Sustainability **2014**, *6*, 2786-2801; doi:10.3390/su6052786

OPEN ACCESS

sustainability

ISSN 2071-1050

www.mdpi.com/journal/sustainability

Article

Solar and Lighting Transmission through Complex Fenestration Systems of Office Buildings in a Warm and Dry Climate of Chile

Waldo Bustamante [1,3,*], Sergio Vera [2,3,†], Alejandro Prieto [1,†] and Claudio Vásquez [1,3,†]

[1] School of Architecture, Pontificia Universidad Católica de Chile, El Comendador 1916, Providencia, Santiago 7520245, Chile; E-Mails: alejandroprieto@uc.cl (A.P.); clvasque@uc.cl (C.V.)

[2] Department of Construction Engineering and Management, School of Engineering, Pontificia Universidad Católica de Chile, Vicuña Mackenna 4860, Macul, Santiago 7820436, Chile; E-Mail: svera@ing.puc.cl

[3] Center for Sustainable Urban Development (CEDEUS), Pontificia Universidad Católica de Chile, El Comendador 1916, Providencia, Santiago 7520245, Chile

† These authors contributed equally to this work.

* Author to whom correspondence should be addressed; E-Mail: wbustamante@uc.cl; Tel.: +56-2-2354-5579.

Received: 28 January 2014; in revised form: 28 April 2014 / Accepted: 28 April 2014 / Published: 13 May 2014

Abstract: Overheating, glare, and high-energy demand are recurrent problems in office buildings in Santiago, Chile (33°27'S; 70°42'W) during cooling periods. Santiago climate is warm and dry, with high solar radiation and temperature during most of the year. The objective of this paper is to evaluate the thermal and daylighting performance of office buildings transparent façades composed of three different complex fenestration systems (CFS). Each CFS contains a different external shading device (ESD): (1) external roller, (2) vertical undulated and perforated screens, and (3) tilted undulated and perforated screens. The study was carried out by *in situ* monitoring in three office buildings in Santiago, Chile. Buildings were selected from a database of 103 buildings, representing those constructed between 2005 and 2011 in the city. The monitoring consisted of measuring the short wave solar and daylighting transmission through fenestration systemsby means of pyranometers and luxometers, respectively. This paper shows measurements that were carried out during summer period. A good performance is observed in a building with the external roller system. This system—applied to a northwest façade—shows a regular and high solar and daylighting control of incoming solar radiation.

The other two ESD systems evidence a general good performance. However, some deficiencies at certain times of the day were detected, suggesting a non-appropriated design.

Keywords: external shading devices; short-wave solar transmission; daylighting transmission; office buildings

1. Introduction

The size and type of glazed areas of office building's envelope is a key variable to be considered during their preliminary architectural design stages. Façades transparency of this type of buildings directly impacts the occupant's thermal and visual comfort and has an intrinsic relationship with the heating, ventilation and air conditioning (HVAC) and lighting final energy consumption. Fenestration areas provide panoramic views to outdoor and transmission of solar radiation, allowing solar heat gains and daylighting to indoor spaces. Therefore, windows directly impact comfort, productivity, and health of the occupants [1–3]. At the same time, daylight can significantly reduce buildings electric energy consumption, due to reduction of using artificial lighting [1,4]. This also may decrease internal gains, which reduces the buildings cooling energy demand. High energy cooling demand and overheating have become recurrent problems in fully glazed façade office buildings during the last few years [5]. For example, studies show that 70% of the peak cooling loads of Galileo building in Frankfurt, Germany, are caused by the excessive solar heat gains transmitted through its fully glazed façade [6].

Cooling demand is significantly higher than heating demand in office buildings with fully glazed façade located in Central Chile. In fact, highly glazed buildings in Santiago and Valparaíso (33°S) show significant overheating and glare problems during summer and intermediate seasons of the year [7–9].

Similar results were obtained in a study made for a building located in Sweden, a country with a colder climate and less solar radiation than Santiago and Valparaíso. This study concluded that the energy performance of the analyzed building strongly depends on the size of the glazed surfaces of the building's envelope [10]. Thus, the impact of using a fully glazed façade in office buildings of Sweden must be carefully analyzed. Office building with 30% and 60% of envelope's glazed areas are highly more energy efficient than those with fully glazed facades. Highly transparent façades of office buildings in Sweden generate high cooling energy demand and glare problems in their interior spaces [10].

Glare problems in buildings have been extensively studied in different countries [11–14]. According to some studies, the window-to-wall ratio highly impact on the interior illuminance of office buildings, affecting their occupant's comfort [9,13]. High illuminance may suggest glare problems for occupants.

For achieving indoor visual comfort and high-energy performance in office buildings, particularly in cooling periods, a careful design process of the building's envelope must be done from its early design stages. The façade system could include an ESD, as an effective way for controlling solar heat gains, and, hence, overheating prevention and/or air conditioning energy savings during cooling periods of the year.

Given the direct relationship between thermal and lighting behavior of office buildings, and in order to achieve comfort with architectural criteria and design strategies that improve the energy performance of office buildings, several studies have been aimed to analyze them simultaneously by means of energy and lighting simulation tools [13,15–19].

Research on thermal [3,20,21] and visual [22–24] comfort in office buildings have been carried out in different countries. One of these studies [3] analyzed the effect of different kinds of interior blinds and curtains on occupants' comfort during winter days under different weather conditions. In this study, interior surfaces temperatures of glazing, shading devices, and floor were measured. In addition, a thermal comfort meter to register the operative temperature and an indoor climate analyzer for registering indoor environmental conditions were placed at 1.3 m from the façade at height of 1.1 m. Depending on the sky condition (clear or overcast sky) the use of the interior blinds and curtains may significantly contribute on improving comfort conditions in the measured zone. In fact, during clear-sky days, even with cold external temperatures, the interior glass surface may reach quite high temperature, causing discomfort to occupants in the measured zone, when no interior shading device was used. This study concluded that interior blinds and curtains can effectively minimize the incident solar radiation on the occupants, allowing a better thermal environment around them [3].

On the other hand, illuminance measurement and occupant behavior observation was performed in an office building in San Francisco, California. It was found that Northwest and Southeast external shading devices were not enough to prevent glare and the use of interior curtains was necessary [20].

Just a few of the mentioned studies consider an experimental protocol to simultaneously analyze the thermal and lighting energy performance of office spaces. In fact, with the aim of analyzing the thermal and lighting performance of a building located in Sheffield, England, luminance, illuminance, and temperature measurements were performed during different seasons. Overheating and glare were detected in working spaces [25]. However, this study lacks of measurements of transmitted solar radiation through the transparent sections of the façade, thus, overheating and glare problems cannot be correlated, quantitatively, to the magnitude of solar heat gains and daylighting transmission. In this city, average of sunshine hours during the month of January is 43.1 h and during July is 194.4 h [26].

Santiago presents a warm and dry climate, with high daily temperature variations, especially in summer and intermediate seasons. From October to March there are almost no precipitations, observing high levels of solar radiation and high temperatures. Average of sunshine hours during January is 325.7 h and during July are 118.2 h. During January (the hottest month), the mean maximum temperature is 29.7 °C and the mean minimum temperature is 13.0 °C. However, temperature can rise over 35 °C in some summer days. During the coldest month (July), the mean maximum temperature is 14.9 °C, and the mean minimum is 3.9 °C [27].

Different studies in office buildings of the city of Santiago de Chile have shown that there are severe problems of overheating and glare when highly transparent facades are used. In office buildings, when decreasing the window to wall ratio, these problems are significantly reduced. Facades with external shading devices highly decrease office building's cooling energy demand, positively impacting in the occupant's thermal and visual comfort [7,28]. Conclusions of these studies are based on daylighting and thermal performance simulations. No experimental studies exist in Chile regarding to thermal and daylighting performance of complex fenestration systems, which includes glazing and shading devices with complex geometries (such as perforated screens, blinds, and curtain rollers) with optical properties highly angular dependent [29]. These types of complex systems are difficult or impossible to be modeled in a simulation tool.

On the other hand, not many studies where SW (Short-Wave) solar radiation and daylighting transmission are simultaneously monitored in existing buildings have been found.

The objective of this paper is to simultaneously evaluate the thermal and daylighting performance of office buildings' complex fenestration systems containing three different external shading devices (ESD): (1) external curtain roller, (2) vertical undulated and perforated screen, and (3) tilted undulated and perforated screen.

To achieve this objective, a methodology to measure the solar radiation transmitted as solar heat gain and daylight, through a complex fenestration system, was designed. This methodology was implemented in three existing office buildings in Santiago of Chile (33°27'S; 70°42'W), which have incorporated the mentioned three different kinds of ESD.

2. Methodology

2.1. Definition of the Case Studies

A complete database of 102 office buildings built between 2005 and 2011 in different districts of the city of Santiago was generated. This database includes information about the building itself (*i.e.*, useful surface, number of stories, building's geometric compactness) and variables for the façade system characterization (*i.e.*, kind of system, type of glazing, existence of shading devices, and window-to-wall ratio). The information to generate this database was obtained from building permits of the different municipalities, where buildings have been built. In some cases, information was complemented by contributions of the respective designers.

Then, the buildings were characterized by means of a descriptive analysis of their formal variables and façade properties, prioritizing those cases that incorporate systems to control solar radiation (*i.e.*, selective glazing, shading devices) due to the objectives of the research. Finally, the results obtained from the descriptive analysis were considered for selecting the case studies to be analyzed in this paper. Additionally, the database accomplished a secondary objective of showing a panorama of the contemporary construction of office buildings in Santiago, Chile.

2.2. Measurements

This paper shows measurements in three case studies during summer days, in order to characterize the performance of the façade with different ESD systems for this periods of the year. Due to the extensive use of the office spaces, measurements were mainly registered during weekends. According to that, data collection lasted as long as three days, considering continuous measurements in 10-minute intervals.

The registered data correspond to measurements of solar radiation and illuminance.

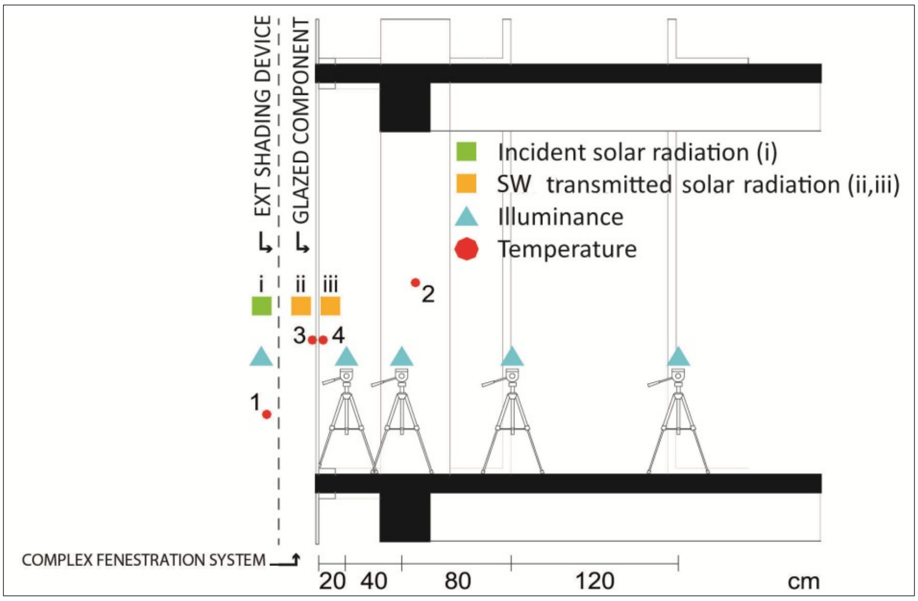
2.2.1. Measurements of Short-Wave (SW) Solar Radiation Transmission

Kipp & Zonen's SP Lite 2 pyranometers were used for measuring incident irradiance and transmitted short-wave (SW) solar radiation. These instruments were located in different parts of the façade, as shown in Figure 1. The incident solar radiation is registered in the vertical plane between

100 cm and 120 cm over the floor, in three points: Exterior (i), solar between the glazing and the ESD (ii), and interior (iii).

The SP Lite2 has a 180° view field, sensitivity from 60 to 100 µV/W/m² and a spectral range between 400 and 1100 nm. Since the instrument considers a smaller spectral range than pyranometers of higher precision, comparisons were made between the SP Lite2 and another Kipp & Zonen pyranometer, the CMP11, which covers a spectral range from 285 to 2800 nm. The comparison sessions were performed during four days, registering the irradiance in a vertical plane facing north. The results of this verification showed an excellent agreement between the two types of pyranometers, which shows that the SP Lite2 is appropriated for measuring incoming and transmitted SW solar radiation on a vertical plane, and for indirectly evaluate the performance of façade systems in terms of controlling solar heat gains.

Figure 1. Location of the sensors for *in situ* monitoring of incident and transmitted SW solar radiation and illuminance.



2.2.2. Measurements of Illuminance

Horizontal illuminance measurements were performed 80 cm over the floor, in five positions located in a perpendicular line to the glazing. The first point corresponds to an exterior illuminance measurement, while the other four sensors are located in the interior, at different distances from the façade (Figure 1). Five sensors were connected in series to a Konica Minolta T-10A luxmeter, which accounts for a 2% of error. Illuminance and SW solar radiation measurements are done simultaneously.

Measurements obtained by the pyranometers and luxmeters were obtained every 10 min. Pyranometers were connected to an Agilent 39470A data acquisition system, while the illuminance sensors were connected to their own data acquisition system.

3. Monitored Buildings

3.1. Office Buildings in Santiago, Chile

Buildings of the already mentioned database (point 2.1) are from 4 to 32 stories, with constructed area between 2000 m^2 and 40,000 m^2. The building facade of 41% of the sample is exclusively curtain walls, 10% is lightweight façade, 17% is loadbearing walls, and 32% corresponds to a mix of more than one type of façade.

The preference of non-structural façade systems as curtain walls (41%) over load-bearing walls (17%) allows installation of a large transparent envelope area. In fact, 51% of the buildings register window-to-wall ratios between 75% and 100%, and 33% between 50% and 74%. Due to Santiago's climate, with high level of solar radiation, this large transparency on the office building envelope may cause an intensive risk of glare and overheating or high cooling energy consumption.

Due to risk of overheating and high cooling energy consumption, some office buildings incorporate ESD to reduce solar heat gains. From all the registered buildings in the city, only 18.6% of them use ESD in at least one of their facades. From this fraction, a 42.1% use overhangs, 36.8% use brise-soleil and 10.5% louvers. The rest of ESD correspond to other types of systems. It is important to notice that this classification only considers the existence of shading devices in any façade of the buildings and that the sole existence of the ESD in the building does not mean that it works properly or that it was conceived under energy efficiency criteria. The authors are certain that in some cases, the ESD were probably incorporated for aesthetic criterion rather than being used as sun protection systems. In fact, for example, overhangs on east and west oriented facades, which are observed in some buildings, are not effective as solar protection systems.

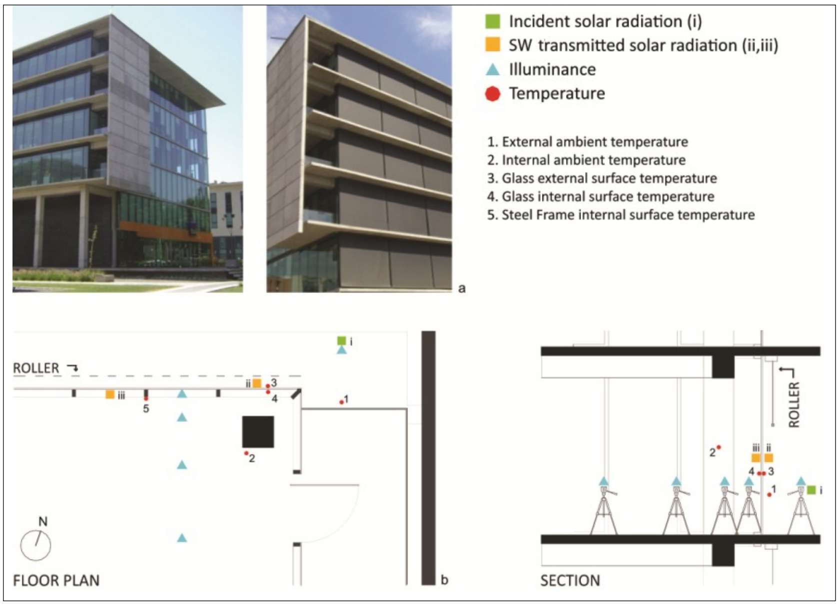
3.2. Analyzed Buildings

The monitored buildings correspond to three office buildings with similar characteristics in terms of dimensions, but with different types of CFS. Each CFS is evaluated within the context of the building where it is located, in terms of controlling SW solar and daylight transmission.

3.2.1. Building A

This a six-story building of 5200 m^2 with a lightweight façade system, made of full-glazed components from floor to ceiling, having a 100% window-to-wall ratio (Figure 2). On its northwest façade, the building presents a concrete overhang and an exterior curtain roller that is automatically deployed through a photo sensor located at the roof. The curtain is operated during working days and occasionally during weekends. Artificial light is off excepting before 9:00 and after 19:00. Measurements were performed in the 6th floor, in a space close to a terrace, which allows access to the exterior of the building for installing outdoor instrumentation. Instrumentation was located according to Figure 1. Measurements were carried out during weekend to capture periods or days when the exterior roller were completely down or not deployed, allowing analysis of the system's performance.

Figure 2. Complex fenestration system and location of the instrumentation in Building A.

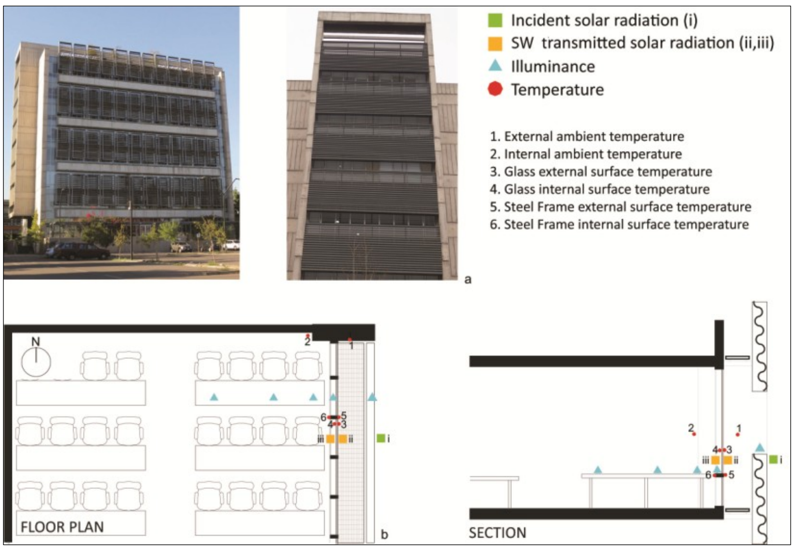


3.2.2. Building B

This is a nine-story and 6300 m^2 office building, with light-weight glazed façade, with an operable double-clear-glazing fenestration system with aluminum framing. Even though this building presents some opaque zones on its envelope, its window-to-wall ratio is between 75% and 100%. East and west-facing facades of the building have metallic undulated and micro perforated sunscreens, while the north-facing façade has a set of horizontal micro perforated louvers, contained in evenly-spaced two-story steel frames.

Even though measurements were performed on the west, north, and east-facing façade, only the latter is analyzed on the present document, aiming to characterize the performance of the metallic sunscreen. Instrumentation was installed on the third floor, in a classroom, facing east (Figure 3). Artificial light is off during measurements.

Figure 3. Complex fenestration system and location of the instrumentation in Building B.

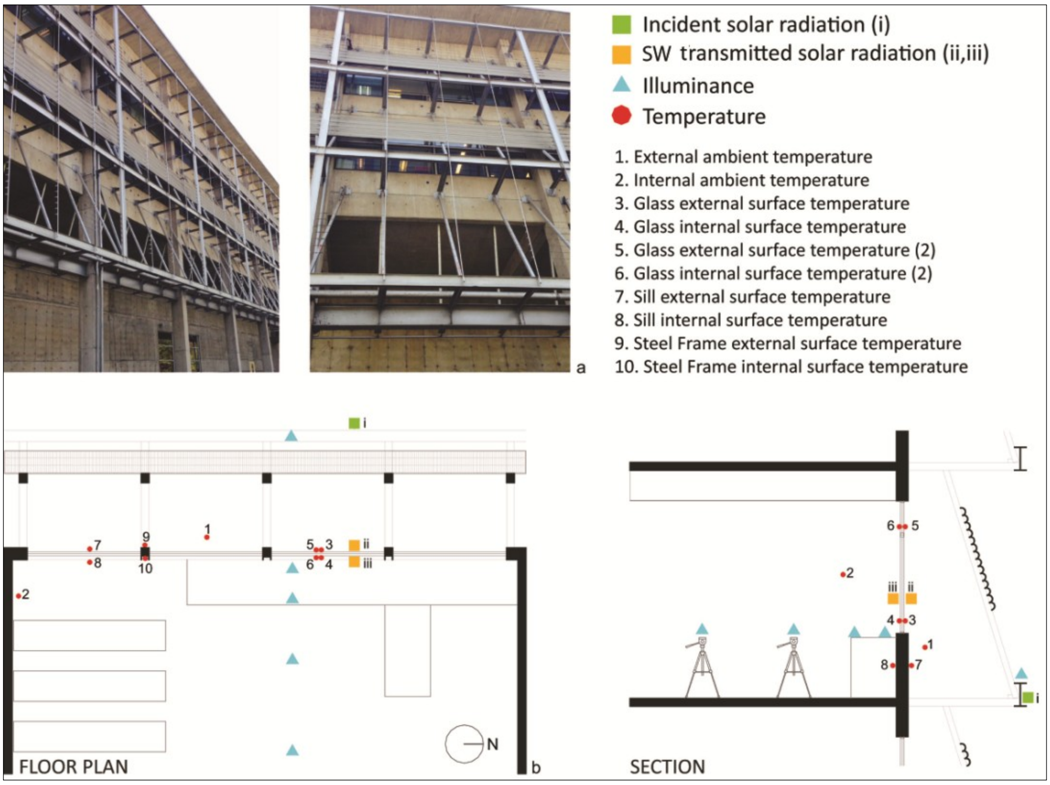


3.2.3. Building C

This is a four-story and 5500 m^2 office building, with load-bearing walls and operable windows. The total window-to-wall ratio varies between 50% and 74% for east and west-facing facades (main facades of the building). While single clear glass is installed on the east-facing windows, the west-facing façade considers clear double-glazing units and an undulated micro-perforated sunscreen as a solar control strategy. This screen is supported by a secondary structure, which positions it in an angle of 30° with respect to the vertical plane.

Measurements were performed on the third floor, in a closed space facing west. The space is used as a library, and, thus, it is used sporadically as a working space. Instrumentation was installed as shown in Figure 4. Artificial light is off during measurements.

Figure 4. Complex fenestration system and location of the instrumentation in Building C.



4. Results and Analysis

4.1. Measurements

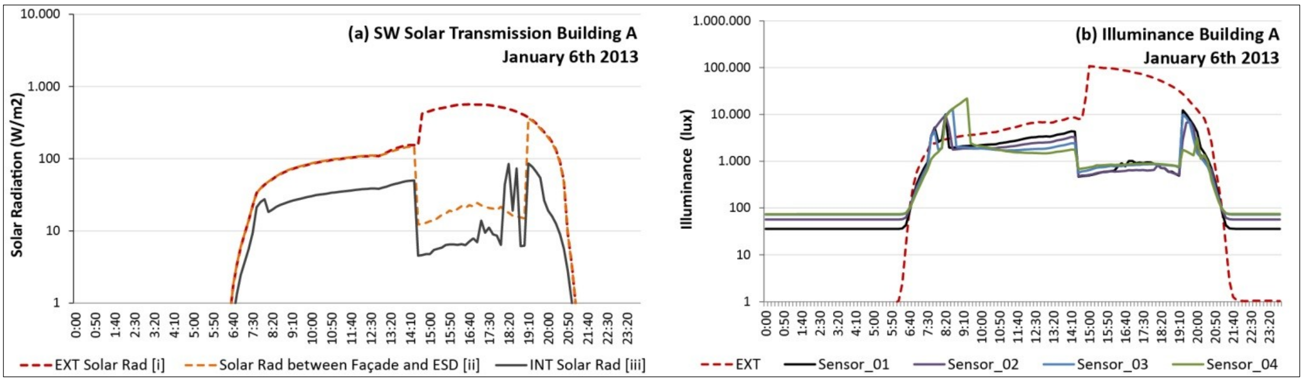
The following data correspond to measurements performed during a clear-sky day, and will be used for evaluating the performance of the different CFS in terms of SW solar and daylight transmission through them.

4.1.1. Building A

First, data corresponding to building A is shown in Figure 5. It can be observed that the exterior roller can significantly reduce both SW solar and daylight transmission to the interior space. It can also be observed that this system was deployed from 14:00 to 19:00. This is the period when sun rays directly strikes this façade.

Since the data correspond to a clear-sky day, the registered values show a very high exterior illuminance (up to 100,000 lux), while only 500 lx to 1000 lx are measured on the interior, when the curtain roller is deployed.

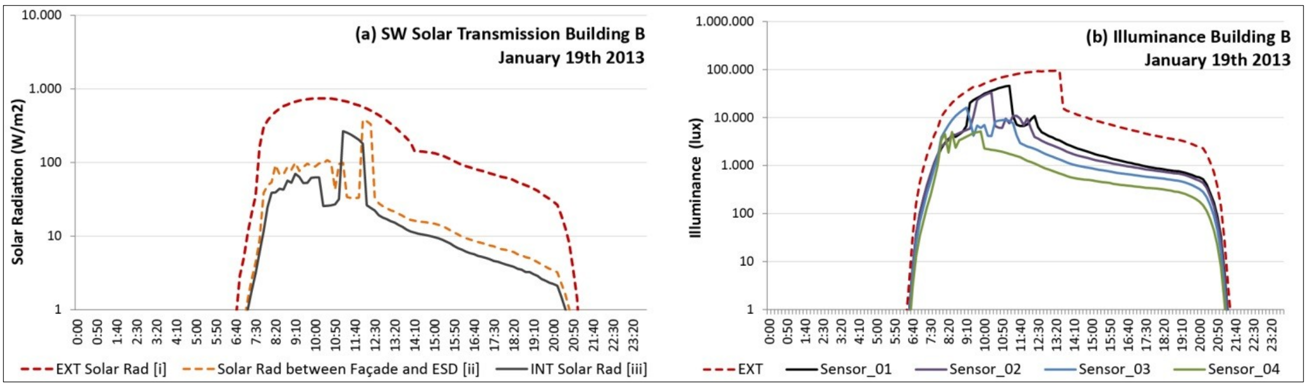
Figure 5. Solar Radiation (**a**) and illuminance (**b**) registered during a clear-sky day in Building A.



4.1.2. Building B

On the other hand, data from Building B was obtained from measurements on the east façade (Figure 6). In this case, a considerable reduction of the incoming solar radiation is observed indoor. SW transmitted solar radiation reaches values of around 266 W/m^2. Regarding daylight transmission several interior illuminance peaks were registered on this building. These peaks are observed during the incident period of solar radiation (07:00 to 13:00), which suggests design deficiency in the ESD. During this period, illuminance values from around 5000 lx to 45,000 lx were measured.

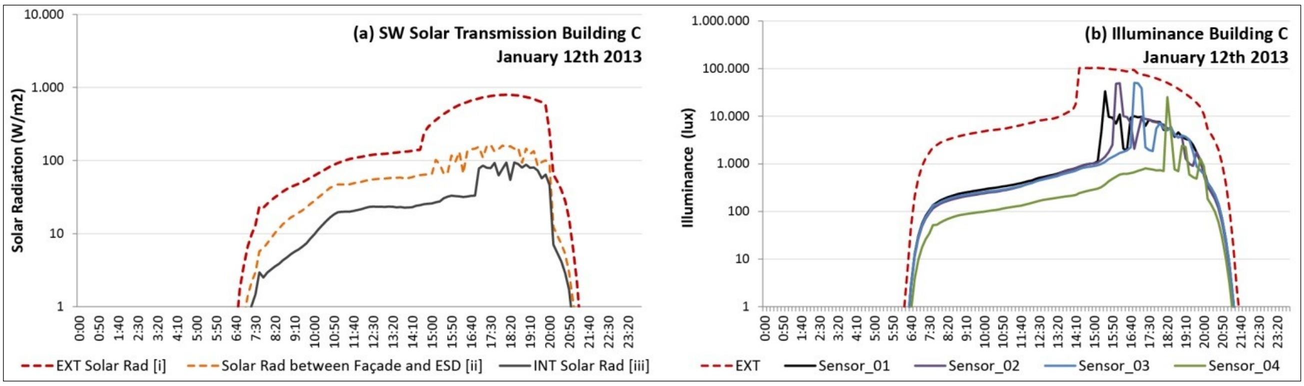
Figure 6. Solar Radiation (**a**) and illuminance (**b**) registered during a clear-sky day in Building B.



4.1.3. Building C

According to data of building C, the use of an ESD system also shows an important reduction of the incident solar radiation, being this very clear after 15:00, when beam radiation starts reaching the west façade. Also, an important reduction on the interior illuminance can be seen with respect to the exterior one, even though values of 10,000 lx were registered by sensors 01 and 02 during the afternoon (Figure 7). Data in building C show illuminance peaks during the afternoon, reaching maximum values of about 50,000 lx.

Figure 7. Solar Radiation (**a**) and illuminance (**b**) registered during a clear-sky day in Building C.



4.2. System Efficacy

The previous results provide insight information about the performance of CFS during daytime in summer. In order to analyze this performance, an index is used to quantify the efficacy of each system in terms of reducing the SW solar radiation This index is defined as the ratio of the registered values of the interior pyranometer (or luxmeter) over the values registered by the exterior pyranometer (or luxmeter). In addition, for SW solar transmission, this value was estimated in a daily-integrated basis.

4.2.1. Daily Integrated Factor for SW Solar Transmission

Values of the daily-integrated factor for summer days and for the 3 CFS are shown in Table 1.

Table 1. Daily-integrated interior/exterior short-wave (SW) solar factor for different summer days of the three buildings.

Building	**Orientation**	**Complex Fenestration System**	**Day**	**Month**	**Internal/External SW Solar Transmission Index**
Building A	NW	selective double glazing + roller	Day 01	January	0.12
			Day 02	January	0.11
Building B	E	clear double glazing + undulated perforated screen (vertical)	Day 01	January	0.11
			Day 02	January	0.11
Building C	W	clear double glazing + undulated perforated screen (tilted)	Day 01	January	0.10
			Day 02	January	0.11

It can be observed that the daily-integrated Interior/Exterior SW solar factor value of the 3 evaluated CFS remains relatively constant, reaching values from 0.10 to 0.12.

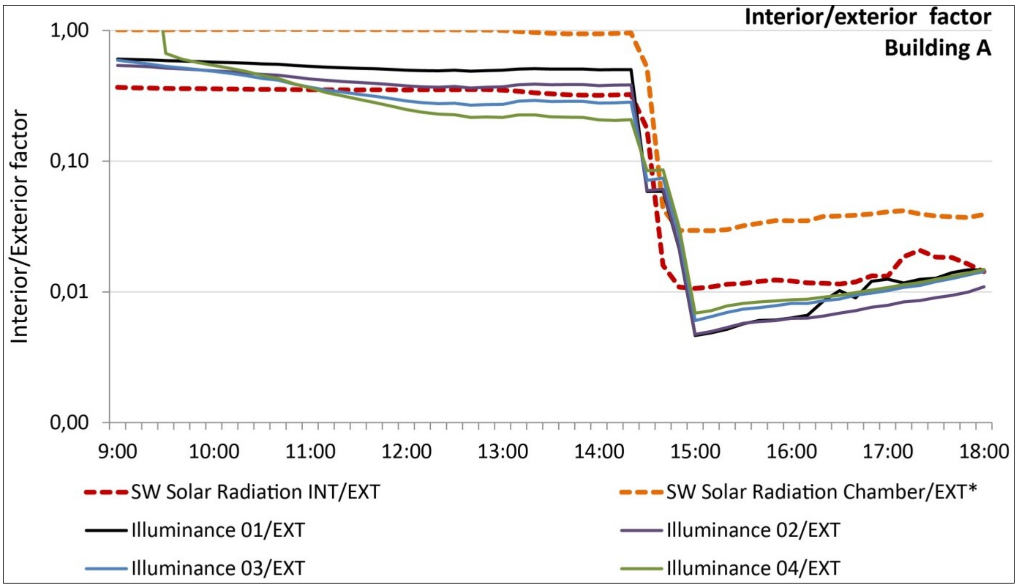
4.2.2. Instantaneous Index for SW Solar and Daylighting Transmission

The fact that similar results were found for the different cases) suggests that all three CFS reaches almost identical effectiveness in terms of blocking SW solar radiation. However, differences in their performance can be seen in different times of the day, which require a deeper analysis. According to that, Interior/Exterior factor for instant values are plotted for both SW solar radiation values in Figures 8–10 for buildings A, B and C, respectively. Also the variation of an illuminance instantaneous factor is shown in these figures. This illuminance interior/exterior factor corresponds to the ratio between the registered values of the different interior luxmeters over the value registered by the exterior luxmeter.

Figure 8 shows that the performance of the system installed on building A varies strongly at 15:00, when the roller is deployed. Despite of that, the values of the SW Interior/exterior factor before and after this discontinuity are almost constant, being a little less than 0.4 in the morning (with the roller up) and close to 0.01 in the afternoon (with the roller down).

Similar behavior can be seen for the illuminance values registered by sensor 01 (the closest to the façade). However, the data registered by sensors 02, 03, and 04 is distorted during the first hours of the morning because the space receives diffuse radiation from the east-facing facade (the analyzed space is located in a corner of the building). This is the reason why these sensors stabilize and follow sensor 01 and solar irradiance's tendency from 12:00 to 14:30 hours. According to that, values of 0.5, 0.4, 0.3, and 0.2 are found for sensors 01 to 04, respectively. Illuminance factors data when the curtain is deployed show values of around 0.01, similar as for SW solar radiation interior/exterior factor.

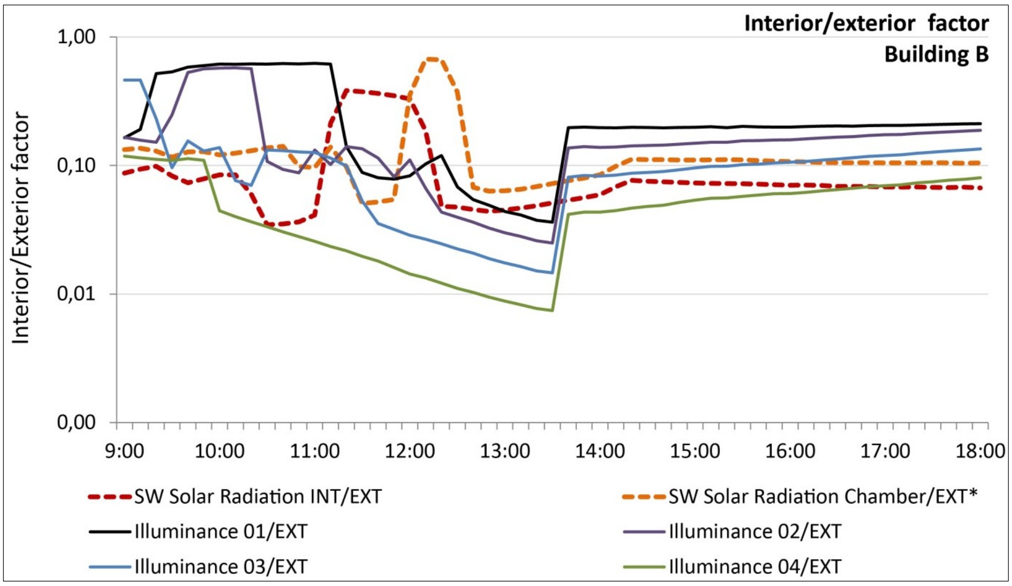
Figure 8. Solar radiation and illuminance internal/external factor for Building A.



On the other hand, building B shows a variable ratio between the interior and exterior values for different illuminance and SW solar radiation sensors, with important peaks during morning hours (Figure 9). As expected, during afternoon (14:00 to evening), both SW solar and illuminance factors are constant due to the presence of diffuse solar radiation.

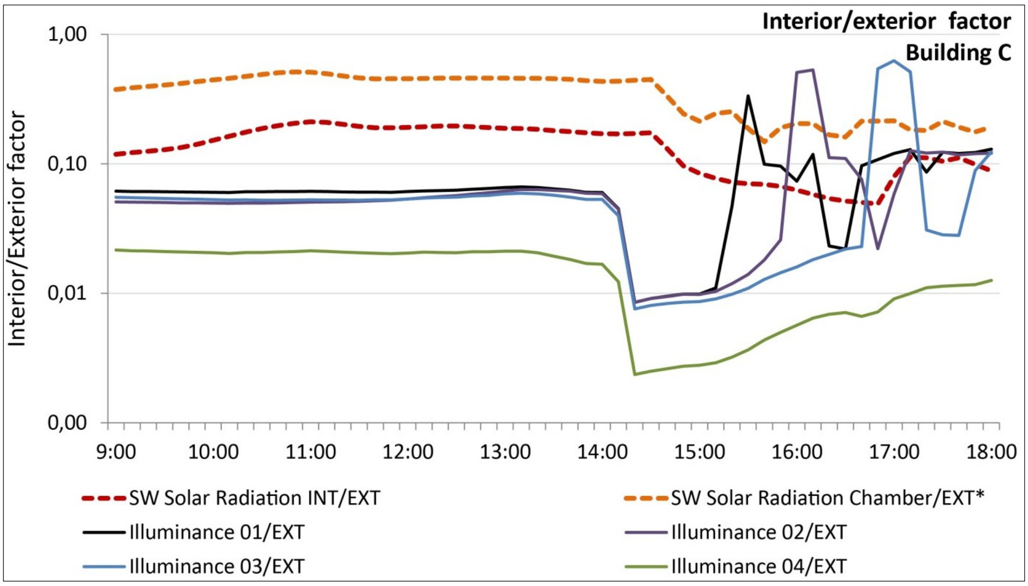
The registered behavior is caused by discontinuities in the undulated screen, suggesting probable deficiencies in the solar protection system design of the CFS.

Figure 9. Solar radiation and illuminance internal/external factor for Building B.



Similar to building B, building C shows constant Interior/Exterior SW solar factor values in some periods and unstable values in some others (Figure 10). During the morning, Interior/Exterior SW solar factor values vary from 0.1 to 0.2, and reaches values of around 0.1 in the afternoon. The Illuminance Interior/Exterior factor values present peaks and instability from 15:30 p.m., when the façade starts receiving direct solar radiation.

Figure 10. Solar radiation and illuminance internal/external factor for Building C.



In building C, peaks are mainly observed during the evening, in sensors 01, 02 and 03 (20, 60, and 140 cm from the façade, respectively), when the angle of incidence of solar radiation over the facade is much lower. Accordingly, the vertical discontinuity of the CFS (micro perforated and undulated screen) leaves unprotected spaces that, at certain times of the day, allow beam radiation to enter the space.

5. Conclusions

A methodology for studying the solar and daylight transmission through building facades has been presented and implemented in office buildings in Santiago, Chile. The methodology consists in continuous measurements of vertical solar radiation inside and outside of the building façade. The collected data was used to calculate an index called the Interior/Exterior SW solar factor, which is defined as the ratio of interior over the exterior vertical SW solar radiation. This value can be considered a quantification of the efficacy of the complex fenestration system in terms of blocking solar radiation in a building's facades.

The methodology also consists on measuring horizontal outdoor illuminance and in different points of the interior space of the building, data that can be lately used to calculate a similar index to the one explained before. As in the case of the solar radiation, this factor intends to quantify the efficacy of the ESD in terms of blocking daylight, and observing phenomena that can be associated to visual comfort problems.

For both illuminance and SW solar radiation, Interior/Exterior solar factor values are calculated instantly during the measurement period. However, in the case of solar radiation, a daily-integrated coefficient was also calculated.

The methodology was implemented in three office buildings in Santiago, Chile, each one with different CFS, during summer days. When observing the daily-integrated Interior/Exterior SW solar factor, with values of 0.10 and 0.12, which may suggest good performance of each CFS, considerably reducing the direct solar radiation.

The data corresponding to the instantaneous Interior/Exterior factor values shows singularities in transmission of both solar radiation and daylight. The system that presents the most homogeneous results is the exterior roller installed in building A. However, despite of the good daily-integrated Interior/Exterior SW solar factor values of the systems in buildings B and C, transmission peaks can be seen for both solar radiation and daylight, which may cause indoor thermal discomfort and probable glare during some periods of summer days. It may be concluded from these results that a good daily-integrated Interior/Exterior SW solar factor value does not necessary assures a good performance of the CFS. A careful analysis of these systems in design stage of the building is highly recommended. Finally, it is worth noticing that even the exterior roller (which—as mentioned—offers the most homogeneous solar control) can present design problems. That system, in the particular case of building A, has been installed only in the North-West oriented façade, and not in the North-East oriented one, effect that can be noticed in the measured data. Coherence between the different solar protection systems applied to façades in the building is a fundamental factor for reaching good thermal and visual comfort conditions in all the spaces of the building.

Acknowledgments

This work has been developed with the support of CONICYT-Chile through Project FONDECYT 1111001. The authors also gratefully acknowledge the research support provided by CEDEUS, CONICYT/FONDAP 15110020.

Author Contributions

Waldo Bustamante has written the article with collaboration of Alejandro Prieto, Sergio Vera and Claudio Vasquez. The experimental protocol has been defined by Waldo Bustamante and Sergio Vera. The implementation of the protocol has been made by Alejandro Prieto. Waldo Bustamante, Sergio Vera, Alejandro Prieto and Claudio Vasquez have collaborated in the analysis of results.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. American Society of Heating, Refrigerating and Air Conditioning Engineers. *ASHRAE Handbook Fundamentals*; American Society of Heating, Refrigerating and Air-Conditioning Engineers: Atlanta, GA, USA, 2005.
2. Heschong, L. Daylighting and human performance. *ASHRAE J.* **2002**, *44*, 65–67.
3. Bessoudo, M.; Tzempelikos, A.; Athienitis, A.; Zmeureanu, R. Indoor thermal environmental conditions near glazed facades with shading devices—Part I: Experiments and building thermal model. *Build. Environ.* **2010**, *45*, 2506–2516.
4. Lee, E.; DiBartolomeo, D.L.; Selkowitz, S.E. Thermal and daylighting performance of an automated venetian blind and lighting system in a full-scale private office. *Energy Build.* **1998**, *29*, 47–63.
5. Simmler, H.; Binder, B. Experimental and numerical determination of the total solar energy transmittance of glazing with venetian blind shading. *Energy Build.* **2008**, *38*, 648–660.
6. Kuhn, T. Solar control: Comparison of two new systems with the state of the art on the basis of a new general evaluation method for facades with venetian blinds or other solar control systems. *Energy Build.* **2006**, *38*, 661–672.
7. Pino, A.; Bustamante, W.; Encinas, F.; Escobar, R. Thermal and lighting behaviour of office buildings in Santiago of Chile. *Energy Build.* **2012**, *47*, 441–449.
8. Bustamante, W.; Encinas, F.; Otárola, R.; Pino, A. Análisis de estrategias para confort térmico y lumínico de edificios en diferentes climas de la zona central de Chile. *Rev. Arq*. **2012**, *82*, 16–19. (In Spanish).
9. Bustamante, W.; Encinas, F. Parámetros de Diseño y Desempeño Energético en edificios de clima mediterráneo. *Rev. Arq*. **2012**, *82*, 20–23. (In Spanish).
10. Poirazis, H.; Blometerberg, A.; Wall, M. Energy simulations for glazed office buildings in Sweden. *Energy Build.* **2008**, *40*, 1161–1170.
11. Matusiak, B.S. Glare from translucent façade, evaluation with an experimental method. *Sol. Energy* **2013**, *97*, 230–237.
12. Hirning, M.B.; Isoardi, G.L.; Coyne, S.; Garcia Hansen, V.R.; Cowling, I. Post occupancy evaluations relating to discomfort glare: A study of green buildings in Brisbane. *Build. Environ.* **2013**, *59*, 349–357.

13. Shen, H.; Tzempelikos, A. Sensitivity analysis on daylighting and energy performance of perimeter offices with automated shading. *Build. Environ*. **2013**, *59*, 303–314.
14. Li, D.H.W.; Lam, J. Evaluation of lighting performance in office buildings with daylighting controls. *Energy Build.* **2001**, *33*, 793–803.
15. Goia, F.; Haase, M.; Perino, M. Optimizing the configuration of facade module for office buildings by means of integrated thermal and lighting simulations in a total energy perspective. *Appl. Energy* **2013**, *108*, 515–527.
16. Ochoa, C.; Aries, M.B.C.; van Loenen, E.J.; Hensen, J.L.M. Considerations on design optimization criteria for windows providing low energy consumption and high visual comfort. *Appl. Energy* **2012**, *95*, 238–245.
17. Lee, J.W.; Jung, H.J.; Park, J.Y.; Lee, J.B.; Yoon, Y. Optimization of building window system in Asian regions by analyzing solar heat gain and daylighting elements. *Renew. Energy* **2013**, *50*, 522–531.
18. Bellia, L.; de Falco, F.; Minichiello, F. Effects of solar shading devices on energy requirements of standalone office buildings for Italian climates. *Appl. Therm. Eng.* **2013**, *54*, 190–201.
19. Irulegi, O.; Serra, A.; Hernández, R.; Ruiz-Pardo, A.; Torres, L. Fachadas ventiladas activas para reducir la demanda de calefacción en los edificios de oficinas. El caso de España. *Inf. Constr.* **2012**, *64*, 575–585. (In Spanish).
20. Wagner, A.; Gossauer, E.; Moosmann, C.; Gropp, Th.; Leonhart, R. Thermal comfort and workplace occupant satisfaction—Results of field studies in German low energy office buildings. *Energy Build.* **2007**, *39*, 758–769.
21. Kuchen, E.; Fisch, M.N. Spot monitoring: Thermal confort evaluation in 25 office buildings in Winter. *Build. Environ*. **2009**, *44*, 839–847.
22. Nicol, F.; Wilson, M.; Chiancarella, C. Using field measurements of desktop illuminance in European Offices to investigate its dependence on outdoor conditions and its effect on occupant satisfaction, and the use of lights and blinds. *Energy Build.* **2006**, *38*, 802–813.
23. Correia da Silva, P.; Leal, V.; Andersen, M. Occupants interaction with electric lighting and shading systems in real single-occupied offices: Results from a monitoring campaign. *Build. Environ.* **2013**, *64*, 152–168.
24. Konis, K. Evaluating daylighting effectiveness and occupant visual comfort in a side-lit open-plan office building in San Francisco, California. *Build. Environ*. **2013**, *59*, 662–677.
25. Altan, H.; Ward, I.; Mohelnikova, J.; Vajkay, F. An internal assessment of the thermal comfort and daylighting conditions of a naturally ventilated building with and active glazed façade in a temperate climate. *Energy Build.* **2009**, *41*, 36–50.
26. Met Office. Sheffield 1971–2000 averages. Available online: http://www.metoffice.gov.uk/climate/uk/averages/19712000/sites/sheffield.html (accesed on 15 April 2014).
27. Instituto Nacional de Normalización. *NCh 1079 Of 2008. Arquitectura y Construcción—Zonificación Climático Habitacional para Chile y Recomendaciones para el Diseño Arquitectónico*; Instituto Nacional de Normalización: Santiago, Chile, 2008. (In Spanish).

28. Bustamante, W.; Encinas, F.; Pino, A.; Otárola, R. Strategies for improving thermal performance and visual comfort in office buildings of Central Chile. In Proceedings of the 27th International Conference on Passive and Low Energy Architecture, Louvain la Neuve, Belgium, 13–15 July 2011; Bodart, M., Evraud, A., Eds.; Presses Universitaires de Louvain: Louvain la Neuve, Belgium, 2011; pp. 903–908.
29. Molina, G.; Bustamante, W.; Fazio, P.; Rao, J.; Vera, S. Evaluation of Radiance's genBSDF capability to assess solar bidirectional properties of complex fenestration systems. *J. Build. Perf. Simul.* **2014**, doi:10.1080/19401493.2014.912355.