SHADING DEVICE CONTROL: EFFECTIVE IMPACT ON DAYLIGHT CONTRIBUTION

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ABSTRACT

This paper presents the results of a project funded by the Swiss Federal Office for Energy that focused on the effective use of movable shading devices in offices, and on the impact on the indoor daylighting availability.

The first part of the project consisted in the observation of the use of sunscreens when the command is not automated (office buildings, operating webcams from 01-02-2013 to 31-01-2014 over 125 openings, e.g. more than 500,000 individual blind positions analysed). The key finding is that sunscreens are adjusted infrequently (less than 2 movements blinds / week) regardless of the orientation or season. The consequence of this misuse is that the contribution of natural light is far from being optimised.

The second part of the project focused on the simulation of the actual contribution of daylight in each of the observed rooms (Simulations DIAL + / Radiance). This allowed us to compare the results with those that would have been achieved with automated blinds. The results of these simulations were then used to estimate the electricity consumption for lighting. This study shows that the energy savings associated with automated blinds can reach several kWh/m^2 per room and per year. Comparison with SIA 380/4 calculations points out that the actual version of the Swiss Standard underestimates the potential related to blinds automation and also tends to overestimate the effects of artificial lighting automated control.

The main conclusion of this study is that the implementation of automatic blinds can significantly increase the number of hours during which artificial lighting is not required while preserving the visual comfort and freedom of choice for users. The other conclusion is that the Swiss Standard should encourage the use of daylight by imposing specific targets on this topic.

Keywords: Movable blinds, Manual-use, Web-cams, Daylighting, Automation.

INTRODUCTION

Solar shading constitutes a major element in the energy performance of a building, both for the thermal balance and for lighting. The users are not always aware of this and move the shading for all kinds of reasons, except energy saving. This study quantifies how users handle manually operated shading devices and shows how this behaviour can affect electricity use for lighting when compared to automated operation of the shading devices.

This study is an observation of the solar shading devices (external venetian blinds) of three (3) office buildings in the EPFL Innovation Park area near Lausanne, Switzerland. The objective was to characterise the use of the blinds when these are not automated and its consequences on the level of natural light in the buildings. The purpose was also to make recommendations for a review of Swiss Standard 380/4 regarding lighting. The complete reports of this study is available on our website [1].

Figure 1: Photo of the west façade of building PSE-C on February 5, 2013, overcast sky

Figure 1 shows that there is no correlation between the position of the blinds (down or up) and the weather conditions. This building has 58 groups of blinds; only 11 windows show blinds in the 'up' position (red), while the sky is overcast and there is no risk of glare. The blinds are almost completely down on 7 windows (blue), preventing the harvesting of natural light. Behind 15 windows, the electric lights are on while the blinds are partially or completely down (yellow), in the middle of the afternoon of a day in February. In other offices, the lights are not switched on even when the blinds are down.

METHODOLOGY

The blinds were tracked over a period of one year and are situated on four levels, from the second to the fifth floor. The three buildings are occupied by start-ups of the EPFL (Swiss Federal Institute for Technology, Lausanne). Each building was observed with a webcam. The position of the blinds was recorded and saved every hour by full HD webcams, Model D-Link DCS2210. The images were subjected to visual analysis to determine at each time the position of the blinds.

Every hour, the covered area of the windows was recorded, in steps of 25%. The tilting angle of the blinds' slats was classified in one of the three following categories: vertical (closed), 45° tilted and horizontal). The testing period ran from February 1, 2013 till January 31, 2014. A blind going 'up' or 'down' is recorded as a 'movement'. A change of slat angle in a given blind position also represents a 'movement'. However, when the slat angle is changed during an 'up' or 'down' action, this is not considered a separate 'movement'.

RESULTS AND DISCUSSION

Movements recorded

Table 1 shows the total number of movements during the 365-day period of observation. The grey areas indicate the number of movements per window (total number of movements divided by the number of windows per façade). As the recording took place every hour, it is possible that some movements may not have been detected. However, it is highly improbable that a user will change the position of a blind twice in one hour, with the blind in exactly the same position the second time. We may therefore consider that the results are relevant.

Orientation (nb of window per facade)	East facade (28)		South facade(40)		West facade (58)	
	Movement per year	Movements per window	Movement per year	Movements per window	Movement per year	Movements per window
Movements "Up"	990	36.7	115	27.9	1189	20.5
Movements "Down"	1062	39.3	1126	30.7	1421	24.5
Slat angle change	365	13.5	697	17.4	3505	60.4
Total nb. of movements	2417	89.5	3038	76	6115	105.4
Average nb. of movements per week	48.5	1.72	58.4	1.46	117.6	2.03
Weighted average per week	1.74					

Table 1: Summary of blind movements during office hours on three façades – grey areas indicate movements per window.

Percentage of window covered

Apart from observing the 'up' and 'down' movements of the blinds, we have also looked at the degree of coverage of the glazed surface (Table 2). On the south façade, an average of 74% of the surface was covered by the blinds. On the west orientation, the percentage was 56%, while the east façade had the lowest percentage (35%) resulting in a weighted average of 57% for all the façades together, leaving 43% of the glazed surface uncovered. To the extent that we know that the top of the windows is also the most effective to bring light to the back of the room, we can predict that the manual management of blinds leads to a very poor use of natural light. It should be emphasized that the analysis period was characterized by a negative sunshine record between January and May [2], which may partly explain the difference between winter and summer for façade East.

Facade	Winter	Summer	Year
East (motorized)	22%	48%	35%
South (manual)	69%	78%	74%
West Manual	58%	55%	56%
Weighted average	53%	60%	57%

Table 2: Percentage of window covered as a function of the façade orientation and the season

Contribution to natural daylight in the offices

To evaluate how much natural daylight is brought into the offices, we conducted simulations, hour by hour during the complete test year, to calculate the daylight availability in each of the rooms, taking into account the blind position and the climatic conditions (from MétéoSuisse station in Pully). The simulations were made with an advanced release of the DIAL+Lighting software [3], based on the calculation engine RADIANCE [4], and targeted 5 points at 0.75m from the floor. To keep the simulation time within limits, the geometry of the slats has been simplified (flat slats with a diffuse reflectance coefficient of 0.30). The results may therefore be somewhat underestimated but the comparison between scenarios remains valid.

For a given room, the way the blinds are used is unpredictable and therefore the effective gain in natural light varies considerably. Figure 2 shows the annual diffuse daylight autonomy values [5] (percentage of time during which the indoor illuminance due to the diffuse component exceeds 500 lux) for west oriented rooms. The range is between 2% and 81% for point 1, close to the window, between 2% and 34% in the centre of the room (point 3) and between 0% and 7% in point 5, furthest from the window.

The great differences between users, indicates that some of them are very ‘tolerant’, often leaving the blinds in the ‘up’ position, others are more ‘protective’, closing the blinds most of the time.

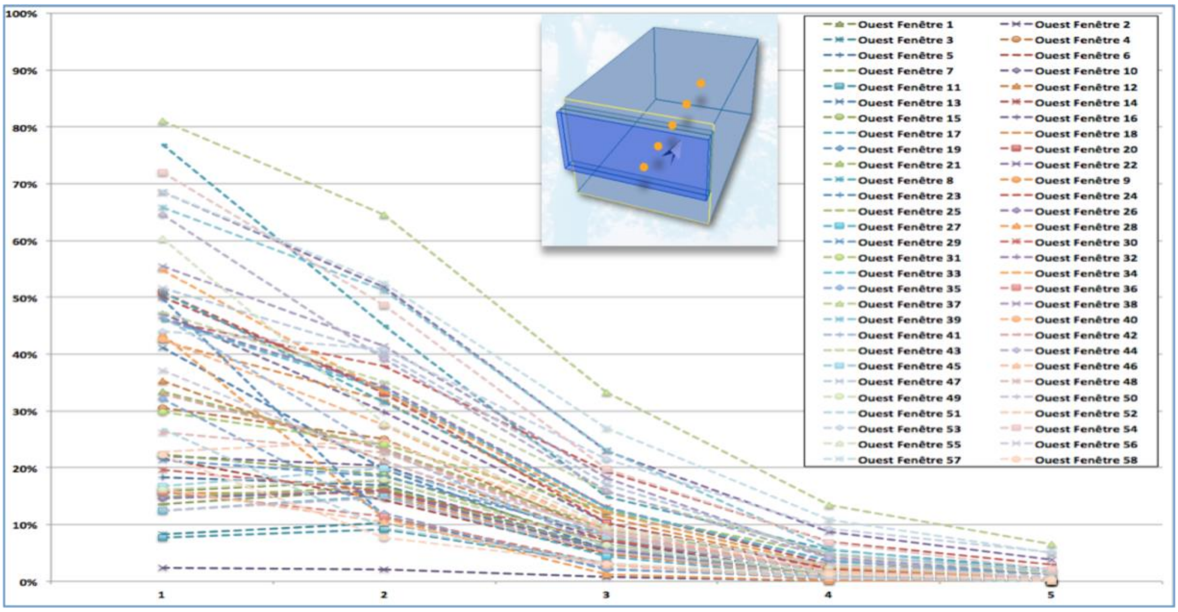

Figure 2: Percentage of the time (7AM- 6PM), during which daylight contribution ≥ 500 lux on the 5 reference points, for each of the 58 west oriented rooms. Each line corresponds to a room. Point 1 (left), is located close to the window and point 5 (right) at the back of the room.

Scenario for automating the blinds

The second part of the study deals with the comparison of the results if the blinds had been fully automated. It should be emphasised that the study did not focus on the thermal aspects but only on the lighting issues. With the DIAL+Lighting software [3], a second run of simulations was done, for every façade, hour by hour during one year, with an “Continuous” automation systems. In this scenario the blinds are lowered each time the incident solar radiation reaches 200 W/m² during the hourly measurements. In summertime, the blinds are lowered to cover 75% of the window area, in wintertime 100%. The slat angle varies with the position of the sun, from 0° to 20° to 25° and 45°. When the sun is absent, the blinds are raised to benefit from diffuse lighting, but a buffer time of one hour is set so that the users are not interrupted by too many movements.

The daylight level of 500 Lux is then calculated and compared between, on the one hand, the ‘manual’ situation, where the users operate (or not) the blinds, and on the other hand the automated situation. For each orientation, the maximum, minimum and median ‘manual’ results are graphically represented and compared. *Figure 3* shows an example of results for west oriented façade. The full report [1] shows all the detailed results of the calculations and measurements in the five points of each room in each of the three façades.

- In the first two measuring points, closest to the window, the results obtained with automated blinds are as good as, or better than, the one obtained by the most “tolerant” users (Maxi). In the centre of the rooms, the autonomy drops slightly but remains better than the ‘median’ manual result. In the back of the room (point 5) the results are similar to the median values.
- Compared with a median user, the blind automation reduces by 20% the number of hours that the lights are switched on, for an illumination level of 500 Lux.

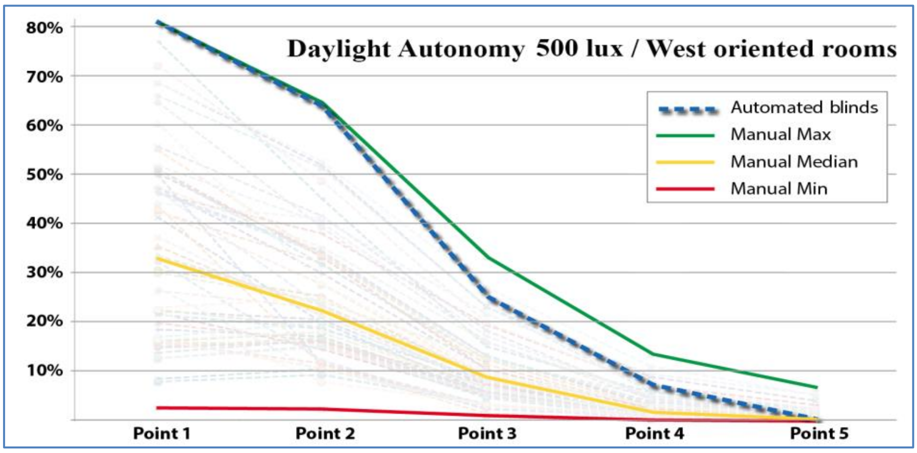

Figure 3: Daylight autonomy profiles for West oriented rooms (500 Lux required).
- Green line = Maximum observed (blinds almost always opened throughout the year).
- Orange line = Median values (50% of the users are above, 50% below).
- Red line = Minimum observed (blinds almost always closed throughout the year).
- Dark Blue dashed line = Daylight autonomy achieved with "Continuous" automated blinds.

Daylight Autonomy for 150 lux required

During this study we observed that, when electric lighting is not automated, users tend to turn on the lamps when the interior light level is usually less than 150 lux at the centre of the room. On the other hand, we know that very often, users also tend to forget to switch-off the lights, even if the daylight contribution exceeds 500 lux. To evaluate this "realistic" scenario, we have simulated the case when:

- Lights are turned ON when indoors illuminance ≤ 150 lux (centre of the room).
- Lights are switched-OFF when users leave the room (at 1 PM and 6 PM).

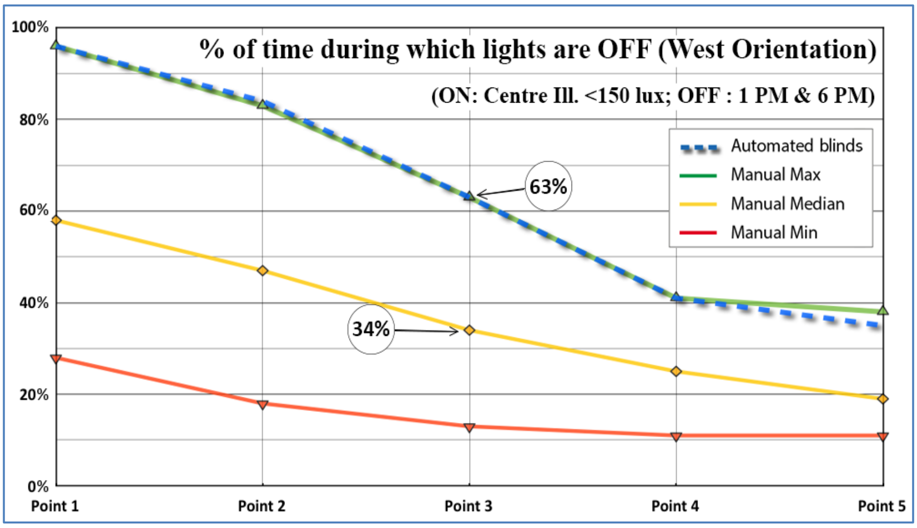

Figure 4: Percentage of time (7AM-6PM) during which lights are off. The conditions are as follow: - Lights turned-on if indoors illuminance ≤ 150 lux (centre of the room).
- Light turned-off at 1 PM & 6 PM.

Figure 4 shows that in this scenario, the percentage of time during which the lights are turned OFF is the same for "Automated blinds" and "Manual Maxi". It means that the time during which lights are turned ON is reduced to the minimum. Comparison with "Manual Median" shows that the time without electric lighting is almost divided by two (63% vs. 34%). This gives an idea of the high potential for lighting energy savings linked to the implementation of automated blinds in office buildings.

CONCLUSION

The observation during 12 consecutive months has resulted in a considerable collection of data. These data have so far been analysed and used for information on the lighting of the rooms and have allowed several conclusions on the real-life use of non-automated solar shading blinds.

The main conclusion is that people are very poor users of their shading devices. With less than two movements per window and per week on average, the daylight contribution to the indoor lighting is far from optimum. Furthermore, the average position of the blinds leads to a significant obstruction. With an average of 57% of the window surface covered by the blinds, the use of electric lighting is almost mandatory for the back part of the room.

Thus the implementation of automation system to control the blinds position is of high interest. This study has shown that such systems can achieve performance comparable to those observed in the case of very "tolerant" users. In Switzerland, where the implementation of Venetian blinds is widespread, the issue of automation is particularly important and this information should be disseminated among designers and building owners.

The question is: how to combine the best shading device with the best use of it. In our daily practice, we are often faced with this problem. Most of the time we propose to our clients to implement automated control systems based on 2 or 3 reset movements per day. With such systems, whose parameters have to be carefully tailored to the different localizations and orientations, it is possible to largely improve the operation of shading devices without causing rejection reaction by users. In this case, the position of the blinds should also consider the thermal aspects (optimization of winter solar gains and reduction of overheating risks in summer).

We sincerely believe that this approach leads to greatly optimize the behavior of buildings and thus contribute to the necessary reduction in energy consumption and associated CO_2 emissions.

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