# Double Glazings: Spectrophotometric Characterization for Facade Modules

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ABSTRACT: Glazing contributes significantly to heat transfer between outdoor and indoor spaces and these surfaces act directly on daylighting and thermal comfort. Based on these aspects, spectrophotometric characterization of double glazings was accomplished to study components for a modular facade system for the climate of Portugal. This study focused on results of spectrophotometric measurements of optical behavior in the different solar spectrum intervals – ultraviolet, visible and near infrared, specifically transmittance of two types of double glazings. The first double glazing presents a single pane of green glass with a solar control foil and a single pane of a glass with an extremely low-emissivity foil; the second one presents a single pane of self-cleaning glass and a float clear annealed glass. Results show the percentage of transmission to spectrum intervals, which enabled the verification of the efficiency of the glazing in terms of daylighting and the correlation to thermal performance. These results generate subsides and indications for specification and adequate uses of transparent surfaces, and also complements the datasheets available from the manufactures.

***Keywords*** *Facades; Daylighting; Double Glazing; Spectrophotometer Tests; Energy Efficiency.*

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## 1. INTRODUCTION

The specification of transparent materials for building facades requires the careful consideration of the product performance characteristics and building codes, among other demands. 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 in the façade design 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 (Sacht, 2013).

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 (Caram, 1998).

The transmission of glazings also depends on the wavelength of the incident radiation. People typically spend many hours in buildings bathed in the ultraviolet, visible, and infrared radiation produced by natural or electric lighting, which can damage tissue regardless of their possible influence on the visual and circadian systems (Boyce, 2010).

Baldinelli (2009) 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.

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 & Kim (2010). 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.

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Li et al. (2015) present a spectroscopic method developed to determine the optical constants of float glass material including refractive index and absorption coefficient based on the transmittance spectra modeling. The transmittance spectrograms of single float glass glazing units at normal incidence with different glass thicknesses in the wavelength 337–900 nm were measured. The optical properties of single and double glazing units were numerically investigated and results show that the optical performance of glazing units reveals a considerable difference in the measured wavelength region.

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.

Based on these aspects, spectrophotometric characterization of double glazings was accomplished for the study of glazing components for a modular façade system for the climate of Portugal. The study focused on results of spectrophotometric measurements of optical behavior, in the different solar spectrum intervals – ultraviolet, visible and near infrared, specifically transmittance of two types of double glazings.

## 2. MATERIALS AND METHODS

The development of this 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 Glasses Specimen

Rectangular samples of 50mmx50mm dimension were used for the tests. The spectrum measurement range was 200 to 1100nm, which comprehends three regions: ultraviolet (200 to 380nm), visible (380 to 780nm) and near infrared (780 to1100nm).

The double glazings were fixed in a hard paper device (Fig. 1 a-b).This device enabled the configuration of the double glazings with an indoor air layer. The samples were placed 6mm from each other in the spectrophotometer, differently from the usual position, i.e.,

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12mm. However, the results would be significant for the analysis of the influence of the air layer on the transmission of the double glazings. Table 1a-b presents the description of the samples analysed.

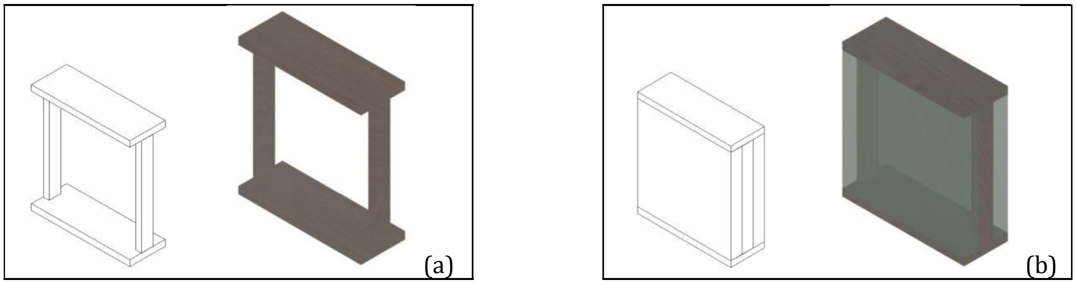



Figure 1. a-b. Device made with hard paper for the conformation of the double glazing (a); device with the specimens positioned (b).

Table 1a. Description of the Glass Specimens.

| Simple Glazing | | | | |
|---|---|---|---|---|
| Identification | Type of Glass | Thickness | Number of Specimens 50x50 mm | Position of Coating |
| Glass B | Green glass with a solar control metallic foil that confers it characteristics of solar control | 6mm | 3 | Face 2 |
| Glass E | Glass with an extremely low-emissivity foil. | 6mm | 3 | Face 2 |
| Glass C | Self-cleaning glass manufactured by depositing a transparent layer of photocatalytic and hydrophilic mineral material onto clear glass. | 6mm | 3 | Face 1 |
| Glass G | High quality, clear annealed glass, manufactured by the float process. | 6mm | 3 | No coating |

Table 1b. Description of the Glass Specimens.

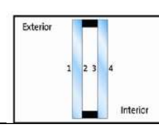
| Double Glazings | | | | |
|---|---|---|---|---|
| Identification | Type of Glass | Thickness | Number of Specimens 50x50 mm | Position of Coating |
| Glazing 04 | Glass B<br>Glass E | 18mm* | 3 | ** |
| Glazing 07 | Glass C<br>Glass G | 18mm* | 3 | ** |
| | **Faces of Double Glazing**<br>*6mm - Air layer 6mm – 6mm | | **  | |



Table 2 shows the samples of the selected glazings to provide the visual aspect of the selected materials. In the samples, the rusty part corresponds to the abrasion band on the face with the film, so that the glazings could be correctly positioned in the spectrophotometric characterization tests.

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Table 2. Specimens of Glasses

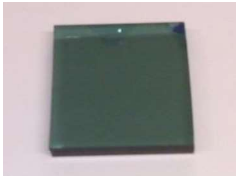
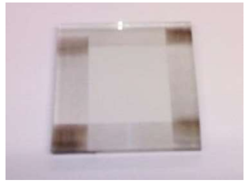
| Glass B (green solar control) | Glass E (extremely low-e) | Glass C (self-cleaning) | Glass G (clear float annealed) |
|---|---|---|---|
|  |  |  |  |

Table 3a-b shows other characteristics of the studied glazings, as the U-values, solar heat gain coefficient (SHGC), shading coefficient and relative heat gain ($W/m^2$).

Table 3a. Characteristics of the Glazings.

| Simple Glazing | | |
|---|---|---|
| Characteristics | Glazings | |
| | Glass B (green solar control) | Glass E (extremely low-e |
| Thickness | 6mm | 6mm |
| U-Value ($W/m^2K$) | 5.68 | 5.66 |
| Solar Heat Gain Coefficient (SHGC) | 0.43 | 0.62 |
| Shading coefficient | 0.50 | 0.71 |
| Relative Heat Gain ($W/m^2$) | 351 | 485 |
| Characteristics | Glazings | |
| | Glass C (self-cleaning) | Glass G (clear float annealed) |
| Thickness | 6mm | 6mm |
| U-Value ($W/m^2K$) | 5.80 | 5.80 |
| Solar Heat Gain Coefficient (SHGC) | 0.81 | 0.85 |
| Shading coefficient | 0.94 | 0.98 |
| Relative Heat Gain ($W/m^2$) | 631 | 657 |

Table 3b. Characteristics of the Glazings.

| Double Glazings | | | |
|---|---|---|---|
| Characteristics | | Glazings | |
| | | Glazing 04 (double) | Glazing 07 (double) |
| Pane | Outer | Glass B | Glass C |
| | Inner | Glass E | Glass G |
| Thickness | | 18mm | 18mm |
| U-Value ($W/m^2K$) | | 2.36 | 3.10 |
| Solar Heat Gain Coefficient (SHGC) | | 0.33 | 0.71 |
| Shading coefficient | | 0.38 | 0.82 |
| Relative Heat Gain ($W/m^2$) | | 260 | 543 |

## 2.2 Spectrophotometer tests

According to the ASTM (1993), the 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.

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The device used for the tests was the UNICAM UV/VIS (Fig. 2). It can provide data on absorption, reflection and transmission of the tested materials. Due to the purpose of this research was only used the mode of transmission. A tungsten lamp was used for the whole spectrum. The samples were tested at 0° with the 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 analyzed glasses.

Figure 2. Spectrophotometer UNICAM UV/VIS.

The glazings with special films (except the self-cleaning one) were tested with their face treated, facing the inner part of the device and not in contact with the sheaf of light. Such a procedure was performed according to the manufacture´s recommendation that 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 the air.

The software started the sweeping procedure at 200nm with the equipment closed and ended at 1100nm. A 200 to 1100nm spectrum was analyzed in this spectrophotometric characterization test. Another division was created in this interval and other sub-intervals were generated to characterize the ultraviolet (300 to 380nm), visible (380 to 780nm) and part of the infrared (780 to 11nm) regions.

## 3. RESULTS

The experimental results from the spectrophotometer are provided in graphs for a good visualization of what occurs regarding transmittance inside the glazings studied for each sample subjected to normal incidence of radiation. Such results will be shown per type of glazing in a graph.

Regarding the 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 (Caram, 2002):

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

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The LT coefficient should be 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 curves of results will be discussed based on such considerations and from the point of view of thermal comfort and daylighting.

### 3.1 Glass B, Glass E and Glazing 04

The 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. Regarding visible transmission, the value was 14%. The transmission in the UV and infrared regions has confirmed the solar control characteristics of the glass (Fig. 3), which are lower in comparison with the simple float glasses.

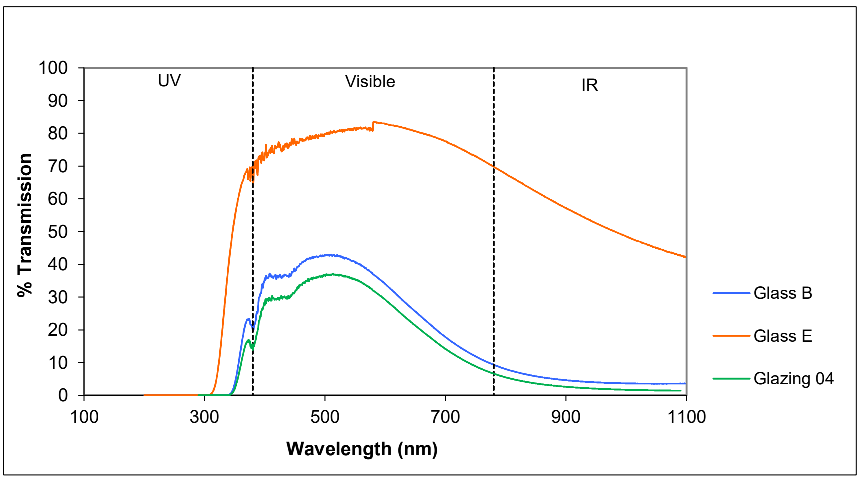


Figure 3. Transmission curves: Glass B, Glass E and Glazing 04

The Glass E (extremely low-e) in terms of transmission presents 15.94% transmission in the UV region, 78.07% in the visible region, 54.38% in the infrared and 57.10% total transmission.

A substantial decrease was observed in all regions of the spectrum for Glazing 04, composed of the Glass B (green solar control), an air layer and Glass E (extremely low-e). The visible and infrared regions, which showed percentages of 25.15% and 2.63%, respectively, must be highlighted. The lowest transmission values among all analyses in the infrared interval have proven the efficiency of the use of such glazing (25.15%) in the decrease of nominal cooling needs in terms of visible transmission. A decrease in the transmission is observed for a green glass of solar control (outer) and low-e glass (inner).

### 3.2 Glass C, Glass G and Glazing 07

The percentage of transmission of the Glass C (self-cleaning) in the UV region was 17.03%. Regarding visible light, it transmits 82.52%, which guarantees a high transmission and better conditions of daylighting. In terms of infrared radiation, its transmission is 70.78%, which indicates its use will cause higher heating in the indoor environment, however with a small decrease of UV radiation (Fig. 4). 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.

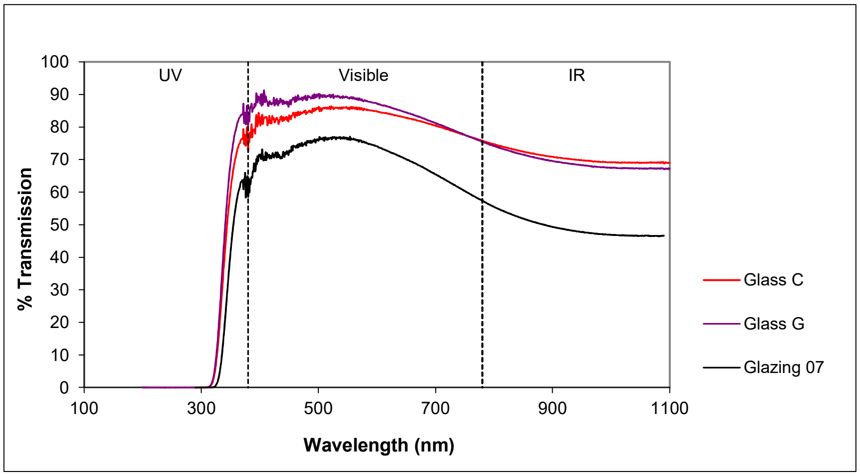


Figure 4. Transmission curves: Glass C, Glass G and Glazing 07

Glazing 07, composed of Glass C (self-cleaning), a layer of air and Glass G (clear float annealed) has shown a percentage of transmission in the UV region of 23.92%. Regarding visible light, it transmits 70.34%, which guarantees high daylighting. In terms of infrared irradiation, its transmission is close to that of Glass E (extremely low-e), which indicates its use may heat the internal environment, however with a small decrease in the UV radiation transmission. In this case, the self-cleaning coating caused no differences in terms of transmission in comparison to the composition of double glazing with the low-e glass analyzed.

## 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 the visible light to favor daylighting. In other words, such glazing should enable good transmission in the visible region and a small amount of heat from the near infrared so as to help 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.

According to the results of the spectrophotometric tests, the lowest values of total transmission and in the visible and infrared intervals were observed for the Glazing 04, which employs the Glass B (green solar control) in the outer pane and Glass E (extremely low-e) as inner pane. The lowest transmission result was observed for the simple Glass B for the ultraviolet region. Such a characteristic has proven the performance of the green glass was good for use in climates in which the decrease in the nominal cooling needs is a priority.

The total transmission of Glazing 07 (Glass C-self-cleaning in the outer pane and Glass G-clear float annealed, in the inner pane), mainly in the infrared region, has also proven its efficiency regarding the decrease in the heat energy needs. The data of transmission of

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solar radiation are directly related to the thermal comfort conditions, principally in relation to the results for the infrared interval.

Each type of glazing has led to distinct transmissions for each band of the solar spectrum. The conception of a good daylighting system and thermal comfort requires attention regarding the localization and orientation of the building, but also the variations of the daylight in function of the seasons of the year, time and weather conditions. The results show that evaluates the transmission only in function of the luminous transmission (in the visible region) of the glazing is not adequate and may not be correct, because the transmission in the other intervals will also influence the thermal comfort.

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