

Shading Devices Designed to Achieve the Desired Quality of Internal Daylight Environment

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ABSTRACT: The main purpose of this study was to design the geometry, position and finishing materials of shading devices for central Europe latitude and weather conditions. There were two main factors considered in our study to determine the parameters of the devices. The first one – maximum daylight utilization (from energy savings point of view) and the second one – daylight distribution inside the space (on the level required by visual comfort parameters – the illuminance level and the glare index). There were some initial assumptions limiting the number of solutions. The most important was that all the elements of the devices must be permanently fixed and no rotation was permissible. It means that only one solution is required for summer and winter season. The numerical analyses were done using advanced numerical techniques based on Backward Ray Tracing Method for selected sky conditions.

Keywords: daylight, shading devices, visual comfort

1. INTRODUCTION

Bioclimatic solar design mainly concentrates on providing heating space during winter as well as on avoiding overheating during the summer period. Traditional shading devices are mainly designed to prevent direct solar transmission from getting into the building space. While excessive quantity of solar gains causes an overheating effect, insufficient amount of daylight can be a reason for low illuminance at the working plane. Therefore, individual design solutions are necessary for different locations and climatic conditions. The main purpose of this work was to find the best solution of three advanced solar blind systems designed for Central Europe location and conditions.

More advanced blind devices [1] considered in the presented work are two types of fixed louvers:

- “Okasolar” system - consists of fixed, equally spaced reflective louvers,

- “Fish” system – consisting of fixed horizontal louvers.

“Fish” system consists of fixed horizontal louvers with a triangular section that has been precisely aligned by special connections to the louver itself. This system is designed especially for vertical windows. Its main purposes are to limit the glare and redirect diffuse light. They are designed so that the light from the upper quarter of the sky is transmitted to the upper quarter of the room.

“Okasolar” system consists of numerous equally spaced, three-sided reflective louvers, usually placed inside a double glazed window. The system reflects the light up towards the ceiling in winter and gives shading effects during summer. There are additional classifications of “Okasolar” system: type 1 with a concave upper louver and two convex lower sides, and type 2 with all the three surfaces flat or sometimes with the upper sides completely flat.

2. ADVANCED SHADING SYSTEMS

Depending on a slat angle, surface finishing lining and spacing between the slats, both sunlight and skylight may be reflected to the interior. Louvers and blinds can be used in all orientations and at all latitudes. Exterior blinds affect the architectural and structural design of a building, while interior blinds have a smaller impact. In the presented study only horizontal louvers have been considered as more general and successfully applicable in all building orientations.

Both types are classic daylight systems that can be applied for solar shading to protect against the glare and redirect daylight into the room space. They are composed of multiple sloping slats with highly sophisticated shapes and surface finishings. Fixed systems, which are considered in this work, are usually designed for solar shading. However, the aim of our work was to find the kind of shape and inclination angle that could redirect some amount of light as well. The second problem for the occupants and a technical barrier for the architects is the obstruction of direct view on the outside. The second requirement for the designed system was to leave gaps huge enough to provide that kind of view. The elements are generally made of PVC, chrome steel or painted aluminium. The distance between the louvers is constant and the width of a single element is 5÷20cm (internal systems) or 20÷50cm (external systems).

3. SLATS GEOMETRY AND MATERIAL

For the purpose of our study three shapes of slats have been considered. The geometry and the main rules of how the system works in different periods of the year are presented in figures 1÷3.

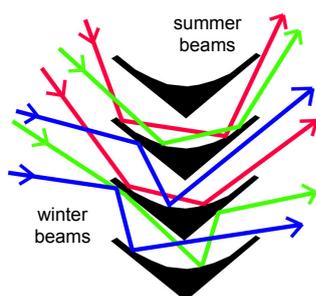


Figure 1: "Fish" louvers

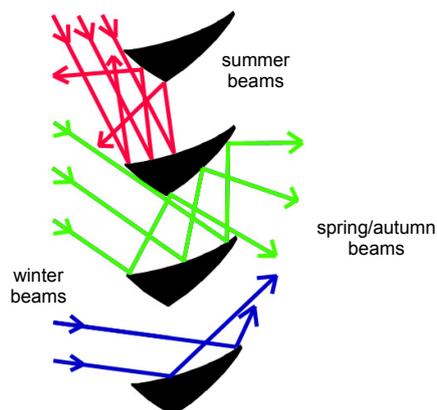


Figure 2: "Okasolar" type 1 louvers

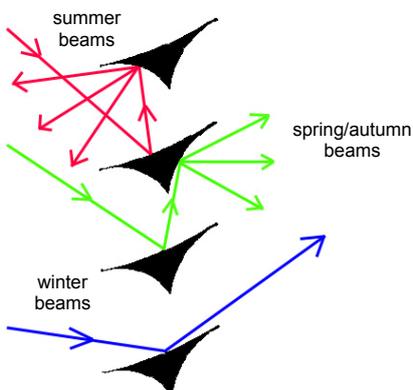


Figure 3: "Okasolar" type 2 louvers

Detailed dimensions of three types of single louvers are presented in figures 4-6. They were designed according to the altitude and bearing angles for the location 52,00N and 21,00E (Central Europe). Optimal angles were found for 12:00AM, 21st March, June and December. To obtain exact dimensions of the slats, presented in figures 4-6, the sun position (sun altitude and bearing angle) were specified for the selected days and location (longitude, latitude and meridian respectively 52.25N, 21.0E, -15.0). It was assumed that sun beams should not reach the room space as direct light.

All the elements of the devices must be permanently fixed and no rotation is permissible. The shape and angle of the louvers were chosen especially from the user's height and looking perspective. The distance between the louvers should allow to have an eye contact with external environment, only when people stay close to the window face.

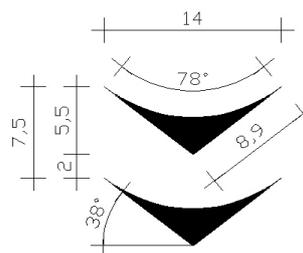


Figure 4: Main dimensions of "Fish" louvers.

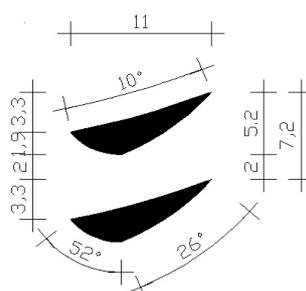


Figure 5: Main dimensions of "Okasolar 1" louvers.

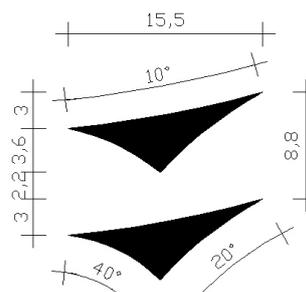


Figure 6: Main dimensions of "Okasolar 2" louvers.

4. NUMERICAL RESULTS

The analyses have been conducted for a single room 6.0×8.0×3.0m presented in figure 7. The window is 6m wide and 2m high.

The numerical analyses have been done using RADIANCE-based methodology [2]. The luminance of the sky was assumed according to the Standard Overcast Sky Distribution developed by the Commission Internationale de l'Eclairage (CIE) [3]. The mean value of Linke Turbidity Factor obtained from other works for a city is $T_L=3,75$ [4].

The results of illuminance distribution along the room are presented in figures 9-11. The upper image is a rendering of view scene. The lower one is luminance distribution in the analysed room. The highest luminance is obtained with "Okasolar 1", about 73500Nits. With "Fish" and "Okasolar 2" the luminance is about 10% smaller. The analyses have been done using a clear sky distribution model. Similar results for all three cases are reported for June (max. ~4 000 Lux) and December (max. ~7 000 Lux). The highest differences are noticed for March when "Fish louvers" allow the increase of the

illuminance to almost 12 000 Lux. However, the Fish type guarantees 500 Lux also in the deepest parts of the room. In June the illuminance dropped below 500 Lux on the fifth meter from the window with “Okasolar louvers” and on the sixth meter with “Fish louvers”.

The daylight factor (DF) distributions inside the room are presented in figures 12÷14. The DF was calculated for a cloudy uniform sky model. The results obtained are very similar for the three analysed cases. For all the cases the DF is lower than 6 in the whole room space. The required values of the $DF \geq 2$ are provided for 2,5÷3,0m from the window, when for the windows without slats it is 2 times more (about 6m). “Fish” and “Okasolar 1” give the highest reduction of the DF in December. In March and June the highest reduction was obtained for “Okasolar 1”. The lowest luminance differences were reported for “Fish” and “Okasolar 2”. Also, the highest illuminance and daylight factor values in the room were reported for the same cases.

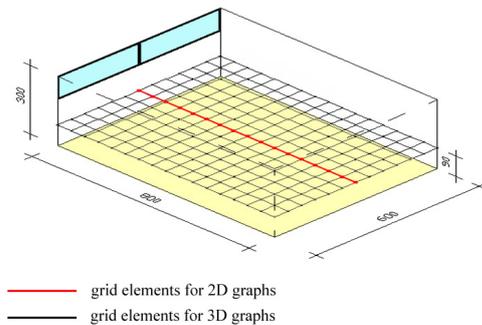


Figure 7: The prospective view of the analysed room.



Figure 8: The schematic view of the louvers.

5. LABORATORY MEASUREMENTS

The second part of the analyses concerns a laboratory experiment done for the selected “Fish” type of the louvers. The analyses have been done using Sun Simulator. In the analysis three different types of the materials were compared: white paint, aluminium and wooden finishings. The view of the model is presented in figure 15. The images of the louvers from the inside of the room are presented in figures 16÷18. The analyses have been done for the worst sun position, low sun altitude angle – perpendicular to the elevation. The results show how the different materials and colours change the effect of the glare. The best results were reported with the

case with wooden finishings. With aluminium the whole part of the louvers shines with high reflected lights.

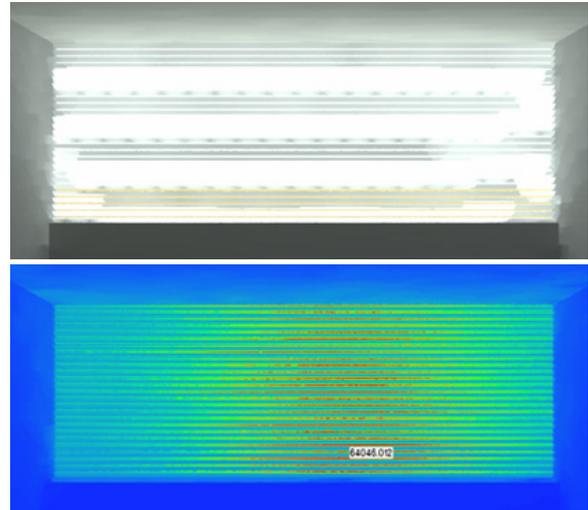


Figure 9: Results for “Fish” louvers.

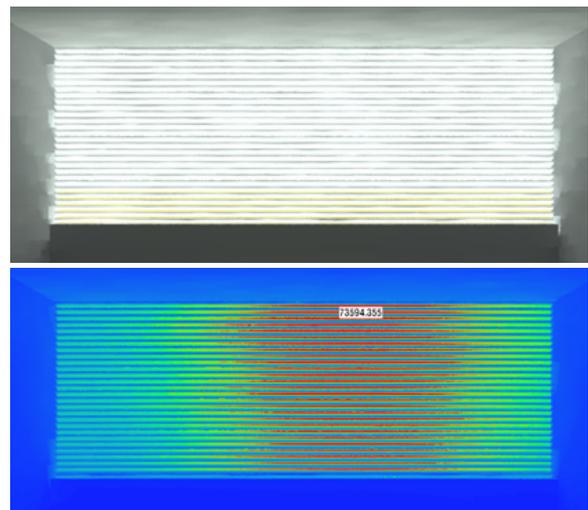


Figure 10: Results for “Okasolar 1” louvers.

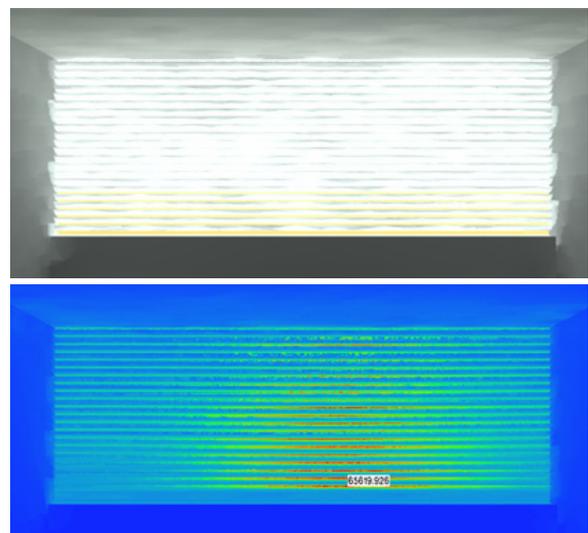


Figure 11: Results for “Okasolar 2” louvers.

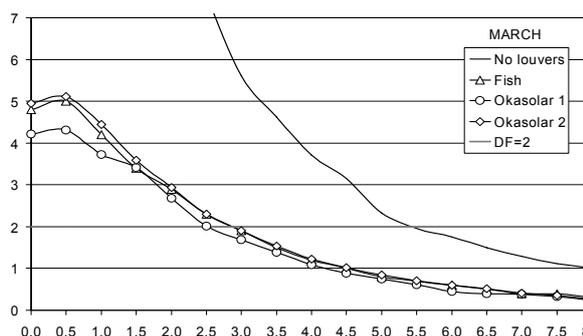


Figure 12: Illuminance results for 21st March.

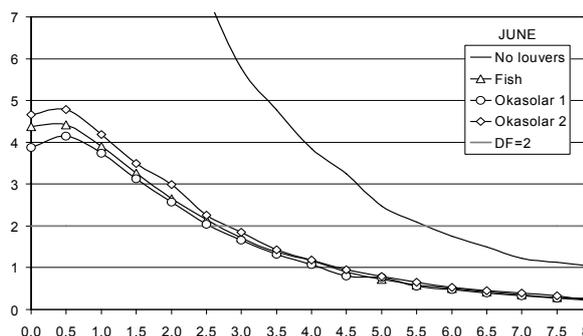


Figure 13: Illuminance results for 21st June.

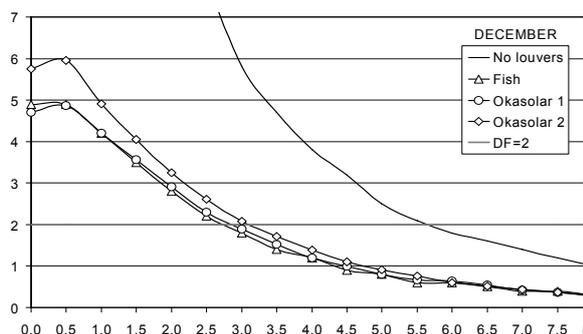


Figure 14: Illuminance results for 21st December.

The pictures 15÷17 were analysed using graphical software to find the brightness of the light reflected from the elements of the louvers. The highest differences between the light source and the slats were obtained with wooden finishings covering (more than 2 times higher). With aluminium panels the brightness of the light source and the brightness of the reflective light are almost the same.

6. CONCLUSIONS

The numerical analyses were divided into two parts. The first one concerns the required level of illuminance inside the room space. From that point of view, the best type of the louvers is “Fish” which allowed to guarantee the required values of illuminance in the whole room during March and December. The second part of the analyses was devoted to the Daylight Factor calculated for a cloudy sky. In that case the best solution was obtained with the louvers type “Okasolar 1”. The presented results

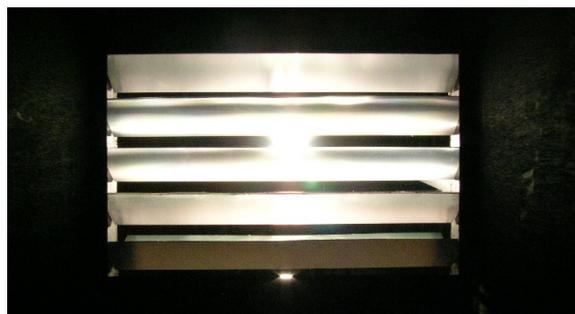


Figure 15: View for aluminum “Fish” louvers.

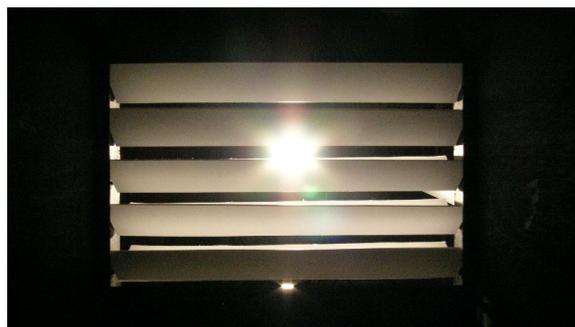


Figure 16: View for white painted “Fish” louvers.

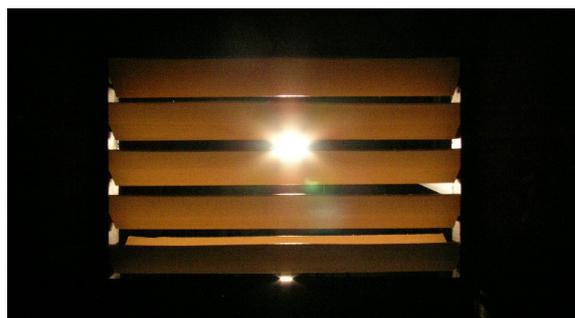


Figure 17: View for wooden “Fish” louvers.

do not show significant differences between different types of the louvers. The comparison of analytical results was based on brightness measurements.

ACKNOWLEDGEMENT

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