Asymmetrical awnings – a way to increase daylight in buildings without increasing the overheating.

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Abstract

Different shapes of asymmetric awnings for east and west windows are investigated mathematically as well as by measurement in a model. A box with 90 cm side and a 30x30 cm window was placed outdoor in overcast weather and the daylight factor was measured at the bottom of the box when the window was unshaded or equipped with different awnings. The average daylight factor in the box decreased from 4.6% for the unshaded window to 1.0% when a full awning was used. With "the best" asymmetrical awning, the average daylight factor was 80% larger than with the full awing. Using Dutch climate, calculation of the energy from direct radiation transmitted through the window during the cooling season showed that this was decreased from 100% as an annual mean for the unshaded window down 22% with a full awing. With "the best" asymmetrical awning, 26% of the energy was transmitted. Calculation of the indoor temperature in a hypothetical row house in Netherlands show that the use of either normal or asymmetrical awnings considerable decrease the indoor temperature during the hot season. Therefore the use of asymmetrical awnings for east or west faced windows considerable can increase the daylight in buildings, with almost no change in overheating, compared to if traditional awnings are used.

Keywords: Awnings, daylight, overheating, window

Introduction

Shading devices are often used to reduce overheating of buildings by preventing direct radiation to enter the room. However, at the same time the irradiation entering the room is reduced, the daylight in the room is reduced, eventually to such low levels that the electric light has to be turned on. A good shading for preventing overheating can therefore be a device which prevent the direct radiation to enter the room, but letting as large part of the diffuse radiation as possible to enter, since this can increase the daylight in the room without increasing the energy contribution from direct solar radiation.

Awnings are most often squared, both by technical reasons and since this will prevent direct radiation to enter the window from all directions, see figure 1. For a south faced window this means that the awing prevent direct radiation to enter the window both before and after noon. However, for windows directed to east and west, the square awing is not necessary optimal due to the solar motion with very little direct radiation entering from the north direction (solar azimuths $|\gamma_s| > 90°$). This can be seen in figure 1, showing an east directed window with the sun coming from south-east. Since the direct radiation is incident from the side, a large part of the shadow from the awing hit the wall and not the window. An asymmetric awing may therefore be suitable for these windows since this can increase the diffuse radiation transmitted through the window, but still preventing direct radiation entering the room.

Method

For calculating the daylight factor, a cubic model with 90 cm side was built. The cube had one window (without glass) with the size 30*30cm in the middle of one side and all interior surfaces was painted white (figure 2). The illumination in the box was measured with a horizontal luxmeter at the bottom at 32 measurement points. At the same time, the outdoor horizontal illumination was measured on top of the box. All measurements were performed outdoors during days between April 30 and May 17 with overcast weather and an average horizontal illuminance between 22600 – 33300 lux. The measurements were performed on a place with only marginal obstructions from surrounding buildings or trees. The construction of the model and the measurements are further described in [1].

Figure 1. Awning on an east window with the sun from south-east.

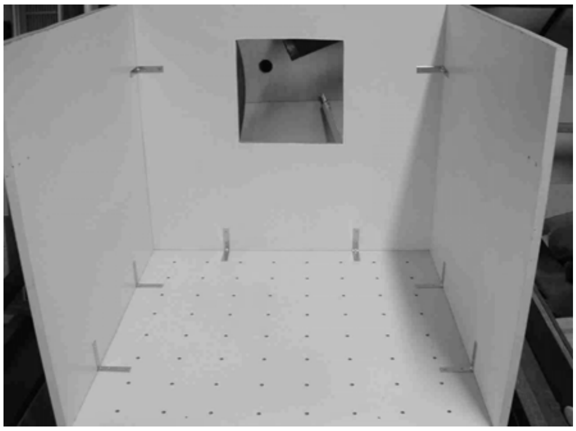


Figure 2. Picture of the scale model before the roof and back side was mounted. The window hole is seen from inside.

The daylight factor (DF) at the bottom of the box was calculated according to

$$DF = \frac{E_i}{E_o} \times 100\%, \tag{1}$$

where E_i is the illuminance on a certain point at the bottom of the box and E_o is the outdoor illuminance on top of the box. The daylight factor was first measured for a box without any shading device for the window. Measurements were also performed with the window equipped with square awnings as well as asymmetrical awnings. There was no glass on the window, thus the measured daylight factors are larger than it would be in real applications. However, the relative difference between the measurements with different awnings should be the same.

For calculation of the cooling period when awnings are needed to prevent overheating, a fictive house in the Netherlands, latitude 52N, was defined. This house had a total UA-value of 344 W/K of which 150 W/K is due to ventilation (one air change/hour). The house was a row-house with approx. 10 m^2 double-glazed windows each to the west and east and a small window to the south. The indoor temperature T_i was estimated by

$$T_i = T_a + \frac{g}{(UA)}, \tag{2}$$

where T_a is the ambient temperature and g is the internal heat generation, calculated as 586W + solar irradiation through the windows. For calculating the energy through the windows, a G-value of 0.77 was used together with an incidence angle modifier coefficient $b_0 = 0.17$. For the calculations, daily climatic data from 2003 was used [2]. It was found that the period with possible overheating (> 25°C indoor temperature) was between April 15 and September 21. Therefore the awnings were designed for shading the windows between March 21 and September 21.

Construction of asymmetric awnings for east and west windows

Windows with four different awnings were studied, together with an unshaded window as reference. The geometry of the awnings is illustrated in table 1 together with geometrical data. The pictures in the table illustrate awnings suitable for east windows, thus the south direction are to the left in the pictures. For west faced windows, the pictures should be reversed. The area of the window is 1*1 length unit (lu). The drawings of the awnings are as they are seen from the front side of the window, as illustrated by figure 3.

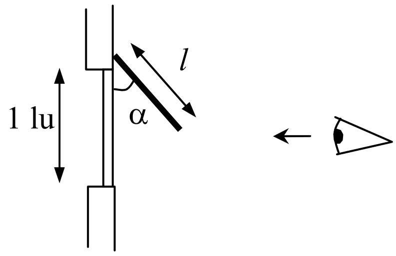
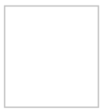
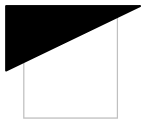
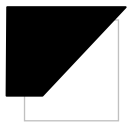
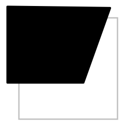


Figure 3. Viewpoint to the awnings illustrated in table 1.

Table 1. Geometry of awnings used for experiment and calculations. The three asymmetrical awnings are for east faced windows. An unshaded window is used as reference.

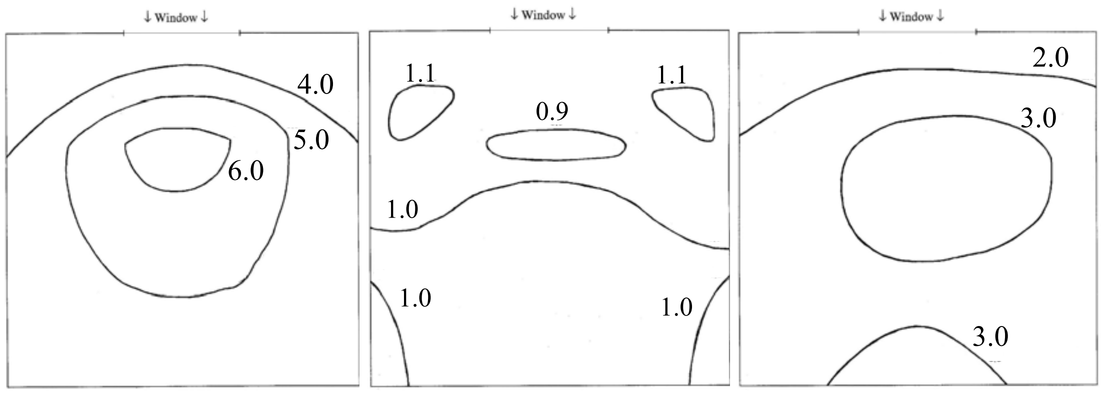
Type	No awning	Full awning	Half awning	Part 1 awning	Part 2 awning
Shape, as seen perpendicular to the window					
Window size	1*1	1*1	1*1	1*1	1*1
Distance awing - window upper edge		0.1	0.1	0.1	0.1
Tilt α degrees	-	40	40	40	40
Awing length l	-	0.8	0.8	1.1	1.0
Awing width (upper/lower part	-	1.4	1.4	1.2/0.37	1.1/0.68

The *full awning* dimensions are derived as representative from photos taken on different awnings in the city of Borlänge, Sweden. The *half awning* is the full awning cut through the diagonal of the awning. The part 1 and part 2 awnings are designed to have maximal shading during the hour when the irradiation on the window is highest.

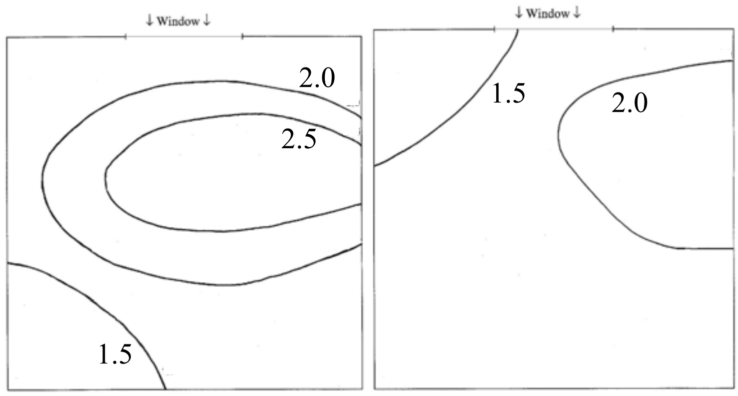
For September 21, calculations show that the highest irradiation onto the window during a clear day at latitude 52 is at 08.00 AM. Thus the shadow from right (inclined) edge of the *Part 1 awning* will hit the right edge of the window at 08.00 September 21. To compensate the reduced awning size compared to a full awning, the part 1 awning is made a bit longer. In the same way the shadow from right edge of the *Part 2 awning* will hit the right edge of the window at 07.00 June 21, which is the time the irradiation onto the window is largest.

Results of measurements

The results from the daylight measurements in the box model are shown in figure 4 showing contour maps of the DF at the bottom of the box. The average daylight factors (ADF), calculated as the mean value of the 32 measurements, are also shown in the figure. It is seen that the ADF is decreasing from 4.6 for an unshaded window to 1.0 when a full awning are used. The ADF for the measurements with asymmetrical awnings are between 1.8 and 2.8, thus increasing the daylight in the box with 80 – 180% compared to a full awning, while they still work as protection devices for direct radiation.



No shading, ADF = 4.6 Full awning, ADF=1.0 Half awning, ADF=2.8



Part 1 awning, ADF =2.1 Part 2 awning ADF = 1.8

Figure 4. Contour maps of the daylight factor at the bottom of the box, using different geometries of the awning (see table 1). A window without awning is shown as reference.

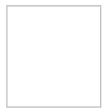
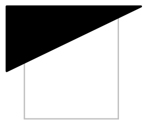
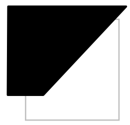
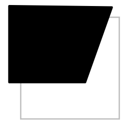
Incident energy

The energy incident through windows with different shapes of the awning was calculated for four days, June 21, July 21, August 21 and September 21. For each hour of these days, the shape of the shadow from the awnings on the wall and window was calculated. Then the unshaded area of the window for each hour of the representative days was calculated, assuming the window facing east. The direct irradiation on a typical clear day was calculated by using formulas from [3]. The calculation of the unshaded window area and the direct irradiation, combined with window data (G-value and incidence angle modifier) was then used to calculate the amount of energy transmitted through the window.

The result is seen in table 2. It is seen that the full awning reduces the amount of direct radiation through the window between 72-83% compared to an unshaded window, depending on the day for the calculation. As a mean, the reduction is 78%. The part 2 awning reduces the direct radiation almost as good, between 71 – 79% with a mean value of 74%. The part 1 awning and half awning has poorer performance with lower reduction of the direct radiation transmitted through the window.

In order to estimate the overheating when asymmetric awnings are used on east and west faced windows, the indoor temperature in the house described earlier was performed, using eq. 1. Daily climatic data from [2] was used together with PVSYST [4] to calculate how much direct radiation that was incident on each wall of the house. Assuming Part 2 awnings over the windows on the east and west facades together with the data in table 2, it was possible to calculate the amount of energy transmitted into the house during one day. This value was divided by 24 to give the hourly mean value during this particular day and then added to g in eq. 1 when calculating the mean indoor temperature. When data from table 2 was used, it was assumed that the percentage of the direct radiation that was transmitted through the window during one day was representative for the whole month. Due to symmetry, the values for July-September were also used for March-May. The same calculations were performed assuming full awnings for all windows and no awnings respectively.

Table 2. Percent of direct radiation through an east faced window during a day with clear weather.

Type	No awning	Full awning	Half awning	Part 1 awning	Part 2 awning
Date					
21-jun	100%	17%	58%	39%	25%
21-jul	100%	19%	57%	37%	24%
21-aug	100%	28%	72%	42%	29%
22-sep	100%	28%	61%	30%	25%
Mean value	100%	22%	61%	38%	26%

The result, seen in figure 5, show that using part 2 awnings over the windows will give almost the same indoor temperature as when using Full (or “normal”) awnings. There are still days when the mean indoor temperature is > 25°C, but this is independent on which type of awnings that are used. There are considerable more days with high indoor temperature, in the same time the indoor temperature gets considerable larger when the windows are unshaded compared to when awnings are used.

In the calculations, the simplification was made that the values in table 2 was valid for the total irradiation on the wall, including diffuse radiation, although table 2 was calculated out from direct radiation. This will overestimate the effect of the awnings since the transmitted diffuse radiation is omitted. However, the interesting days are when it is clear weather with strong direct radiation which can cause overheating, and during these days the amount of diffuse radiation most often are small, so the error should be small.

Discussion

The indoor temperature calculations contain certain simplifications, as assuming a house without thermal mass, and a constant solar contribution over the day. In more detailed calculation the maximum indoor temperature may be considerable larger during days with strong insulation, in the same time a large thermal mass of the house can reduce the temperature swing between days with changing weather. Furthermore, forced ventilation, like opened windows during hot days, has not been taken into account.

Treating all irradiation as direct give an error in the calculations, especially for days with overcast weather. However, the calculations of the indoor temperature in figure 5 should be seen as illustrative, showing the difference between using awnings above the window or not. It is clearly seen that using a part 2 awnings gives almost the same reduction of the overheating as using the full awning. The presented calculations also show that a part 2 awning can increase the daylight factor in rooms with east- or west faced windows with almost a doubling of the daylight performance in the rooms. The experiment and calculations therefore show that it is possible to significant increase the daylight with asymmetrical awnings, with only insignificantly increase of direct radiation through the window.

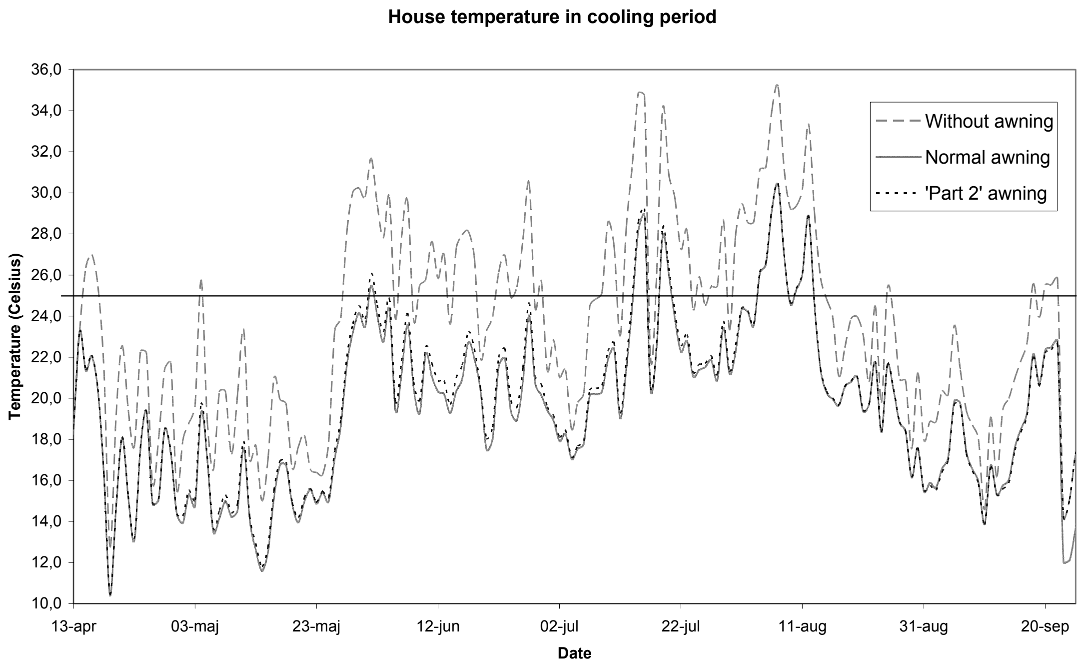


Fig. 5. Mean indoor temperature with no awnings, normal awnings and part 2 awnings.

In [1] is also presented calculations for awnings or overhangs for south-faced windows, which can have a slightly rounded shape instead of the traditional square shape for increasing the daylight into the room and still work properly. The difference in daylight factor between the two is however small, and therefore the use of rounded awnings for south faced windows are probably not of interest in practical applications.

In future work, more detailed simulations should be done, taking more detailed internal heat gains and thermal mass of the house in account. It is probably possible to improve the shape of the asymmetrical awnings further. It would be of special interest to study awnings for office buildings, which often have a large cooling need due to large internal heat gains. If the daylight factor can be increased in such buildings without increasing the direct irradiation, it is possible to use less artificial light and still have good light conditions. Since clear sky radiation have a high efficacy (typical 150 lm/W) compared to artificial light (typical 50-80 lm/W for fluorescent lamps and considerable less for light bulbs), the use of asymmetric awnings may further reduce the overheating compared to when normal awnings are used.

References

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