OUTDOOR MEASUREMENTS OF G-VALUES FOR EXTERNAL, INTERPANE AND INTERNAL SUNSHADES

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ABSTRACT

Solar shading devices can significantly improve thermal comfort and reduce cooling loads and potential glare problems in highly glazed buildings. This paper describes results from an extensive measurement program that started in 1997, covering external shading devices, products placed between two panes (interpane), and internal shading devices. Measurements of the total solar energy transmittance (g-value) have been performed using a double hot-box arrangement placed in a real climate. One box was equipped with the solar shading device, while the box with a bare window was used as a reference. Thus, the g-value of each product (g-sunshade) has been estimated as g-system/g-window.

In general, external shading devices have a larger potential to reduce cooling loads since the absorbed solar heat is mostly dissipated to the outdoor air. Interpane products have a slightly higher g-value and internal products show the highest g-values. This is demonstrated within the project, although the variation among each group is large. The average g-value within each group (g-sunshade) was 0.3 for external products, 0.5 for interpane products and 0.6 for internal products. Thus, on average, external products are twice as good as internal products in reducing peak cooling loads.

KEYWORDS

solar shading, shading device, g-value, solar energy transmittance, measurements

INTRODUCTION

Commercial buildings with large glazed surfaces may easily suffer from overheating problems or large peak cooling loads. Solar shading devices can significantly reduce these cooling loads, improve thermal comfort and also reduce potential glare problems (Dubois, 2001). Due to lack of relevant data as to how well sunshades protect buildings against unwanted insolation, the solar shading project was initiated in 1997 at Lund University, Lund, Sweden. One aim of the project has been to measure the solar transmission properties of a large selection of solar shading available on today's market, in order to provide comparable g-values measured under similar conditions. The measurements have been divided into three groups: external shading devices, devices between panes (interpane), and internal shading devices. Phase 1 of the Solar Shading Project included measurements on exterior shading devices only, and was completed in 1999. A full report of Phase one activities is found in (Wall & Bülow-Hübe, 2001). Phase 2 is ongoing and includes both interpane as well as interior devices. This article summarizes Phase 1 and Phase 2 field measurement results performed so far.

METHOD

The measurements were performed in two well insulated boxes, placed in a room at about 20°C. The boxes had a double glazed unit (1.17 m × 1.17 m) which was in contact with the sun and the outdoor climate through a hole in the south wall of the building, see Fig. 1. A sealed insulated glass unit (4 mm – 12 mm – 4 mm, clear float) was used for external and internal shading products. For interpane products a double-glazed unit was used (4 mm – 30 mm – 4 mm, clear float), which corresponds to a coupled window, typical of older Swedish buildings. The boxes were placed in Lund at 55.7°N.

Figure 1: Twin-boxes equipped with italian awnings (left), and external venetian blinds (right).

A solar absorber (Sunstrip fins) was placed behind the window. The air between the absorber and the window, as well as the water in the pipes of the absorber, was temperature controlled with cooling and electrical heating. The air was held at around 20°C, approximately the same as for the room where the boxes were located, and was blown along the absorber to the reduce the heat resistance between the air and the absorber. For the total solar energy transmittance, the temperature difference between the box and the outdoor air, multiplied by the window U-value (from night measurements), was used. The heat balance for the box is:

$$Q_{sun} = Q_{cool} - Q_{el.heat} + Q_{window} + Q_{room} + Q_{capacity} \qquad \text{(Eqn. 1)}$$

where Q_{sun} is the totally transmitted solar energy, Q_{cool} and $Q_{el.heat}$ are the measured cooling and heating energies, Q_{window} is the measured and calculated heat losses through the window, Q_{room} is the measured and calculated heat losses from the box to the room, and finally $Q_{capacity}$ is a correction term for the heat capacity of the box, when the box temperature has changed during the measurement period.

During the night Q_{sun} is zero. This is used to calibrate the boxes. Equation 1 is used to calculate Q_{sun}, the total solar energy transmitted through sunshade and window. The total solar transmittance of this system is denoted g_{system}, which is calculated by dividing Q_{sun} by the product of global solar radiation on the window, I_G, and the area of the window, A_w:

$$g_{system} = \frac{Q_{sun}}{I_G A_w} \qquad \text{(Eqn. 2)}$$

The solar energy transmittance for a certain sunshade can be calculated in different ways. The simplest way is to assume that the total transmittance is the product of the transmittance for the different parts of the system, and thus solving the g-value of the sunshade as:

$$g_{sunshade} = \frac{g_{system}}{g_{window}} \approx \text{“shading coefficient”} \qquad \text{(Eqn. 3)}$$

As the window is double glazed, $g_{sunshade}$ is the same as the shading coefficient which is sometimes used in connection with sunshades.

It is somewhat inappropriate to use the term “transmittance of sunshade” for $g_{sunshade}$ because reflections between sunshade and outer pane and reflections between the facade and sunshade are included in this value. The value of $g_{sunshade}$ will thus depend on the properties of the glass and the facade. However, this way of calculating $g_{sunshade}$ removes the effects of geometric factors which are the same for measurements with and without sunshades: window embrasure, fixings, etc. For these reasons $g_{sunshade}$ is a value of practical utility which is presumably adequate in most cases except where an outer pane of high or low reflecting properties is used in combination with a facade that is very different from that used in the measurements.

The transmittance of the window, g_{window}, can be either measured or calculated. It is easiest to use one box to measure the transmittance of the sunshade and the other to measure the transmittance of only the window. This is particularly advantageous when there is cloud or haze which makes the solar radiation vary at random. All the results set out below are based on 5 minute means which have been smoothed with a moving average over 50 minutes. In all cases, the global solar radiation on the facade was greater than 100 W/m^2.

The values reported below all apply to the hour with the highest solar altitude, i.e. at 12 o’clock standard time. The estimated maximum measuring error was ± 5% of the calculated transmittance, but was not less than ± 1%. However, the measurements have been performed throughout the year, and the effect of varying solar altitudes have not been corrected for.

External shading devices

Measurements reported here relate to: Two awnings, two italian awnings, two external venetian blinds, three screen fabrics, one horizontal slatted baffle, and a number of solar control films. The two awnings (and the italian awnings respectively) were of the same type and geometry, but one had a light coloured fabric (off-white) and the other a dark blue fabric. The awnings were tested in two positions, fully and partially extended. The external venetian blinds were silver coloured with slats 50 and 80 mm wide respectively. Both blinds were tested fully lowered with the slats in two positions: horizontal and with slats at 45° to the window.

Interpane shading devices

The shading devices mounted between two clear panes were: venetian blinds (25 mm metal slats), two pleated curtains, two roller blinds (Texienne) and one screen fabric. Three different blind colours (blue, white and metal) and also several slat angles were studied. The two roller curtains tested were both of a light colour.

Internal shading devices

The internal shading device were mounted close to the inner side of the window. The products tested were venetian blinds, pleated curtains, roller blinds (both fabrics and solar control films), one screen fabric and several solar control films applied directly on the inner pane. Several of the internal shading devices were identical to those measured between panes. The reflectance and transmittance of the fabrics and films were also measured with a spectrophotometer at Uppsala University.

RESULTS

Figure 2 summarizes the results of the g-value measurements for the three product groups external, interpane and internal shading devices. Although a large variation within each group is evident, external products generally have lower g-values than interpane and internal products. The regression line indicates that the average g-value ($g_{sunshade}$) is 0.29 for external, 0.48 for interpane and 0.63 for internal shading devices. More details of the measurements and results in tabular form can be found on the solar shading project home page: http://www.byggark.lth.se/shade/results.htm.

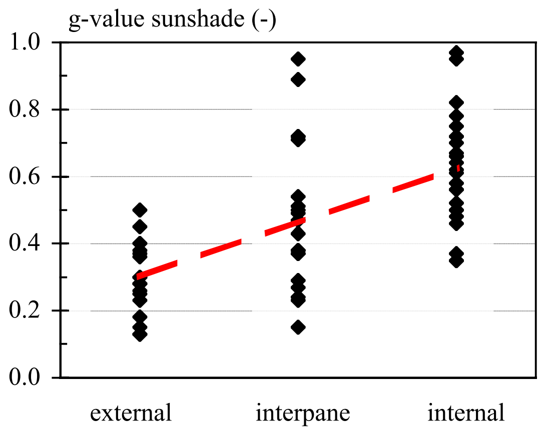

Figure 2: Summary of all measurements of $g_{sunshade}$ for external, interpane and internal shading devices respectively.

Since some of the products are applicable as both interpane and internal devices, ten of them were measured in both positions, see Fig. 3. For these products, $g_{sunshade}$ is on average 0.23 units lower for interpane than for internal placement.

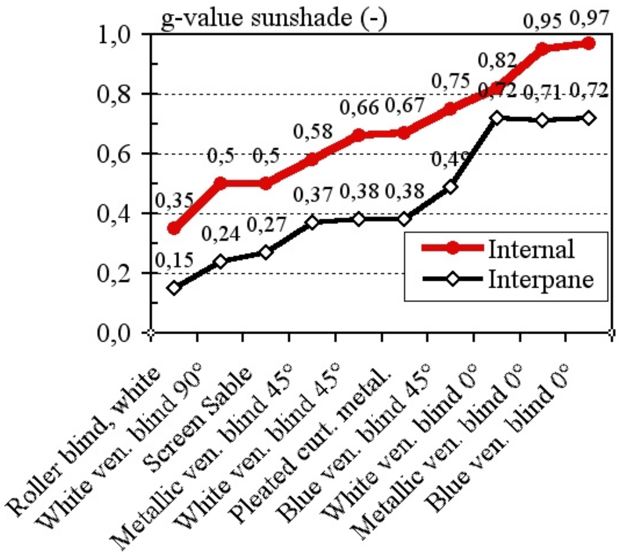

Figure 3: Effect of position of shading device on $g_{sunshade}$ for some interpane and internal products with various colours and slat angles.

The effect of slat angle and colour on $g_{sunshade}$ for venetian blinds is shown in Figure 4a, b. Both figures show a strong dependence of the slat angle, while the effect of the colour is much smaller. The difference seen between colours at equal slat angles may also be due to slightly varying solar altitudes, since the measurements were performed during several months.

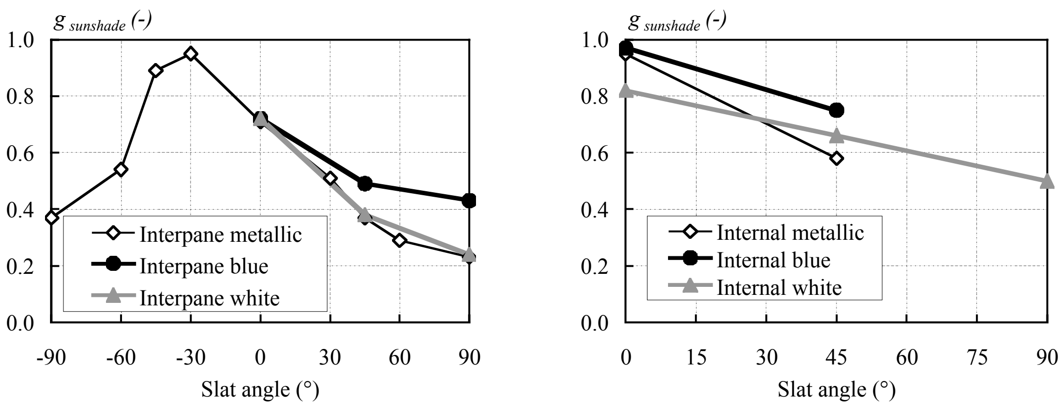

Figure 4a, b: Effect of slat angle on $g_{sunshade}$ for venetian blinds mounted between panes (a, left) and internally mounted (b, right). Zero degrees is equal to horizontal lamellas, 90° is fully closed, and a negative angle means that the outer part of the lamellas are turned upwards.

In order to obtain a low $g_{sunshade}$ for internal solar shading devices, it is important that the fabric used has a light colour, i.e. a high solar reflectance, R_{sol}. This is demonstrated for six roller blind fabrics in Fig. 5. However, it must be kept in mind that the two products with the lowest g-values also have a very low visual transmittance, T_{vis}, on the order of 3-4 percent, thus providing very little daylight to the room behind. The product yielding the highest $g_{sunshade}$ (a dark blue roller curtain) also provides very little daylight to the room (T_{vis} < 1 %). Here, the high g-value is a result of a high solar absorptance (about 80 %). The product which provided the most daylight was a white roller curtain (T_{vis} = 38 %), and its $g_{sunshade}$ was 0.56.

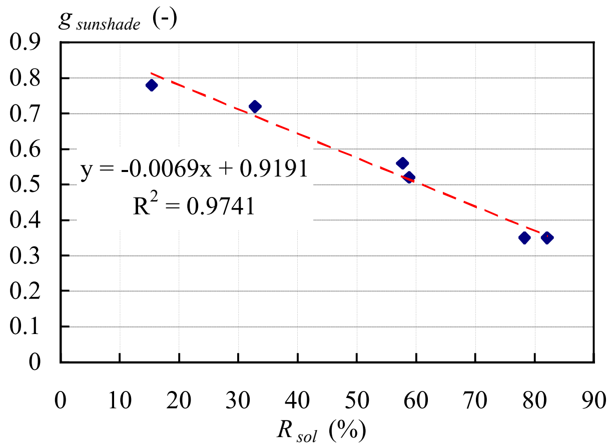

Figure 5: Relationship between $g_{sunshade}$ and solar reflectance, R_{sol}, of some internally mounted roller curtains.

CONCLUSIONS AND DISCUSSION

Naturally, external sunshades have a much greater potential to reduce cooling loads and unwanted solar gains, since the absorbed heat is mostly dissipated to the outdoor air. For internal products it is essential to try to reflect the short wave solar radiation, since the heat absorbed in the sunshade contributes to room overheating. This is quite elementary physics, and these results are also confirmed by the measurements presented in this article. However, depending on colour, slat angle position etc, there is a large variation of measured g-values within each product group of external, interpane and internal sunshades. For internal shading devices it is demonstrated that the reflectance of the fabric is the most important parameter in obtaining low g-values. This is contrary to external shading devices were we have previously shown that for example dark awnings (with low reflectance and high absorptance) provide lower g-values than light ones (Wall & Bülow-Hübe, 2001). In selecting shading products one should also pay attention to the transmitted daylight and effect on the view out. The internal products yielding low g-values provide almost no daylight into the room, and totally obstruct the view out, two of the main points of having a window.

ACKNOWLEDGEMENTS

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