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Spectrophotometric characterization of simple glazings for a modular façade

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Abstract

A large variety of transparent materials is available for uses in buildings façades and all glazing properties must be considered in their choice. Such a selection should be a careful process of evaluation and weighing of tradeoffs. The correct glazing specifications for façades can reduce energy consumption in buildings, because the heat exchange and passage of radiation into the building as light and heat occur through transparent surfaces. Therefore, glazing significantly contributes to the heat transfer between outdoor and indoor spaces, which act directly on daylighting and thermal comfort. This manuscript addresses a spectrophotometric characterization of glazings for the study of components for the design of a modular façade system based on the climate of Portugal. The study focused on results of spectrophotometric measurements of an optical behavior in different solar spectrum intervals (ultraviolet, visible and near infrared), specifically the transmittance of some types of simple glazings. The results show the percentage of transmission to spectrum intervals, which enabled the analysis (OK?) of the efficiency of the glazing regarding daylighting and correlation to the thermal performance. Indications for specifications and adequate uses based on transmission of transparent surfaces have been obtained and complemented the datasheets available from the manufactures.

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1. Introduction

Over the past decades, facade technologies have undergone substantial innovations, as they have integrated specific elements for adapting the mediation of the outside conditions to the user´s requirements in both quality of materials and components and the overall conception and design of the facade system. Such improvements include passive technologies, as sun protections, ventilations, multi layered glazing, among others [1].

A large variety of transparent materials is available for use in buildings façades. However, all glazing properties must be considered in the choice of a material. The selection of glazings should be a careful process of evaluation and weighing of tradeoffs. Among the characteristics required for the specifications of transparent materials, spectrophotometric behavior is an important factor, as it enables improvements in the thermal and visual comfort of a building.

An improvement would be the choice of glazing whose characteristics maximize daylight effectiveness and occupants´ comfort, minimize energy use and accomplish the objectives of the architectural project. All glazing properties must be examined during the choice of the type of glazing to be used in a careful evaluation process. However, some characteristics, as transmission in different spectrum intervals and influence on the daylighting and thermal performance are not provided by the manufacturers [2].

The transmission through glazings depends mainly on the angle of radiation incidence, thickness, chemical composition and superficial characteristic of the glazing. The angle of radiation incidence is the angle between the direction of the radiation and the normal one (90~) to the surface under analysis [3]. The transmission of glazings also depends on the wavelength of the incident radiation. People typically spend many hours in buildings bathed by the ultraviolet, visible, and infrared radiations produced by natural or electric lighting, which can damage tissue regardless of their possible influence on the visual and circadian systems [4].

Baldinelli [5] reported spectral data in the wavelength field of interest for solar radiation and showed the high transparency levels of glazing systems made by internal (stratified glass, air gap, float glass) and external (stratified glass) glazings, as well as the good reflective properties of aluminum in a shading system. According to the author, glazing optical properties depend on the incident angle between the surface and the ray direction; as it deviates from the normal direction (0º), transmissivity decreases, whereas reflectivity and absorptivity increase. The variation in optical properties caused by the incidence angle depends on the glass type and thickness and, in particular, is more pronounced for multiple-pane glazing systems.

Some studies on glass and other transparent materials have focused mainly on the penetration of UV rays through the glazings. Optically functional glasses have been proposed for curbing its excessive penetration and performance assessments of the glazed materials were reported by Kim et al. [6]. Their results show UV protection glass is more effective for controlling UV rays of natural light, clear glass treated with UV protection film would provide excellent control of UV penetration and a pair of clear and UV protection glass treated with UV protection film should be recommended. All such characteristics can achieve 96.7% UV protection from natural light.

The solar spectrum is divided into ultraviolet UV region (100 to 380nm), visible region (380 to 780) and infrared region (780 to 3000). The transmission of glazings for each interval influences some characteristics relative to daylighting condition and heat transfer. The ultraviolet band is more energetic than the light, which has a shorter wavelength, therefore, it penetrates the skin more deeply and causes burns according to the time of exposition to the solar radiation. Although only 1 to 5% of the ultraviolet radiation reaches the terrestrial surface, it must not be ignored. It is responsible for the synthesis of Vitamin D through the skin and exerts a bactericide effect; on the other hand, it compromises the durability of the materials.

The visible region (380 - 780nm) is associated with the intensity of the white light transmitted and directly influences the degree of natural illumination of an environment. It is also called luminous region and provides the visual day-by-day sensation. It is the visible portion of the incident solar radiation in the normal direction to the surface plane.

The infrared region (780 - 3000nm) is invisible to the visual system, although it is perceived in the form of heat. It interferes in the indoor conditions of the environment through solar heat gains, therefore, it cannot be ignored. References of some specifiers regarding such a region of the spectrum include statements as “glass is generally opaque to the infrared”, however, this is wrong information.

Information from glass manufacturers is normally limited to values of mechanical resistance, acoustic insulation and energetic transmission of the solar radiation. The latter is treated in a generalized way and the data on visible region and solar factor ignore the behavior of the material in the ultraviolet and infrared radiations. They usually regard transmittance for the incidence of normal radiation to the surface, which occurs in a minimum period of time. Some information refers to the solar heat gain coefficient. However, in most cases, no datum on the infrared is provided, which hampers an individual and correct analysis of the spectral behavior of the glass.

This manuscript addresses a spectrophotometric characterization of glazings conducted for the study of glazing components for a modular façade system designed for the climate of Portugal. The study focused on results of spectrophotometric measurements of the optical behavior in different solar spectrum intervals, namely ultraviolet, visible and near infrared, specifically the transmittance of some types of simple glazings.

2. Materials and Methods

The development of the research included the characterization of glazing materials, preparation of the spectrophotometer, cleaning, identification and fixation of the specimen on the device and description of the spectrophotometric tests.

2.1. Glass Specimens

Rectangular samples of 50mmx50mm dimension were used for tests. The interval of the spectrum ranged between 200 and 1100nm and comprehended three regions, namely ultraviolet (200 to 380nm), visible (380 to 780nm) and near infrared (780 to1100nm). Table 1 shows the descriptions of the samples analyzed.

Table 1. Descriptions of the Glass Specimens.

Identification	Type of Glass	Thickness	Number of Specimens 50x50 mm	Position of Coating
Glass A	Glass with a solar control metallic foil that confers it characteristics of solar control	6mm	3	Face 2
Glass B	Green glass with a solar control metallic foil that confers it characteristics of solar control	6mm	3	Face 2
Glass C	Self-cleaning glass manufactured by the deposition of a transparent layer of a photocatalytic and hydrophilic mineral material onto clear glass.	6mm	3	Face 1
Glass D	Glass with a low-emissivity foil	6mm	3	Face 2

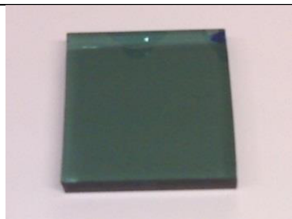
Table 2 shows other characteristics of the glasses, as U-values, solar factor, shading coefficient and relative heat gain of the glazings studied.

Table 2. Characteristics of the Glasses.

Characteristics	Glazings	
	Glass A (solar control)	Glass B (green solar control)
Thickness	6mm	6mm
U-Value (W/m²K)	5.683	5.683
Solar Heat Gain Coefficient (SHGC)	0.503	0.432
Shading coefficient	0.57	0.496
Relative Heat Gain (W/m²)	403	351
Characteristics	Glazings	
	Glass C (self-cleaning)	Glass D (low-e)
Thickness	6mm	6mm
U-Value (W/m²K)	5.799	5.665
Solar Heat Gain Coefficient (SHGC)	0.814	0.708
Shading coefficient	0.936	0.814
Relative Heat Gain (W/m²)	631	551

Regarding the spectrophotometric tests, images of the samples provide the visual aspect of the selected material. Table 3 shows the samples of the selected glazings. The rusty part corresponds to the abrasion band that shows the face with the film, so that the glazings could be correctly positioned for the spectrophotometric characterization tests.

Table 3. Glass Specimens

Glass A (solar control)	Glass B (green solar control)
	
Glass C (self-cleaning)	Glass D (low-e)
	

2.2. Spectrophotometric tests

According to the ASTM [7], a spectrophotometer is the ideal equipment to provide the data of transmission percentage to the ultraviolet, visible and near infrared regions. It also enables a sweeping in the spectrum only in the region of interest.

UNICAM UV/VIS, the device used for the tests, provides data on absorption, reflection and transmission of the tested materials (Fig. 1). By virtue of our objective, only the transmission mode was used. A tungsten lamp was used for the whole spectrum. The samples were tested at 0° with normal incidence (sheaf perpendicular to the sample) and the sheaf incidence was in accordance with the coating of the samples, as it followed the recommendations of the manufacturer for the glasses analyzed.

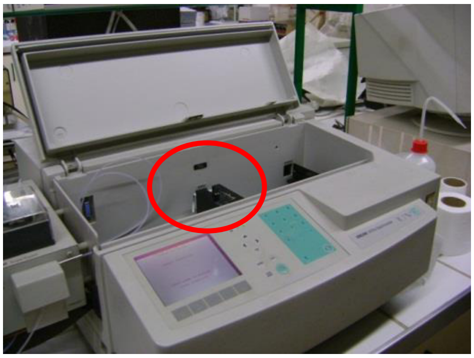


Fig. 1. Specimen inside the spectrophotometer.

The procedure followed the manufacture´s recommendation, i.e., the face must face the inner part of the glazing composition, so that the coating should be intact, as it easily oxidizes in contact with air. The software started the sweeping procedure at 200nm with the equipment closed and ended at 1100nm.

Another division was created in this interval and other sub-intervals were generated for the characterization of the ultraviolet (300 to 380nm), visible (380 to 780nm) and part of the infrared (780 to 1100nm) regions. During the reading of values recorded by the measuring equipment, graphs were generated from the results.

3. Results

The experimental results are shown in graphs (per type of glazing) for a good visualization of what occurs regarding transmittance inside the glazings studied for each sample subjected to normal incidence of radiation. Regarding transmission in the visible region, the use of glazings whose transmission ranges between 30 and 50% is recommended, as they guarantee environments of satisfactory illuminance level and enable the development of activities that require precision of the visual system. The following intervals of luminous transmission (LT) can be established as a parameter [8]:

- LT < 30% weak luminous transmission;
- 30% ⩽ LT ⩽ 50% medium luminous transmission;
- LT> 0,50 strong luminous transmission.

The LT coefficient should range between 30 and 50% in vertical surfaces and 25% and 40% in covered ones. Besides the transmission in the visible region, which is usually the parameter provided by the manufacturers of glazings, the transmission in the intervals of the ultraviolet and infrared must also be considered. The discussion of curves and tables of results are based on such considerations and the point of view of thermal comfort and daylighting.

3.1. Glass A and Glass B: Solar Control - Translucent and Green

The transmission of Glass A (translucent) with a solar control coating in the UV is lower (9,24%). Transmissions in the visible and infrared regions are approximately 47,28% and 24,52%, respectively (Fig. 2). The latter value indicates lower internal heating, in comparison with float simple glasses, for example.

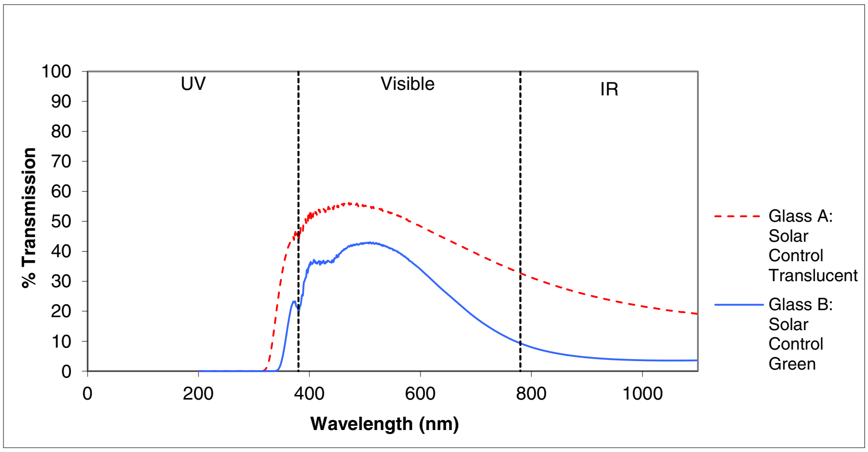


Fig. 2. Transmission curves: solar control – Translucent (Glass A) and green (Glass B)

Glass B (green) showed a large transmission decrease in all regions of the spectrum, mainly in the UV and infrared regions, with percentages of 2,85% and 4,80%, respectively. The value of visible transmission was 14%. The transmission in the UV and IV regions confirmed the solar control characteristics of the glass, which are lower in comparison with the simple float glasses.

3.2. Glass C: Self-cleaning

The percentage of transmission of Glass C (self-cleaning) in the UV region was 17,03%. Regarding visible light, it transmits 82,52%, which guarantees a high transmission that favors the daylighting conditions. The infrared radiation transmission is 70,78%, which indicates its use will cause higher heating in the indoor environment, however, with a small UV radiation decrease (Fig. 3). In this case, the self-cleaning coating does not cause large differences regarding transmission, which is an advantage because, besides higher daylighting and internal heating, a self-cleaning function is expected.

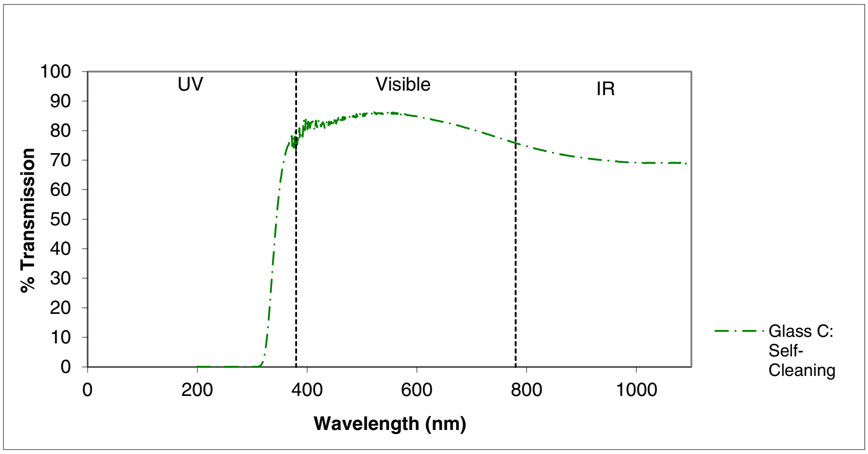


Fig. 3. Glass C: Transmission curve: Self-cleaning glass (Glass C).

3.3. Glass D: Low-e

The transmission of Glass D (low-e) was 79,22% in the visible region, which can be considered strong and superior to that of solar control glasses. Such glasses reduce the thermal losses by radiation in the winter. A 52,75% transmission in the IV region favors heating (Fig. 4).

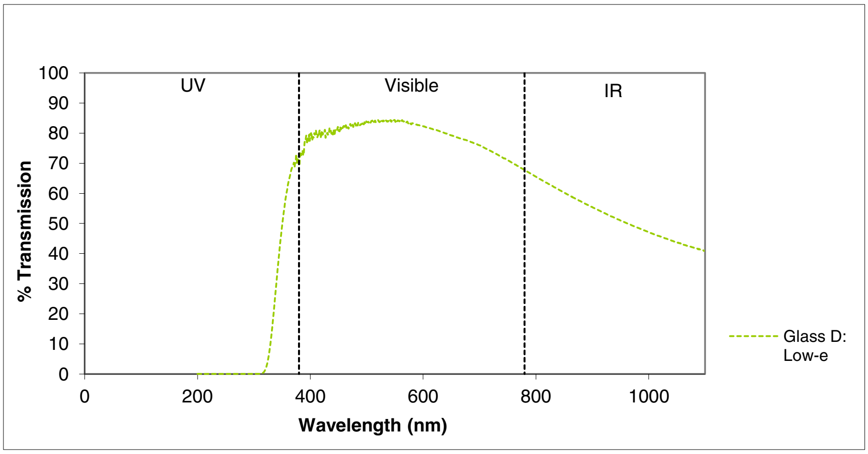


Fig. 4. Glass D: Transmission curve: Low-e glass (Glass D).

Fig. 5 shows all transmission curves. According to the results, Glasses A and B (solar control - translucent and green) provide good illumination and weaken the infrared radiation in the interval analyzed, which reduces the heating. Therefore, such glazings can be efficient in the decrease of the nominal needs for cooling. The solar control glasses (Glasses A and B) have shown little transparency to the ultraviolet, therefore, they can be adequate for shop windows, commercial centers, museums and even residences. The green one is known to always tend to decrease transmission in longer wavelengths.

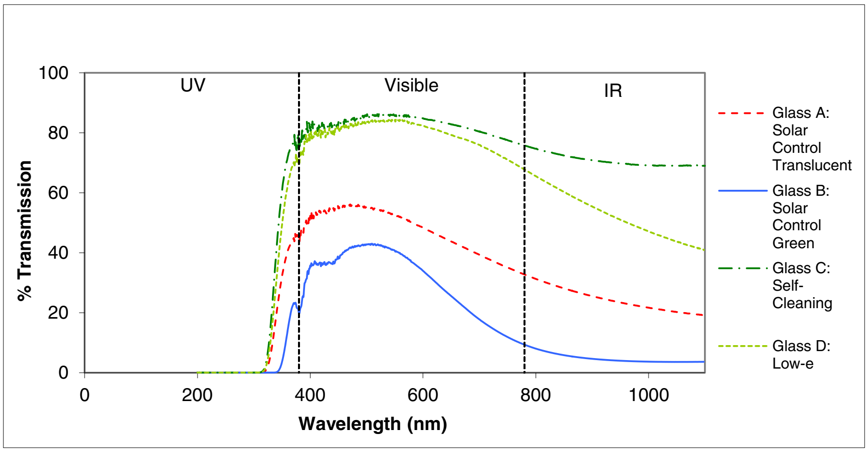


Fig. 5. Transmission curves.

Glass C (self-cleaning) led to a transmission similar to that of Glass D (low-e) regarding visible radiation. The transmittance in the infrared interval indicates stronger heating in an indoor habitable space with the use of such glazings.

4. Conclusions

As the climate in Portugal is temperate, the ideal glazing should work as a barrier against ultraviolet radiation and enable the passage of visible light for favoring daylighting, i.e., transmission in the visible region and a small amount of heat from the near infrared for the heating of the indoor environment. Low-emissivity glazings display those characteristics, as they usually show good thermal performance for temperate climates. The results of high transmission in the infrared for some materials analyzed show their adequacy for use in countries of predominantly cold weather.

Each type of glazing leads to distinct transmissions for each band of the solar spectrum. The conception of good daylighting and thermal comfort requires attention regarding the location and orientation of the building, but also variations in natural light in function of the seasons of the year, time and weather conditions. The results of the spectrophotometric tests show defining transmission as adequate only in function of the luminous transmission (in the visible region) of the glazing may not be correct, as the transmission in other intervals will also influence the thermal comfort.

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