the depth of the room.

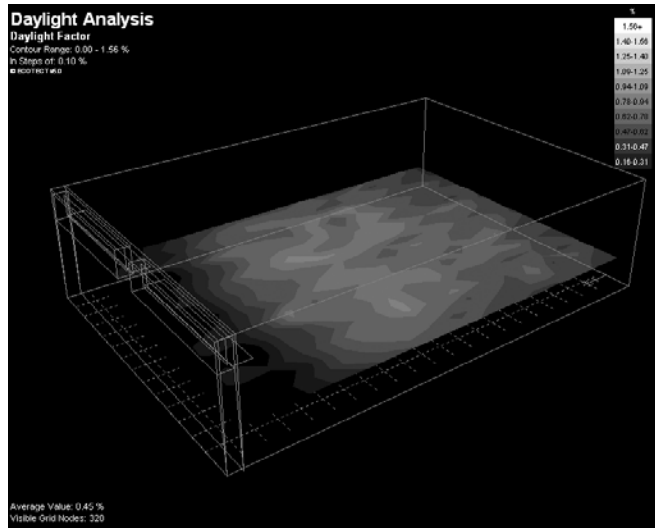


Fig 10. Shows the contours for the daylight factor with an internal light shelf, the natural light is reduced compared with the widow without and an exterior light shelf.

6. CONCLUSIONS

The simulation software used, has the ability to simulate daylighting and solar exposure, insolation and further may be used in other areas of thermal, acoustic, lighting analysis etc. This is helpful as a design tool when these decisions are interdependent. Mostly daylighting and other thermal analysis are done separately, and thus energy implications are considered only with the use of daylighting sensors, where light shelves and techniques may not even be modeled.

Separate simulation tools are used when daylighting is to be analyzed at a room level and other detailed tools are then used for thermal analysis which is hence done only after important design decisions have already been made. This tool is able to provide the desired link to designers, such that they may be able to use the same tool to analyze different aspects of the energy performance of the building. This may also enable designers to make important design decisions after analyzing their effects on the energy performance of the building.

Comparing the solar exposure with and without the reflective light shelves and louvers, it was seen that the solar gain due to the reflective property of the daylighting technique was none or minimal during the peak summer months, due to the high altitude angles. Solar gain however, between September - April were higher.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

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