Journal of Engineering Science and Technology Review 6 (2) (2013) 41-44

Research Article

JOURNAL OF
Engineering Science and Technology Review

www.jestr.org

A Simplified Measurement Method of Solar-Optical Properties of Multi-Pane Glazing Units

Zhuolun Chen[1,2,*]

[1]*Architectural Design & Research Institute, South China University of Technology, Guangzhou, Guangdong, P.R.China*
[2]*State Key Laboratory of Subtropical Building Science, Sou th China University of Technology, Guangzhou, Guangdong, P.R.China*

Received 15 May 2013; Accepted 25 July 2013

Abstract

Energy-efficient windows with double- or triple-pane glazing units are currently widely utilized in building applications. The solar-optical properties of glazing units can greatly affect their energy and daylighting performance. However, it is generally difficult to measure the solar-optical properties of glazings using the current ISO standards, especially for multi-pane units. This paper presents a simplified test method suitable for multi-pane glazing. Three sets of double-pane Low-Emissivity (LOW-E) glazing units were tested under ISO standard and proposed methods. Good agreement between the two testing methods was obtained. However, the simplified method required much less experimental time and labor..

Keywords: Multi-pane Glazing Units, Solar-optical Properties, Total Solar Energy Transmittance, Shading Coefficient

1. Introduction

Energy-efficient windows with multi-pane glazing units are wildly used in modern buildings. It is reported that in 2001, over 7,500,000 square meters of glass curtain wall are produced and installed in china, approximately two thirds of the total production in the world.[1] At the end of 2001, 42,000,000 square meters of glass curtain wall were installed in China. The glazing has improved from simple-pane clear glass in the past to multi-layered glazing units nowadays. Moreover other glazing types, such as Low-Emissivity (LOW-E) glazings and Polyvinyl Butyral (PVB) laminated glazing, are now commonly used in buildings. These glazing can significantly affect the energy consumption by buildings. It is important to test the solar-optical properties of glazing units in order to assess their energy performance under real conditions.

The main effects of thermal and optical properties of glazing units include [2], [3], [4], [5].

1.1 Controllability of solar radiation

Due to heating and cooling requirements, glazing units are supposed to be able to decrease or increase the amount of solar heat transmitted indoors. Parameters, such as total solar energy transmittance (g-value), shading coefficient (Se), and solar heat gain coefficient (SHGC), are utilized to describe the fraction of solar heat that enters through a window. The standard of GB/T2680-94 [6] sets a benchmark on the g-value associated with a 3mm clear glass as 88.9%. [7] Meanwhile, due to their different physical performance of coated surfaces, the ability of other glazing units to transmit radiant heat may vary as well. The hemispherical emissivity εi is used to determine the percentage of radiant heat that is emitted from the surface. For example, a clear glass can have a high εi up to 0.837, while for some LOW-E coated glazings, this value can be as low as 0.05.

1.2 Optical properties

These properties consider not only the solar radiation, but also visible light spectrum. In cold climates, it is highly desirable that solar radiation, in the spectrum range of 300-2500nm, be fully transmitted through exterior windows, while all the infrared radiation with wavelength over 2500nm can be reflected back to inside of the room. As a result, the heating loads can be reduced. In hot climates, all radiation above 780nm should be reflected to the outdoors to reduce the transmitted solar radiation resulting in lower the cooling loads. Meanwhile, visible light in the spectrum range of 380-780nm should be allowed to be transmitted indoors so that the room can benefit from natural light. Thus, the values of visible light transmittance τv and reflectance ρv are critical for glazing products.

1.3 Capability of heat conservation

This property refers to a reduction in conductive and convective heat transfer through glazing units. According to standard (International Organization for Standardization, 1990), under the condition of εi=0.83 and wind velocity at 4m/s, the values of exterior and interior convective coefficient (he, hi) for vertical glazing units are 23 w/(㎡ K) and 8 w/(㎡ K) respectively. However, it is a little complicated to calculate the U-value, especially for multi-pane glazing units with air gaps. Take double-pane glazing units for example. The U-value should be divided into two parts, thermal conductance of glasses itself hg and of air gap G, which needs to consider radiant and conductive heat transfer together.

* E-mail address: gzlun@qq.com
ISSN: 1791-2377

There are many ways to obtain the solar-optical properties of glazing units nowadays. The common one is laboratory tests. The spectral transmittance and reflectance can be measured by using spectrophotometer or other equipments. Then g-value, Se and SHGC can be calculated under the ISO standards. Another way is from software simulations. The Lawrence Berkeley National Laboratory (LBNL) developed a software named Windows, which can calculate these properties of different kinds of glazing products[8]. Meanwhile, LBNL also administrated the International Glazing Data Base (IGDB), which contains optical properties for several glazing products available on the market.[9],[10]

This paper utilizes a simplified laboratory testing method to measure the solar-optical properties of double-pane glazing units. The simplified testing method was developed as an alternative to the ISO Standard method. It can reduce the time and labor effects during the test while having similar results. Three sets of double-pane LOW-E glazing units were measured using both testing methods. [11],[12],[13]

2. Experimental Analysis

All the optical data in this paper were measured from a spectrophotometer Hitachi U-4100. This machine includes a high-sensitivity integrating sphere and a sample compartment to measure spectral transmittance and reflectance in a wide range of radiation spectrum. It also enables color analysis and film thickness estimation. The integrating sphere ensures highly accurate measurements for a radiation spectrum raging from 175 to 2600nm. The sample compartment enables testing of large samples (max. 430×430mm) in a nondestructive way. Meanwhile, data collection is performed automatically by a software named UV Solutions. All the data can be evaluated according to a desired bandwidth.

Three units of double-pane glazing with the same LOW-E coatings (emissivity=0.30) were tested. They have the same size of 250mm×150mm, but the air gap of these three samples differs and ranges from 4mm, 6mm to 8mm. The units are referred to as 6+4A+6, 6+6A+6 and 6+8A+6 throughout this paper. During the experimental testing, the surfaces of each unit were marked from 1 to 4 in the order of outside to inside.

2.1 Standard testing method

Figure 1 shows the testing procedures for the solar-optical properties, according to standards [6] [7]. This method was developed from the theoretical analysis of optical interactions between two transparent materials. As a result, several derived formulas can be used in the calculation of g-value and Se after getting all required transmittance and reflectance values for different spectral range. The testing procedure outlined in Figure 1 requires measuring properties associated to all four surfaces of the glazing unit. Thus, the glazing unit needs to be broken down and taken apart into two separate glasses.

2.2 Simplified testing method

Figure 2 summarizes the testing procedure of the proposed simplified method. When developing this method, real conditions are considered. The multi-pane units are treated as an integral system transmitting solar radiation and visible light. The solar-optical properties as of the integral system can be calculated from the theoretical model used in the standard method. The major difference between these two methods is that the simplified method measures the multi-pane glazing overall performance based on testing the properties of the outer surface.

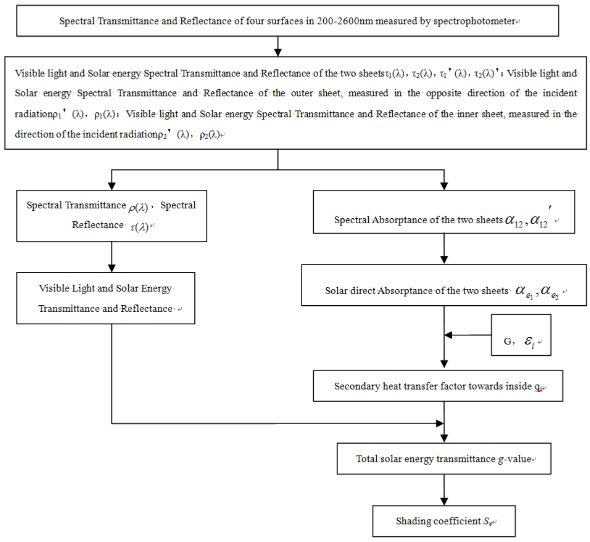

Fig.1. Basic testing procedure of standard method

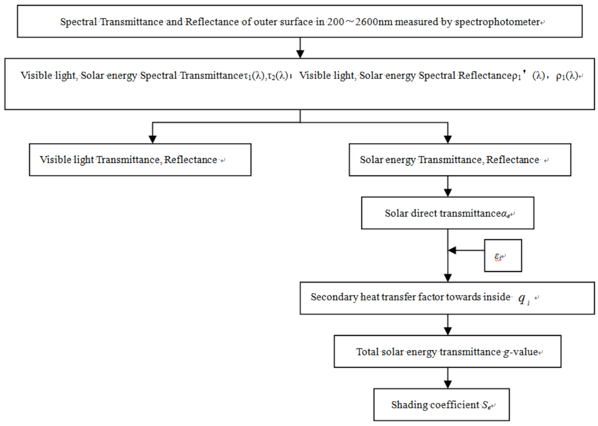

Fig. 2. Simplified testing method

3. Results and Discussion

Several important parameters related to solar-optical properties are commonly utilized to evaluate whether a glazing product is effective in saving building energy consumption or increasing daylighting. The parameters include visible light transmittance τv and reflectance ρv, total solar energy transmittance (g-value), shading coefficient (Se) and solar heat gain coefficient (SHGC). All of these parameters can be calculated from the spectral transmittance and reflectance distributions which can be measured using either the standard method or the proposed simplified method. However, glazing thermal properties, such as U-value (also known as thermal transmittance), require other testing methods and are not presented in this paper.

Table 1 summarizes the testing procedure for both the standard method and the proposed simplified method. In order to estimate the solar-optical properties, the simplified method requires less testing effort and smaller number of parameters to be measured and calculated than the standard method. For the three samples of glazing units (6+4A+6, 6+6A+6 and 6+8A+6) considered in this study, it took on the average one hour of testing for the standard method, comparing to only 20 minutes for the simplified method. Another advantage of the proposed simplified method is that the testing sample can be preserved after completion of the measurement. On the contrary, the standard method needs to break apart of the glazing unit for testing. For instance, any LOW-E coated interior surfaces would easily lose their original properties when they are exposed to the damp and oxygen in the environment.

Table 2 shows the measured results of the solar-optical properties obtained from both the standard method and the simplified method. In general, all the results from both methods are in agreement within less than 5% difference, which is an acceptable threshold for engineering applications. It should be noted that the values from simplified method are consistently lower than those obtained from the standard method.

Table 1. Comparison of Testing Procedure Between the Standard Method and the Simplified Method

	Standard method	Simplified method
Measured surfaces	Both surfaces of two component glass	Outer surface
Number of measured surfaces	4	1
Measured parameters	Spectral transmittance and reflectance, Surface emissivity	Spectral transmittance and reflectance, Surface emissivity
Number of measured parameters	12	2
Calculated parameters	Thermal resistance of air gap, Secondary heat transfer, Transmittance, reflectance and absorptance of visible light and solar energy, g-value, Se	Secondary heat transfer, Transmittance and reflectance of visible light and solar energy, g-value, Se
Number of calculated parameters	10	5

Table 2. Summary of the Testing Results for both the Standard method (M1) and the Simplified method (M2)

Style of glass	6+4A+6		6+6A+6		6+8A+6	
	M1	M2	M1	M2	M1	M2
Visible light transmittance τV，%	57.02	56.90	57.01	56.91	57.02	56.90
Visible light reflectanceρV，%	14.59	14.69	14.59	14.55	14.59	14.56
Total solar energy transmittance g，%	58.29	56.01	58.33	56.04	58.35	55.92
Shading coefficient Se	0.57	0.54	0.57	0.54	0.57	0.54

3.1 Optical properties in visible light

The measured values of visible transmittance and reflectance obtained by both methods agree well. It indicates that there is little difference in estimating optical properties of glazing units obtained from theoretical modeling defined by the Standard method and those obtained from testing under real conditions provided by the simplified method.

3.2 Solar properties

The calculated values of g-value and Se from the simplified method are approximately 5% lower than estimates obtained from the standard method.

3.3 Effects of air gap

Even though both g-value and Se value increase if the air gap is larger, the difference among these values is generally less than 1%. This result indicates that the thickness of air gap does not affect the amount of solar radiation transmitted through the tested glazing units.

The data in Table 1 outlines the differences between theoretical calculations and measured values under real conditions. The main reasons of these differences can be summarized as follow:

Nonparallelism of component glasses

All the theoretical calculations in the standard method assume that the glazing layers and surfaces are parallel to each other. Using the current level of manufacturing technology, the parallelism among all the component glasses is not assured.

Uneven thickness in float glazings

The common production procedure of float glazings always causes asymmetrical problems in the product. The middle area of glass is typically thicker than other parts. This uneven thickness influences the accuracy of the optical test results.

Quality of glass

Common quality problems in glazing products include interior air bubbles, surface scratches and impurity. These quality problems can change the optical and solar properties of the glazing units.

4. Conclusions

This paper describes a simplified testing method to measure the solar-optical properties of multi-pane glazing units. This method can save almost half of the experiment and calculation time, while decreasing the labor required to take apart the unit components, the simplified method allows to preserve the samples in their original conditions. The testing results obtained for three glazing units have indicated that the simplified method is easy to use and provide very close results as the standard method.

Acknowledgements

This study is sponsored by the Youth Science Fund of National Natural Science Foundation of China (No.51108185) and the funding of State Key Laboratory of Subtropical Building Science (No.2013KB24). Support of the University of Colorado at Boulder is also acknowledged. The author would like to thank Prof. Moncef Krarti for supervising the paper content and editing the English.

References

1. Zhang, Q.. "The design and construction manual of building glass curtain walls and glass sky light roof" (In Chinese). China building industry publishing company, Beijing. 2005. pp.102-152
2. Liu Z.W., Luo Y.. "Calculation, design and energy-saving measurements of thermal performances of building glasses" (In Chinese). Energy Efficient Windows. China Building Industry Publishing Company, Beijing, 2003, pp.73-78
3. Nilsson,A. M., Roos, A.. "Evaluation of optical and thermal properties of coatings for energy efficient windows". Thin Solid Films, 517, 2009, pp. 3173-3186.
4. Kim Gon, Schaefer Laura, Kim Jeong Tai, " Development of a Double-Skin Facade for Sustainable Renovation of Old Residential Buildings ", Indoor and built environment, Volume: 22 (S1), 2013, pp.180-190.
5. Yasar Yalcin, Kalfa Sibel Macka, "The effects of window alternatives on energy efficiency and building economy in high-rise residential buildings in moderate to humid climates", Energy conversion and management, Volume:64, 2012, pp. 170-181
6. China Zhijian Publishing House. "GB/T2680-94 Determination of light transmittance, solar direct transmittance, total solar energy transmittance for glass in building and related glazing factors" (In Chinese) , 1994.
7. International Organization for Standardization. "ISO9050 Glass in building — Determination of light transmittance, solar direct transmittance, total solar energy transmittance and ultraviolet transmittance, and related glazing factors".
8. Carmody, J., Selkowitz, S., Lee, E.S., Arasteh, D., Willmert, T.. "Windows systems for high-performance buildings". W.W. Norton & Company, USA, 2005, pp.152-190
9. Mingotti, N., Chenvidyakarn, T., Woods, A.W.. "Combined impacts of climate and wall insulation on the energy benefit of an extra layer of glazing in the facade", ENERGY AND BUILDINGS, 2012, Volume 58, 2013, pp. 237-249
10. Ventrella A., Smeacetto F., Salvo M., " Characterization of New Glass Coated Foam Glass Insulating Tiles by Standard Tests ", JOURNAL OF MATERIALS ENGINEERING AND PERFORMANCE, Volume: 21, Issue: 11, NOV 2012, pp. 2380-2388
11. Buratti C., Moretti E., " Glazing systems with silica aerogel for energy savings in buildings ", APPLIED ENERGY, Volume: 98, 2012, pp.396-403
12. Buratti, C., Moretti, E., "Experimental performance evaluation of aerogel glazing systems", APPLIED ENERGY, Volume: 97, Special Issue: SI, 2012 pp.430-437
13. Max J. F. J., Reisinger, G., Hofmann T., "Glass-film-combination: Opto-physical properties and energy saving potential of a novel greenhouse glazing system", ENERGY AND BUILDINGS, Volume: 50, 2012, pp. 298-307.