A STUDY OF OPTIMIZATION OF THE LIGHT SHELF SYSTEM IN HOT AND ARID ZONES

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ABSTRACT

The objective of the present research is to choose the most appropriate configuration of light shelf system for the town of Biskra (South East of Algeria) optimized according to orientation position material and design. The determination of this configuration requires first of all knowledge of daylight climate of the city. This town is characterized by very large amount of daylight illuminance especially during summer season. NOOR1.1 program has been used for the evaluation of the exterior illuminance levels. This Fortran application has been developed specially for the evaluation of daylight illuminance under typical sky conditions. The results have been used then as an input for the evaluation of the light shelf impact on interior daylight levels and ambiances for a typical side-lit space using the well-known commercial software ECOTECT. The results have been then confirmed through a series of measures monitored on a scale model.

1. INTRODUCTION

From the point of view of sustainability, daylight is a natural resource, clean and inexhaustible. It is therefore, a key element in the architectural design especially during the sketching phase. During this phase, the architect has to make wise and appropriate decisions to ensure visual comfort, good working conditions, improve aesthetics and reduce energy consumption (Smiley, 1996). It has been proved that buildings do consume large amount of electricity for lighting and thus producing tones of CO_2 (0r, 2002; Ihm, et al., 2009). Recently new architectural lighting strategies have been adopted to efficiently reduce the consumption of energy in buildings by introducing different systems in order to optimize the distribution of natural light inside buildings such as light pipes, light shelves and venetian blinds.
Light shelves systems has shown their ability to increase the depth of daylight penetration and to reduce significantly the risk of glare (Wiley, 2000). The reflectance of the light shelf surfaces has a large impact on the overall energy balance of the system. The upper surface needs to reflect a maximum of daylight inside the space and provide shade during hot and sunny days. On the contrary the lower surface of the system should absorb the maximum daylight to avoid glare from the window. However, it is believed that light shelves are not efficient in terms of light penetration under overcast sky conditions and reduce the amount of daylight reaching the interior space (Eagan et al., 2002; Littlefair, 1996; Christoffersen, 1995; Aizlewood, 1993). They are more efficient under clear sunny skies typical of hot and arid regions. The present research was carried out in order to demonstrate this fact under typical sky conditions of Biskra (Latitude 34.48 N, Longitude 5.44 N, Alt. 128 m above sea level). Biskra is a main town in Algeria situated in the south east on

the border of the Sahara desert with a large amount of solar potential 6 kwh/m²/day and 2190 kwh/m²/year according to ASA (ASA,2002). In addition the microclimate of Biskra is characterized with sunny skies, little rainfall and high air temperatures exceeding 30̊ C during nearly half of the year (from April to November). The design strategy adopted mainly in past and contemporary architecture is that of cooling reducing therefore external exposure of building's envelope and narrowing openings and windows. This design approach led unfortunately to an overuse of electricity for lighting especially during summer hot days.

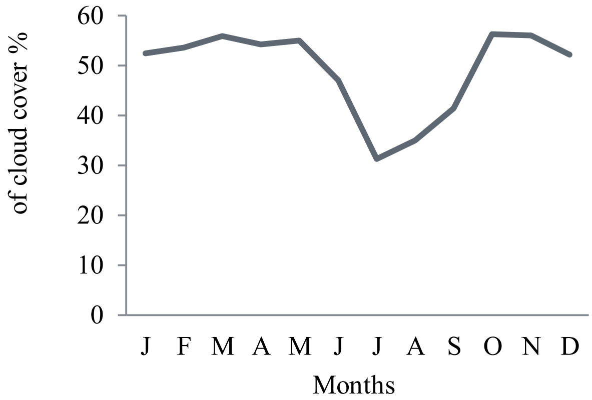

Fig. 1. Average monthly cloud cover in Biskra.

2. MODELING DAYLIGHT CLIMAT OF BISKRA

In order to test the efficacy of using light shelves systems in town of Biskra we have first of all to assess the luminous environment and climatic conditions of the town through a series of indicators such as:

- Monthly average cloud cover.
- Hourly average cloud cover.
- Monthly average occurrence of overcast, partly cloudy and clear skies.
- Mean average horizontal illuminance levels calculated through NOOR1.1 program (Zemmouri,2005).
- Figure 1 present monthly average cloud cover.
- Figure 2 show the time dependent cloud cover.
- Figure 3 gives the monthly frequency of occurrence of percentage of clear, partly and overcast skies at Biskra.

All the represented data have been collated from the NASA SSE program website (www. eosweb. Larc. Nasa.gov/sse). This data set covers a large enough time period to evaluate the statistical properties of the regional analysis.

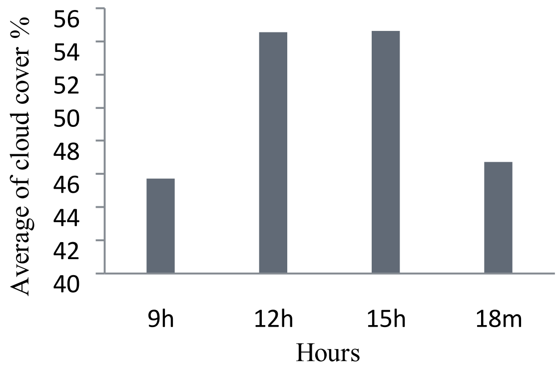

Fig. 2. Average hourly cloud cover in Biskra.

The horizontal illuminance data for Biskra have been calculated using NOOR1.1 code, the results are given in table 1. NOOR 1.1 is a daylight illuminance model developed as a desktop daylight calculation program under visual Fortran for analyzing daylight levels in urban outdoor spaces and investigating daylight availability over main urban agglomerations in Algeria under different sky conditions.

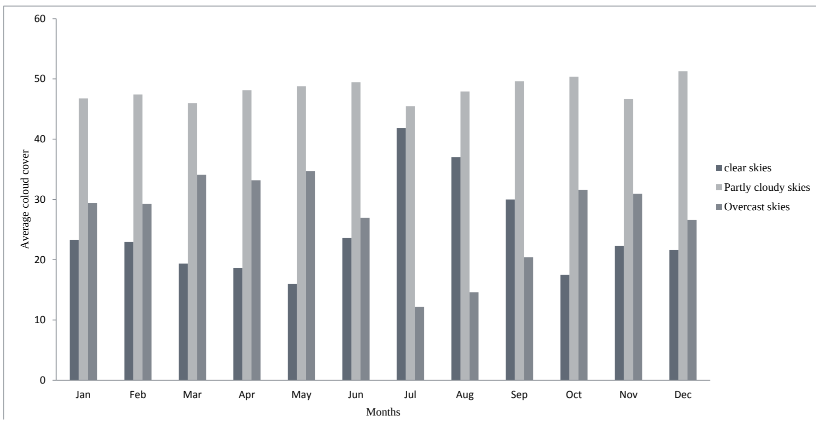

Fig. 3. Average monthly occurrence of overcast, partly cloudy and clear skies in Biskra.

TABLE 1 : CALCULATED AVERAGE HORIZONTAL ILLUMINANCE LEVELS FOR BISKRA IN LUX

Month Hour	9h	10h	11h	12h	13h	14h	15h	16h
January	17034	31515	43024	49039	48172	41384	29133	14559
February	25302	42701	55612	62349	62349	55612	42701	25302
March	40000	58839	70961	76821	76350	69511	56010	36528
April	54560	70430	79619	82560	81760	76387	63801	45272
May	62949	76806	82640	82912	83108	80028	69294	51563
June	57021	68314	72708	71585	72426	71533	63946	49583
July	40858	49980	54152	54266	54459	53409	47815	37418
August	40822	51960	57839	59578	59363	56573	48956	36635
September	39765	53157	61011	63863	62669	56693	45817	29963
October	39141	55626	65618	69353	66014	56349	40149	21167
November	26554	41879	51818	55252	52008	41130	27231	11419
December	17757	31121	40974	45205	43192	35361	22859	9504

3. EVALUATION OF THE EFFECT OF LIGHT SHLEVES CHARACTERISTICS ON INTERIOR DAYLIGHT DISTRIBUTION

Calculations were achieved according to time, light shelves configurations and horizontal illuminance. These conditions were chosen as they gave us the best chance to make sensible comparison. In each case a sequence of simulation was developed separately for, position, width, light shelf and ceilings tilt. An office room of 12m x 6m x3.2m has been considered, see Fig.4. & Fig.5. The fenestration and the light shelf are located in the shorter side. A grid system, sampled in Fig.6. is used for the reference points to determine the illuminance distribution on the working plane which taken at 0.9m from the ground plane.
From the results of simulations given in Fig.6. to Fig.10., it is obvious that using light shelves effectively influence interior daylight conditions. However, the effect of the light shelf tilt and orientation are more complicated. Illuminance distribution in the space is affected by materials, position (interior/exterior) and dimensions. It is clear also that the actual sky conditions vary considerably from the idealized overcast sky model. This is also expected, as we know that the overcast sky represents dark skies with heavy type clouds. Such skies are not typical of the bright partly cloudy skies experienced in Biskra.

Fig. 4. Section in the scale model

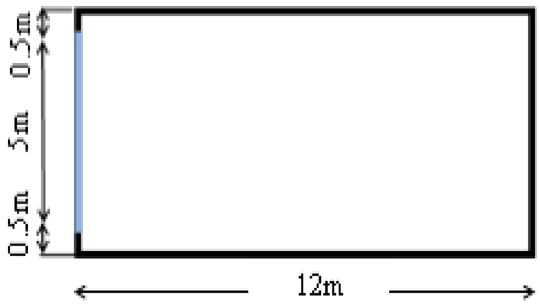

Fig. 5. Plane of the scale model

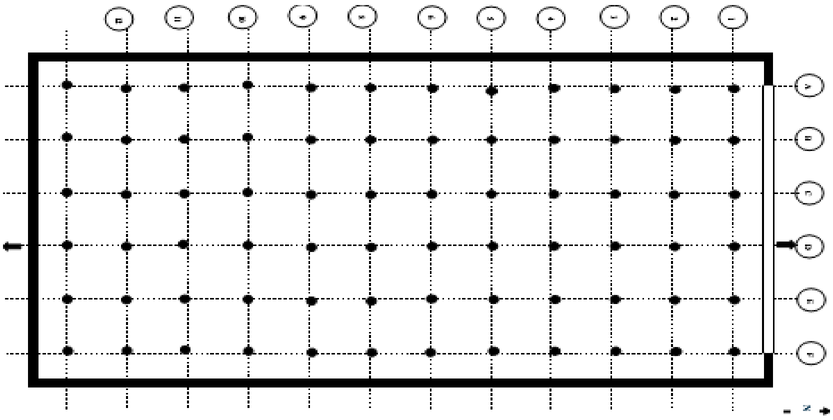

Fig. 6. Established grid system for the calculation procedure

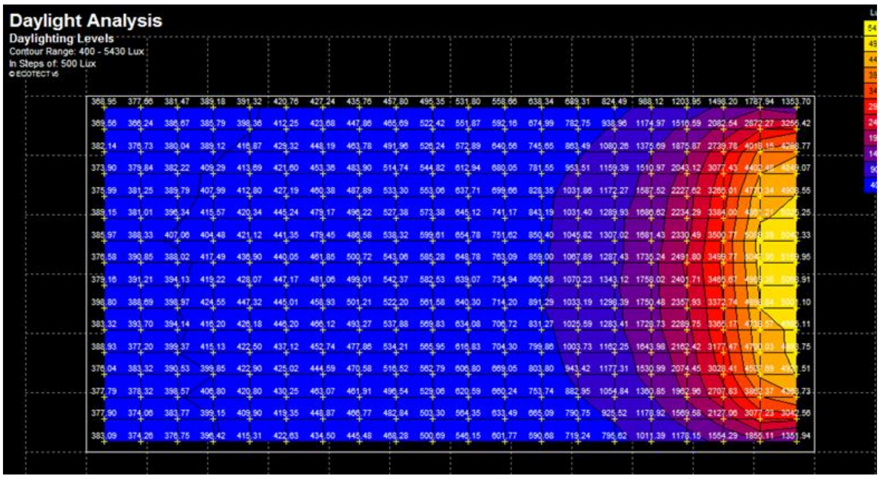

Fig. 7. Inside daylight distribution without light shelf.

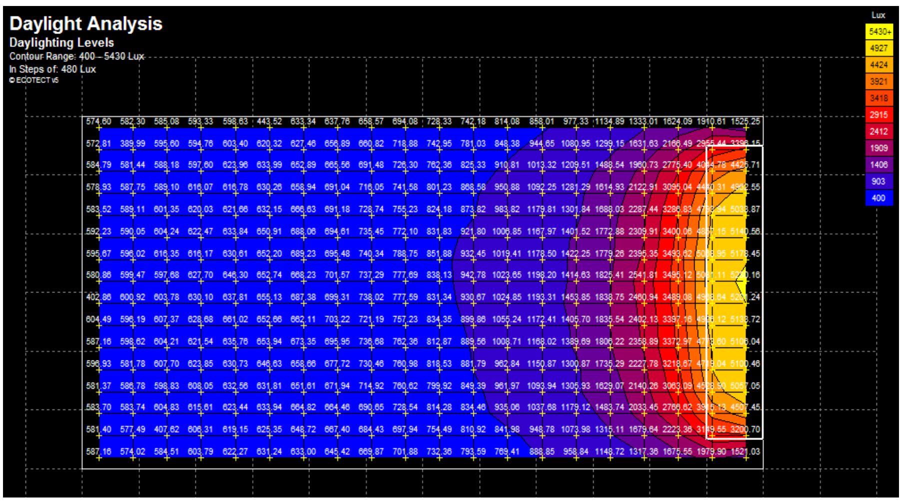

Fig. 8. Optimized daylight distribution with light shelf relative to position.

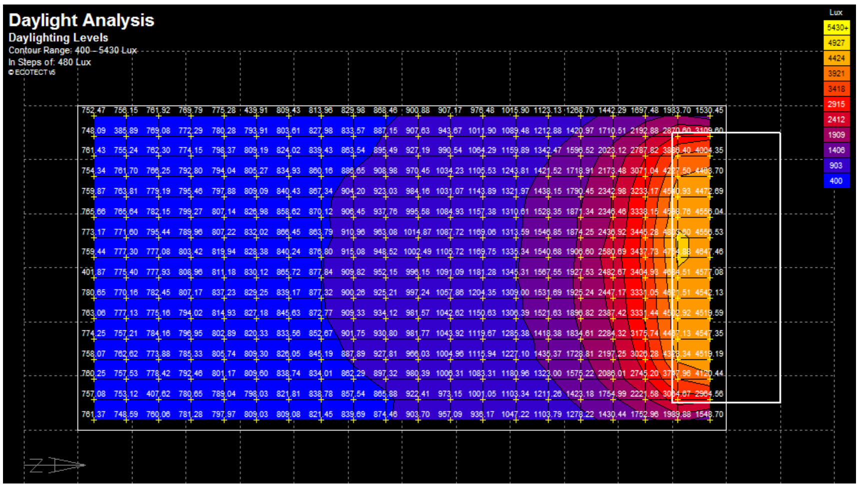

Fig. 9. Optimized daylight distribution with light shelf relative to dimension.

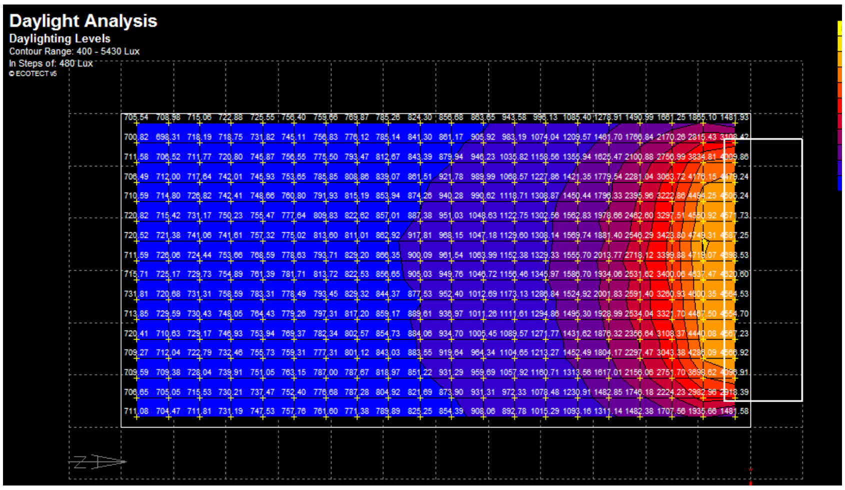

Fig. 10. Optimized daylight distribution with light shelf relative to tilt.

4. VALIDATION

In order to validate the simulation results, a scale model has been constructed and tested under typical partly cloudy sky. The effect of each parameter on the interior illuminance is evaluated individually and the results are presented in Fig.11. It can be observed that results are with a range ±5% of Ecotect results, which suggests a good correlation with the reality, considering predefined daylight external conditions.

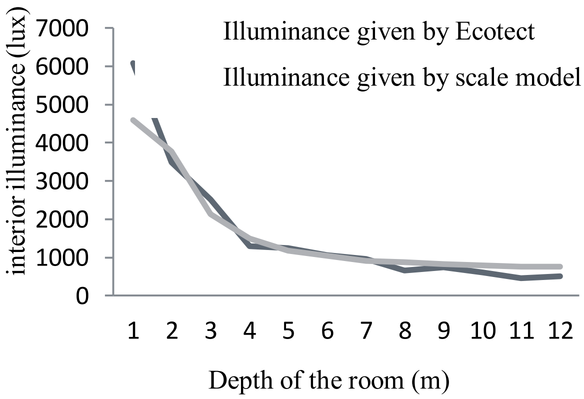

Fig. 11. Validation through measurements in scale model

5. CONCLUSIONS

According to the results of the simulations and measurements, it is possible to conclude that different tilting angles, configuration and a position of light shelves can contribute effectively to better results in naturel lighting design in hot and arid regions. Better naturel daylight contribution is understood as a condition that establishes good illuminance levels in the inner spaces without creating glare or large luminance and illuminance contrast levels.
To prove the applicability usefulness of the light shelf system, a case study was completed for a hypothetical small space under the specific sky conditions of Biskra. This study highlighted the limitations of using arbitrarily light shelves on building' facades and showed the benefit of integrated systems that take into account actual daylight conditions and distributions.

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