PERFORMANCE ANALYSIS OF COMMON SOLAR SHADING DEVICES: EXPERIMENTAL ASSESSMENT AND RAY-TRACING CALCULATIONS USING BI-DIRECTIONAL SCATTERING DISTRIBUTION DATA

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ABSTRACT

This article presents the characterization of solar shading performances from the material point of view to the system characterization point of view.

It introduces the efforts achieved to determine the BSDF of textile screens, its characterization according EN 14500 and 14501 and advanced computer simulations. It also introduces to the tool developed to help the end-user to evaluate those solar shading devices.

Keywords: Solar shading, performance characterization, BSDF, Daylighting, modeling, Raytracing

1. CONTEXT

Solar shading devices have been used for many years to protect building occupants from the negative effects of solar radiation. Because of the increased focus on energy efficiency buildings have to reach still higher insulation and air tightness standards, and thus overheating problems could be intensified. Also due to better awareness for the beneficial effect of daylight access in buildings solar shading systems have become critical issues to guarantee visual comfort as well as thermal comfort for their occupants.

2. INTRODUCTION

Solar shadings are important elements for global energy performance of buildings and when manually adjustable allow the building occupant to control visual and thermal comfort. The most commonly used systems include shading screens and blinds. Given the widespread use of these devices it is important to provide for a more accurate performance characterization.

Simplified models consider solar shading as a uniform parallel layer which reduces incoming energy and light fluxes by a fixed factor without taking into account the angular-dependent properties that affect light and energy distribution patterns. However, especially for devices using metallic slats, spatial distribution of radiation varies strongly. For energy transfer analysis average radiant flux is probably satisfactory as input for dynamic thermal simulations but for visual properties distribution patterns need to be considered.

Another limitation for the detailed understanding of the properties of the solar shading is the restricted information available about material and surface properties.

The European standards EN14500 Blinds and shutter - Thermal and visual comfort - Test and calculation methods and EN14501 Blinds and shutters - Thermal and visual comfort

Performance characteristics and classification - provide criteria for characterization and classification of products based on available data, but the human perception is more complex and real performance does not always match with this classes.

3. PROSOLIS STUDY

3.1. Technology Watch

A first step towards a better understanding of the solar shading devices is to identify the range of products and systems available. It was first decide to review screen products used as solar devices and then at blind systems with metallic slats. This article will only handle the screen products.

3 different materials were identified as most commonly used for the yarns:

- Fibreglass
- Polyester
- Acrylic

Solar shading screens were also examined in function of other characteristics:

- Weft type (Natté, Sergé or other)
- Colour (grey scale)
- Openness Factor (3 to 15 %)

A total of 23 relevant fabrics were selected and tested for the study. Only 3 fabrics, representative of them, will be handled in this paper.

Figure 1 and Figure 2 show the two different types of weft selected. **Error! Reference source not found.**, **Error! Reference source not found.** and **Error! Reference source not found.** show the three different samples.

Table 1 – Characteritics of fabric samples

Solar protection	Weft type	Colour	Openness Coefficient
Sample 1 – Ref. PS_T04	Sergé 2165	Black	3
Sample 2 – Ref. PS_T12	Sergé 2165	White	3
Sample 3 – Ref. PS_T13	Natté 2165	White	10

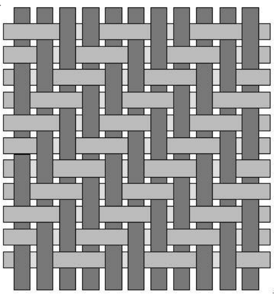


Figure 1 – Weft of Sample 1 and 2 Sergé

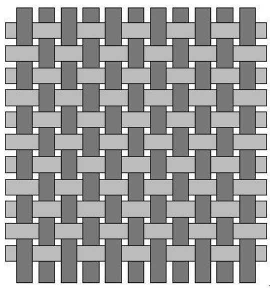


Figure 2 – Weft of Sample 3 Natté

Figure 3 – Sample 1
Ref. PS_T04

Figure 4 – Sample 2
Ref. PS_T12

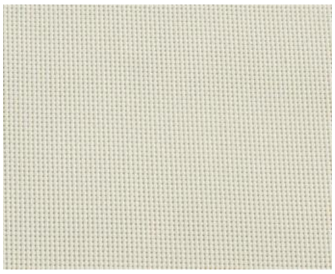


Figure 5 – Sample 3
Ref. PS_T13

3.2. Characteristic's examination

The fabrics were measured with a spectrophotometer for normal or near to normal (for reflectance values) incident angles. The measurements were done according to EN 410 Glass in building - Determination of luminous and solar characteristics of glazing. The specular component is determined as the radiation transmitted within 4° of the specular transmission direction. A special attention was paid to the light transmittance and light reflectance values:

- τ_v : light transmittance
- $\tau_{v,n}$: diff light transmittance normal - diffuse
- $\tau_{v,n-n}$: diff light transmittance normal - normal
- $\rho_{v,n-h}$: light reflectance of outer surface normal - hemispherical
- $\rho_{v',n-h}$: light reflectance of inner surface normal – hemispherical

Additional measurements were achieved to characterize the samples under different incident angles. The purpose is to determine how hemispherical transmission and reflectance values vary for different product and to identify the spatial distribution patterns. These can be done by determined by the bidirectional scattering distribution functions (BSDF). The BSDF gives detailed information about the real scattering properties of materials and surfaces and can only be measured with specific equipment.

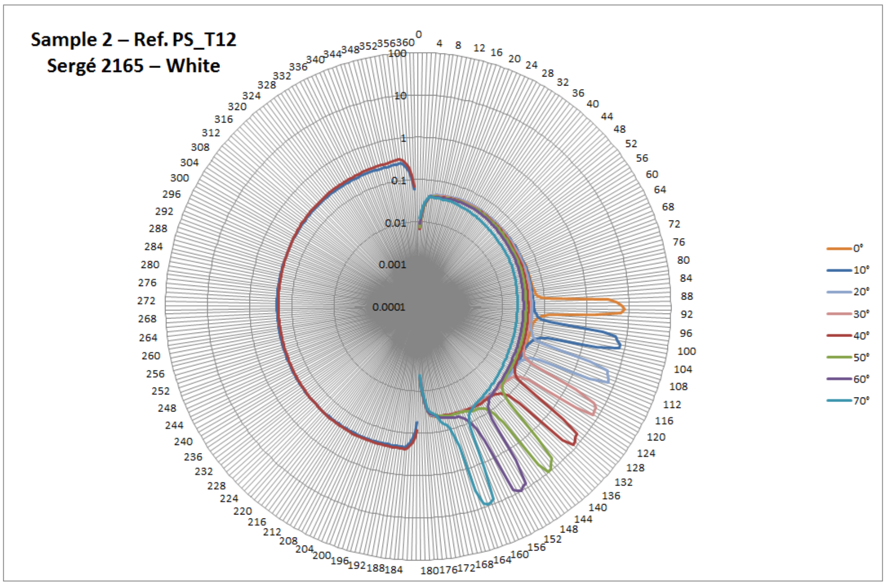


Figure 6 – Representation of BTDF and BRDF in vertical plane for different specific incident angles (0°, 10°, 20°, 30°, 40°, 50°, 60°, 70° for the BSDF – 10° and 40° for the BRDF) for sample 2

The BSDF functions of different solar shading screen samples were determined with a 2D scattered light measurement of the type Reflet 180°. The Reflect 180° is a goniospectrophotometer for measuring back-scattering and forward scattering from diffusing samples or specular surfaces. **Error! Reference source not found.** shows as an example the results for the screen sample 2 (T12).

The measurements show that:

- The direct visual transmission is mainly depending of the type of weave.

  The rays transmitted in specular direction through sample 1 (Sergé 2165 – Black) and Sample 2 (Sergé 2165 – White) have a similar intensity variation for the different observation angles. The direct visual transmission reduces slightly with higher incident angle for serge screens and much more for natté screens.

  For natté screens the maximal radiant intensity in transmission can be two times higher at normal incident angle (i.e. Sample 3 : 20.6) than for the 70° incident angle (i.e. Sample 3 : 10.2).

- The diffuse visual transmission is mainly influenced by the colour of the yarns.

  The diffuse component of radiation through a screen is nearly perfectly lambertian and varies just slightly for different incident angles. The diffuse radiant intensity transmitted through a dark screen as sample 1 (Sergé 2165 – Black) is, for all observation angles, marginal in comparison to the specular transmission.

  For light colour screens types the diffuse radiant intensity is of the same order of magnitude for sample 2 (Sergé 2165 – White) and Sample 3 (Natté 2165 – White) which use the same type and colour of yarns.

- The reflection is perfectly diffuse and is function of the colour.

  The radiant intensity in reflection is much higher for sample 2 (Sergé 2165 – White) and sample 3 (Natté 2165 – White) than for sample 1. (Sergé 2165 – Back).

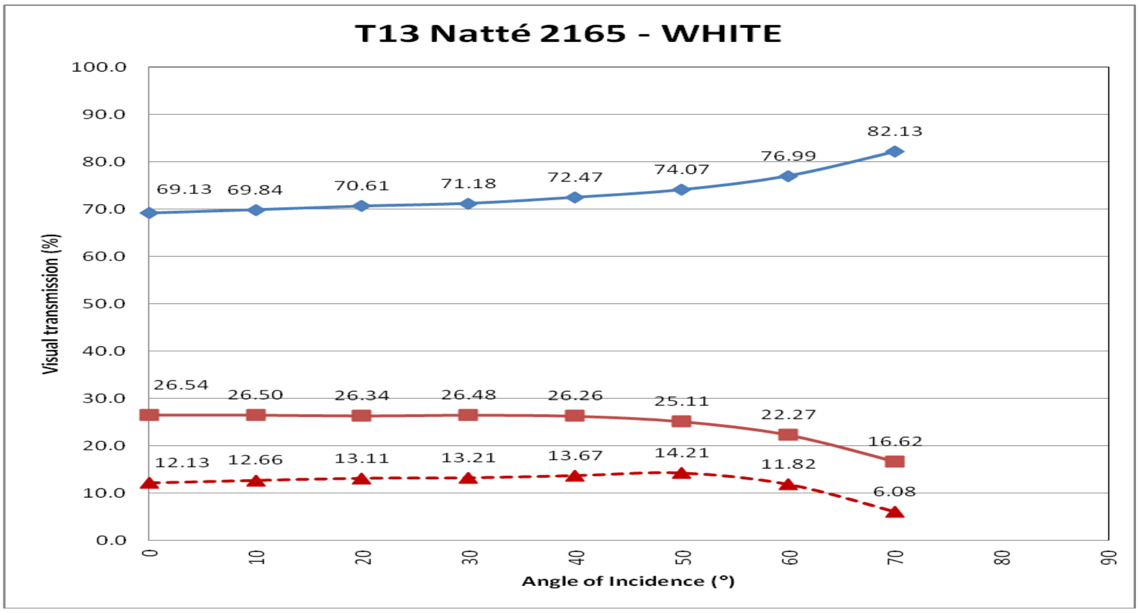


Figure 7 – Hemispherical visual reflectance and transmission for sample 3

By combining the measurements at normal incident angle and the information about angle dependent properties obtained during BSDF measurements we could establish the variation of visual transmission in function of incident angles. **Error! Reference source not found.** shows the results for sample 3. The specular component is represented by the dotted line.

All the fabrics were also characterized according the EN 14501 classification :

- Opacity control;
- Glare control;
- Night privacy;
- Visual contact with the outside;
- Daylight utilisation;
- Rendering of colours;

This classification is depending on three main factors:

- $\tau_{v,\ n\text{-}n}$ normal/normal light transmittance;
- $\tau_{v,\ n\text{-}dif}$ diffused part of light transmission;
- $\tau_{v,\ dif\text{-}h}$ diffuse/hemispherical light transmittance.

Table 1 – Classification of fabric samples according EN 14501

	Sample 1 Sergé 2165 – Black	Sample 2 Sergé 2165 – White	Sample 3 Natté 2165 – White
$\tau_{v,\ n\text{-}n}$	3.3	4.3	12.1
$\tau_{v,\ n\text{-}dif}$	0.4	15.6	14.3
$\tau_{v,\ dif\text{-}h}$	3.7	19.9	26.4
Opacity control	0	0	0
Glare control	3	1	0
Night privacy	2	2	0
Visual contact with the outside	2	0	3
Daylight utilisation;	1	2	2

3.3. Ray-tracing calculation model

Most lighting simulations software's consider all surfaces as perfect diffuse materials. Directionality of the light flux emitted by an artificial light source is generally taken into account during calculations by using detailed photometric files for the luminaire. However angle-dependent properties of materials are generally ignored.

Specific software applications are able to run using bi-directional scattering distributions functions for materials. Software packages integrating BSDF-data and using raytracing algorithms are commonly used in aerospace and automotive industries.

Advanced simulations have already been applied the building industry in order to analyse performances of complex fenestration system and daylight redirecting devices. In this study we used advanced simulations for detailed characterisation of more common products. The use of measured BSDF-data into the software allows us to refine estimation and visualization of the sun light penetration into a space.

The software used for these calculation at BBRI is LIGHTTOOLS - Illumination design and analysis software (version 8.0) developed by Synopsis®.

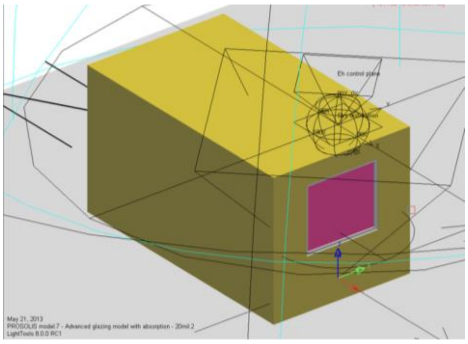


Figure 8 – Model used for the Ray-tracing calculation

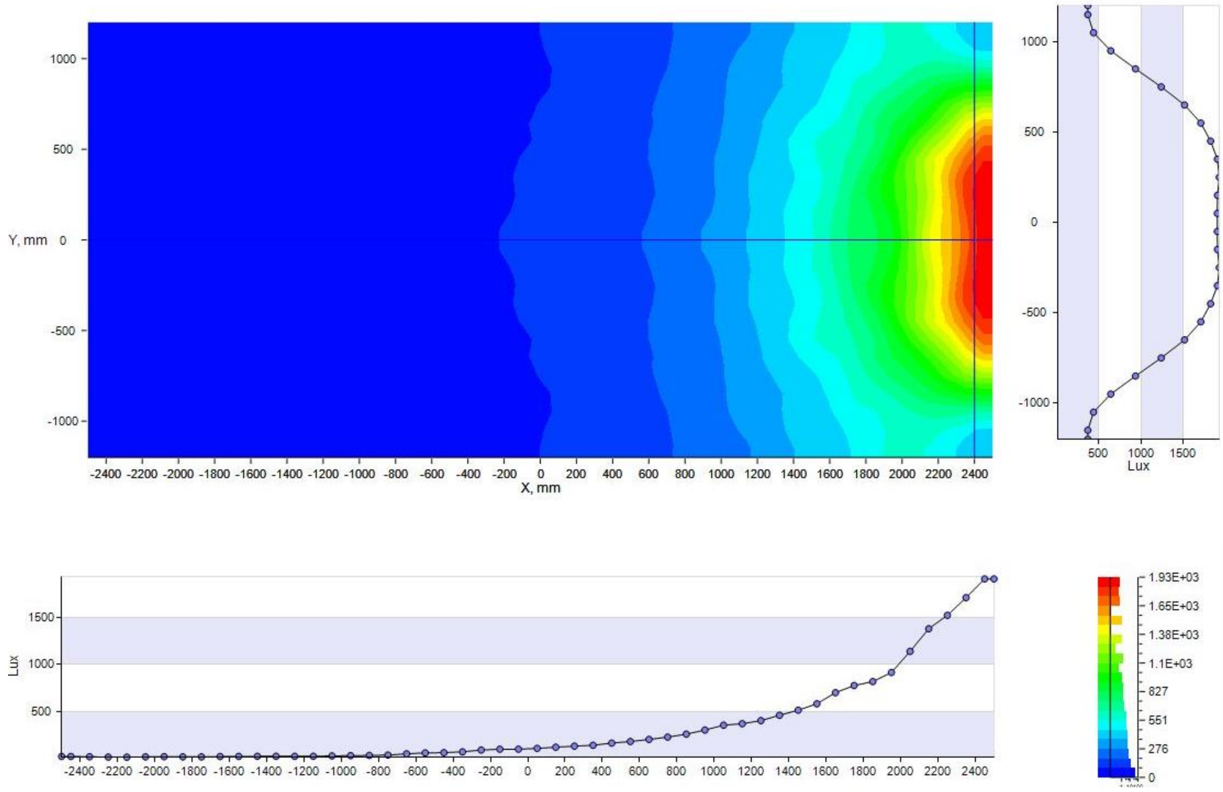


Figure 9 – Results of the Ray-tracing calculation for test cell

4. EXPERIMENTAL SET UP

To check the performances of the solar shading devices test cells were used. The assessment in situ is important to catch the real visual performance and to offer a visualisation of performance.

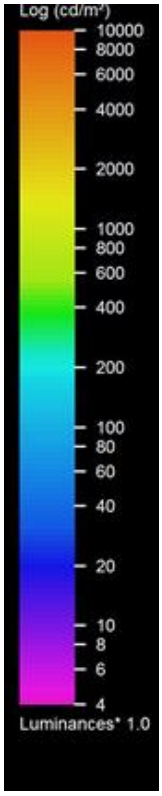
The luminance distribution in the visual field was measured using a Canon 40D and a Sigma Fish-eye lens and using the Photolux Software 3.2.

Figure 10 – Test Cell at BBRI

Figure 11 – Sample 1 – Sergé 2165 – Back - Indoor view

Figure 12 – Sample 2 – Sergé 2165 – White - Indoor view

Figure 13 – Sample 3 – Natté 2165 – White - Indoor view



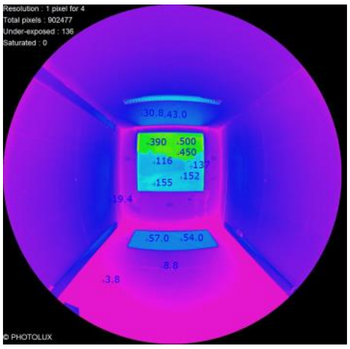


Figure 14 – Sample 1 – Sergé 2165 – Back - Indoor luminance

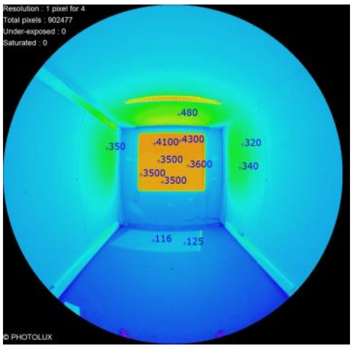


Figure 15 – Sample 2 – Sergé 2165 – White - Indoor luminance

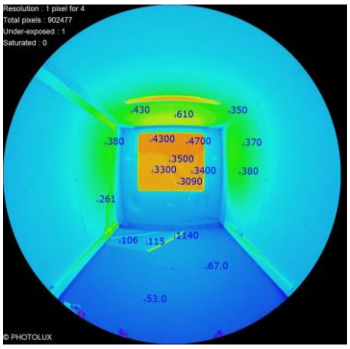


Figure 16 – Sample 3 – Natté 2165 – White - Indoor luminance

Measurements on different solar screens show that for openness factors below 10 :

- view through is only possible for luminance lower than approximately 3.000 cd/m^2 and depends also of the size and distribution of the openings in the screen ;
- glare seems to be more likely for average screen luminance higher than 4.000 cd/m^2.

5. WEB TOOL PROSOLIS

A web tool is now under development within the PROSOLIS research project. The aim of this tool is to help end users to evaluate the impact of most typical solar shading system for standard configurations. Due to complexity of the issue the tool will not target a detailed performance characterization for a specific building, but should help end users to compare most typical solar shading solutions based on a reduced but yet reliable set of data. It considers both visual and energy aspects.

Figure 17 – Selection of the solar shading device

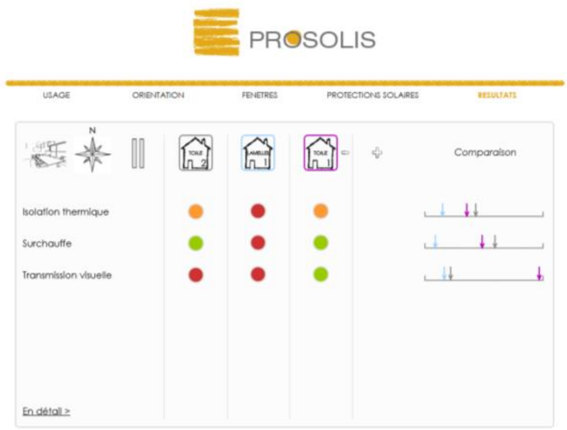


Figure 18 – Comparison of the performance of different solar shading devices

This web tool will allow characterizing different complex fenestration system (window + solar shading device) on energy and visual comfort levels.

6. CONCLUSION

The PROSOLIS project will lead to a better understanding of solar shading devices and to a better comprehension of the software simulation of BSDF elements. It will also lead to the elaboration of a tool that will be a convenient way for end users to select the appropriate solar shading for a building.

7. ACKNOWLEDGMENTS

This work is achieved under the frame of the 'Prosolis Project' supported by the Walloon Government.

8. REFERENCES

ANDERSEN M. Bi-directional transmission properties of Venitian blinds: experimental assessment compared to raytracing calculation, *Solar energy* 78(2005), p 187-198

JONSSON J. Light-scattering properties of a woven shade-screen material used for daylighting and solar heat-gain control, SPIE 2008 San Diego Proceedings, 11 pages

LEE E., 2009, Simulating Complex Fenestration Systems: *An Overview of R&D Activities, Radiance Workshop 2009*, 22 pages

NILSSON A. 2010, Light scattering properties of a venetian blind slat used for daylight applications, *Solar energy* 84(2010), p 2103-2111

SAELENS D., PARYS W., ROOFTHHOFT J., TABLADA DE LA TORRE A. Assessment of Modeling for Louver Shading Devices in Office Buildings – *Proceedings CISBAT 2011*, Lausanne

SAXENA M., WARD G., PERRY T., HESCHONG L. and HIGA R. 2010, Dynamic Radiance - Predicting annual daylighting with variable fenestration optics using BSDF, *Simbuild 2010*, 8 pages

TZEMPELIKOS A. 2008, The impact of venitian blind geometry and tilt angle on view, direct light transmission and interior illuminance, *Solar energy* 82 (2008), 19 pages

WIENOLD J., FRONTINI F., HERKEL S.,MENDE S. 2011, Climate based simulation of different shading device systems for comfort and energy demand, *Building Simulation 2011*, 8 pages