EVALUATION OF DIFFERENT SHADING METHODS IN ADMINISTRATION BUILDINGS ON THE BASIS OF DAYLIGHT EXPLOITATION AND ENERGY SAVINGS

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ABSTRACT

A major design concern in recent years has been the quality and adequate lighting of workplaces in public administration buildings by making appropriate use of natural daylight. This study, examines the influence of different shading methods implemented in public administration buildings on daylight quality and energy savings potential. To be more specific the paper presents an analysis and evaluation of various shading systems that can be applied to public administration buildings, in order to achieve adequate and uniform daylighting in the workplace as well as to reduce the energy required for heating cooling and artificial lighting. It is further investigated, through an existing case study building whether or not the application of shading systems reduces the natural daylight in the interior space, and if their absence leads to the increase of thermal gains. The analysis results demonstrate that the absence of shading systems causes overheating during the summer period as well as glare problems, undesirable in the offices of the building. Taking into account the above analysis, the conclusions of the comparative evaluation of the results lead to useful data for the design and further study of shading methods in administration buildings. These methods can utilize daylighting and provide visual comfort to occupants, while the energy required for heating and cooling can be reduced.

KEYWORDS

Daylight; administration buildings; bioclimatic design; shading systems; visual comfort; energy savings.

1. INTRODUCTION

Daylight in buildings has long been used in order to ensure visual comfort conditions indoors. However, after the energy crisis of 1973, the need to reduce heat gains and losses through the building envelope led to a reduction in both the number and dimensions of the openings of the buildings. As a result, visual comfort offered by daylight was compromised and replaced by the artificial lighting systems. Consequently, the artificial lighting of public office buildings came to represent the 23-28% of the total electricity consumed, making it imperative to reconsider utilizing natural daylight to provide adequate lighting of buildings [1].

The main goals of the daylight design of a building are to ensure sufficient lighting levels inside, so that users' requirements are met, to reduce or eliminate the risk of glare and to avoid strong contrasts in the brightness of internal objects. It should also be highlighted, that in office users prefer daylight as they believe that it leads to less stress and discomfort than working under artificial light [2].

The daylight inside a building is calculated based on the daylight factor (DF), with sufficient values for offices ranging from 2% to 5% [3]. For other uses in building interior spaces, the daylight factor values may range from 0 to 5% in an area that occupies approximately 80% of the interior space and reach up to 10% or 15% near the windows [4].

In order to achieve adequate daylight inside the building, measures must be taken to ensure the building's quality in terms of design and construction. Glazing surfaces and windows allow the diffusion of daylight in the interior space but on the other hand, increase the risk of glare and visual discomfort, as well as the building cooling loads. Quality control is achieved by selecting openings of appropriate size, and suitable location on the building facades, and by using high quality glass panes and shading elements [3].

The design of a building for daylight should include the installation of appropriate shading systems at the openings, in order to avoid overheating and glare indoors. At the same time, care should be taken not to limit lighting to very low levels, mainly in cloudy days.

These shading systems can be distinguished in three general categories: 1) internal 2) external and 3) systems contained in the windows glazing. The third type can be divided into several sub-categories depending on the type of protection they provide and their mode of operation (mechanical, manual or mixed) [5].

The purpose of this study is to evaluate the performance of various shading systems and the potential to achieve at the same time adequate utilization of daylight and energy savings in administration buildings.

2. METHODOLOGY

The assessment of shading systems is performed on a case study building, the Services Building of the Municipality of Makrakomi, situated in Makrakomi, Fthiotida (lat. 38.93^{o}). Two simulation software tools were used, ECOTECT v.2011 and RADIANCE, in order to evaluate the influence of shading systems on the diffusion of daylight at the occupants' working level in the office space of the administration building and on visual comfort. These programs also evaluate how the shading systems affect the requirements for artificial lighting and the heating and cooling loads required to ensure thermal comfort.

More specifically, the interior space studied, is Office no.1 located on the 1st floor of the Services Building (Fig. 1 - 3). This building has a disadvantaged east orientation, without the existence of any shading system. The study evaluated the application of three solar protection systems in the following case scenarios:

Table 1. Examined cases of solar protection.

Shading systems scenarios	Shading system description
Base Case 0	Without shading system
Case 1	Exterior horizontal fixed blinds
Case 2	Exterior horizontal fixed blinds with internal light-shelf
Case 3	Exterior vertical movable blinds

According to the literature research, these systems are common methods of solar protection in administration buildings.

Figure 1. East (main) view of Makrakomi Municipality Service Building in Makrakomi, Fthiotida.

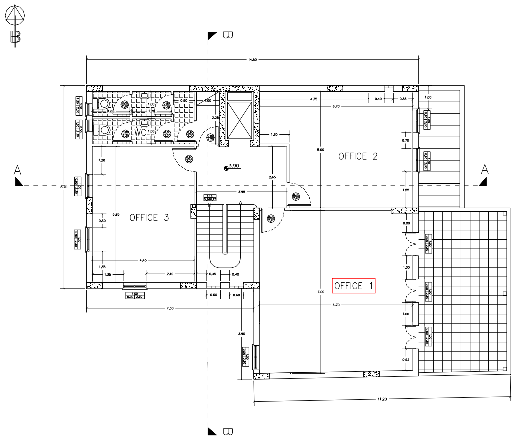

Figure 2. Office no. 1 floor plant.

Figure 3. View Office no. 1.

The above shading systems were tested on the space of Office no.1 for the degree of influence that each one has on both daylight and the reduction of energy consumption. More specifically, the following studies were carried out:

- solar shading study,
- study of daylight distribution,
- analysis of the thermal loads for heating and cooling the office

The analysis was completed with the comparative evaluation of the results.

3. RESULTS AND DISCUSSION

3.1 Solar shading study

From the solar shading study, it emerged that in the current situation (base case) the solar radiation enters the space of Office no.1 mainly from the east openings in the morning and reaches the back of the room, both in the winter period and in the summer months.

The horizontal blinds, with or without the light-shelf, (cases 1 and 2) manage to efficiently shade the office space both in the morning and during the rest of the day during the employees' working hours.

The most effective way of shading the east openings of Office no. 1 is to put vertical movable blinds which can rotate around their support axis and take such a position that prevents the entry of the sun rays inside the office (case 3). Their disadvantage is the restriction to view outside during the hours that are at an oblique angle.

3.2 Daylight analysis

3.2.1 Distribution of daylight study DF%

The Radiance Program was used for the analysis of daylight distribution for overcast sky. The distribution of DF was calculated for the current situation and for every shading system scenario separately (Fig. 4 -7).

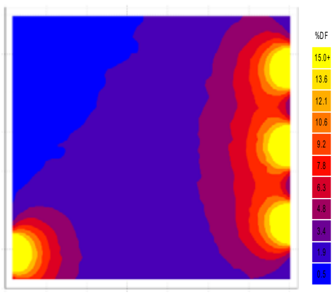

Figure 4. Base Case 0 - Distribution DF (%).

The results for the current situation (Base Case 0) show excessive daylight close to the openings which may cause glare either directly or through computer screens. Also, daylight is not enough in the area of the NW corner of the office.

The application of horizontal blinds (Case 1) manages to prevent glare near the openings and to create a uniform distribution of daylight.

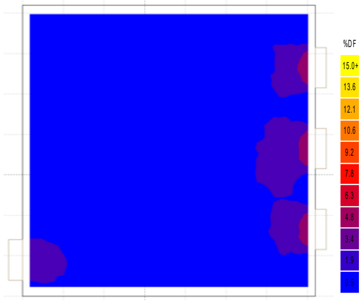

Figure 5. Case 1 - Distribution DF (%).

With the additional application of the internal light shelf (Case 2), it was observed that the area of sufficient daylight is extended further in the room and beyond the space near the openings. In this area the daylight is distributed more efficiently.

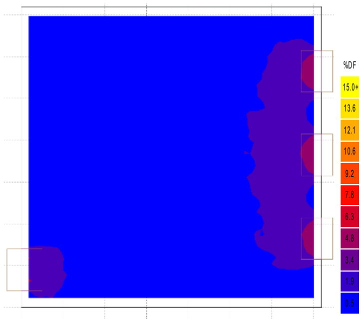

Figure 6. Case 2 - Distribution DF (%).

The placement of vertical movable blinds (Case 3) causes the smallest reduction of the daylight factor DF in comparison with the initial condition. As a result, most of the office's space has sufficient lighting (> 2%).

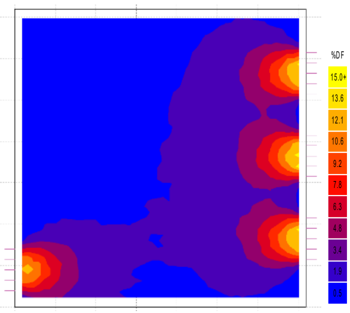

Figure 7. Case 3 - Distribution DF (%).

3.2.2 Study of daylight levels

Radiance program was then used in order to calculate the lighting levels at the employees' working level for sunny sky conditions. The date set for the calculation was June 21th at 8 a.m., as the most unfavorable case in terms of the possibility of glare.

In the current situation (base case) and during the day and time of the study it was observed that the lighting levels were too high in relation to the desired ones (fig. 8).

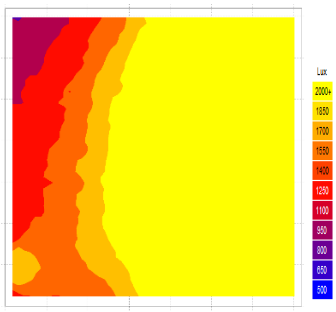

Figure 8. Base Case 0 - daylight levels (lux).

The application of external horizontal blinds (case 1) reduces the levels of daylight on the most unfavorable day, and limits the area of potential glare (above 2000lux) to an area of about 1.00m from the east openings (fig. 9).

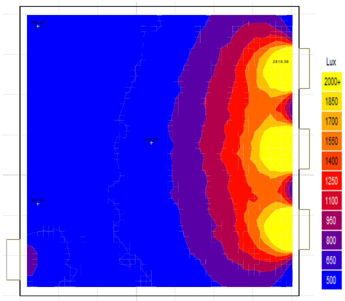

Figure 9. Case 1 - daylight levels (lux).

By installing an additional internal light-shelf (case 2), a larger area of the office has lighting levels above 300lux (fig. 10), and in this way, if employees avoid the area near the openings, they can ensure satisfactory working conditions in terms of daylight provided.

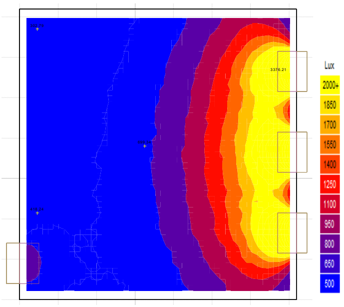

Figure 10. Case 2 - daylight levels (lux).

With the installation of vertical external blinds (case 3), lighting levels of more than 200lux are achieved in the north-west corner of the office and close to 500lux and above in the rest of the office (fig. 11). As a result, if employees avoid those areas, where maximum values are observed, they can work in conditions of satisfactory visual comfort.

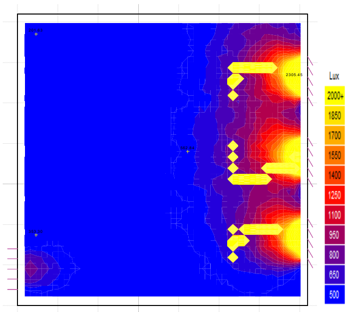

Figure 11. Case 3 - daylight levels (lux).

3.2.3 Study of energy requirements

The energy performance analysis focused on the calculation of heating and cooling loads for the office no.1. The whole analysis was carried out using the program ECOTECT v.2011. The calculated monthly and annual thermal loads for the tested scenarios are presented in the following table (Table 2).

Table 2. Heating - cooling loads and annual energy requirements of Office no. 1.

Cases	**Annual consumption of heating energy (kWh)**	**Annual consumption of cooling energy (kWh)**	**Total annual energy consumption (kWh)**
Base Case 0	636.56	1034.16	1670.71
Case 1	687.45	964.79	1652.23
Case 2	679.39	974.64	1654.03
Case 3	664.93	994.22	1659.15

The results of the energy performance analysis reveal that:

- In the current situation Office no. 1 requires 637kWh per year for heating and 1034kWh for cooling.
- With the installation of the external horizontal blinds the thermal loads increase to 687kWh and the cooling loads decrease to 965kWh.
- The installation of additional internal shelves in addition to the blinds, further reduce the thermal loads to 679kWh and increase the cooling loads to 975kWh.
- The vertical external blinds reduce the thermal loads to 665kWh and the cooling loads to 995kWh compared to the initial condition.

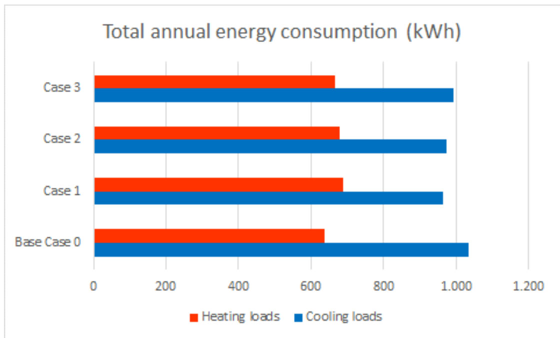

Figure 12. Graphical representation of total annual energy consumption distributed to heating and cooling loads (kWh).

4. CONCLUSIONS

The analysis of the influence of different shading devices on daylight distribution and energy requirements for a case study office space in a public administration building led to the following conclusions:

1. Vertical movable blinds are the most effective way of shading the east openings, as they provide the ability to rotate around their support axis and take such a position that prevents the entry of sunrays inside the office. Their disadvantage is the restriction to view outside during the hours that are at an angle.
2. The application of shading methods results

in a more uniform distribution of daylight at working level throughout the office area and up to its depth. The shading systems also eliminate glare which is observed mainly in the morning and create a working environment with smaller changes during working hours.

3. The disadvantage of the application of shading systems is that they reduce the average daylight factor to levels below 2%. As a result, the use of artificial lighting is required.
4. In the current situation, the office receives high levels of daylight (>800lux) on the examined day on June 21st at 08:30 am. With the application of shading systems, the areas of high daylight levels are significantly reduced and limited to a zone near the east openings.
5. The application of external horizontal blinds causes the greatest reduction of daylight but if combined with internal light-shelves the reduction is less.
6. The vertical blinds placed at an angle of 60o clockwise reduce the levels of daylight on June 21st and limit the area of intense lighting above 2000lux to a small area of about 1.00-2.00m from the east openings.
7. With the installation of shading systems, the required thermal loads increase and the cooling loads decrease.
8. The application of shading systems leads to the increase of the required energy for heating in winter and reduces the required energy for cooling in summer.

In conclusion, the shading systems may control the daylight in the interior of the building to obtain more uniform daylight distribution and to reduce or eliminate glare and cause a decrease of cooling loads in the cooling season and an increase of heating loads in the heating season.

REFERENCES

[1] Greek Ministry of Development, 2008, *Energy Efficiency Action Plan*. Athens. pp. 25-33.

[2] Doulos L., Tsangrassoulis A., Topalis F.V., 2007, *Evaluation of lighting controls in office buildings, 6th WSEAS International Conference on CIRCUITS, SYSTEMS, ELECTRONICS, CONTROL & SIGNAL PROCESSING.* Cairo Egypt. pp. 29-31.

[3] Axarli K., Yannas S., Evaggelinos E., Zacharopoulos I., Marda N., 2001, *Volume A': Bioclimatic design of buildings*. Patra: HOU. pp. 155-250. 960-538-336-5.

[4] Tregenza P., Loe D., 1998, *The design of lighting*. London and New York: Routledge. pp. 156. 0-419-20440-7.

[5] Gherri B., 2015, *Assessment of Daylight Performance in Buildings*. Southampton: WIT Press. pp. 60. 978-1-78466-040-6.