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Polycarbonate panels for buildings: Experimental investigation of thermal and optical performance

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ABSTRACT

Plastic transparent components are increasing their share in the glazing market since they provide good performance with a weight significantly lower than glass and at competitive costs. Typical products are coextruded polycarbonate multi-sheets systems, UV-protected to avoid the quick ageing. These components have limitations on the size and need to be bonded each other via male–female joints that could be a weak point for the façade.

This study is focused on the thermal and optical characterization of three polycarbonate systems for buildings (with different number of chambers and geometry). Thermal transmittance measurements were carried out using a hot-box apparatus, in order to assess the impact of the connection joints on the effective *U*-value and to compare it with data declared by manufacturers, usually referred to the centre of the component. The optical characterization was carried out to monitor the same issue for the light and solar properties, by means of a large integrating sphere apparatus. The investigated polycarbonate systems could be a valid solution in place of classic windows in commercial buildings and the study provides a deepened knowledge about the polycarbonate panels' thermal and optical behaviour and a set of useful data for accurate analyses in building integration.

1. Introduction

Transparent systems are very important elements in buildings, for windows, façades, shed and skylighting roofs, and in external areas for arcades. The thermal and solar transmittance, transparency, the size and the orientation of transparent elements deeply influence energy use in buildings [1]. Commercial and office buildings have large glass windows in order to provide a physical and visual connection to outside. Windows are in fact important both for a nice view and for creating a comfortable indoor environment. They allow the solar radiation getting into the buildings, affecting the heating and cooling demand and the indoor thermal comfort [2–4]. Transparent insulating innovative systems could be used in order to obtain both transparency and thermal insulation [5–8]. Nevertheless they are generally too expensive and many cheaper materials have been diffusing such as polycarbonate sheets and panels.

The use of polycarbonate can enhance daylighting in architectural design at lower costs and, at the same time, significant energy savings in commercial and industrial applications could be achieved, thanks also to multiwall polycarbonate panels designed for improving thermal performance. Moreover, in these applications, visual connection to outdoors is not as important as the incoming light, which gives a more comfortable environment, and it should be avoided in some situations like industrial areas.

In the present paper, multiwall sheets in co-extruded polycarbonate are investigated as a solution for commercial and industrial buildings. The aim is the study of thermal, optical and solar properties of cell structure polycarbonate boards, with different cell geometric characteristics. The installation of these systems takes place thanks to male–female interlock joints, which ensure perfect water-tightness, without needing any sealants. Geometric and constructive characteristics of PC panels make the component complex in the geometry; therefore, the influence of the joints should be deeply investigated both in terms of thermal, lighting, and solar performance [9].

When components cannot be treated as homogeneous (such as when the structure is made of different materials or when the heat transfer is two- or three-dimensional), different approaches are needed to evaluate accurately their thermal resistance: numerical evaluations can be useful, but they need to be integrated by experimental validations [10,11]. In the paper, thanks to the calibrated Hot Box apparatus [12], the thermal performance was measured on assembly panels, simulating in situ behaviour, and the impact of the male–female joints on global performance was investigated.

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Fig. 1. Example of a building with PC façades (DAP Studio in Bergamo, Italy. Courtesy of SEP).

Moreover, conventional instruments as spectrophotometers cannot measure optical properties of such panels because of the geometry and structural complexities, as well as for scattering phenomena in non-regular materials [13]: therefore advanced experimental facilities were used in the paper [14], allowing a careful optical characterization of the material, also depending on the light incidence angle. In fact several studies and international research projects demonstrated that complex glazing systems have a different angular dependence of optical properties with respect to conventional glazing units and require advanced modelling and testing, since no standards exist for such products [15–17].

The accurate experimental analysis provides reliable data that overcome the often ambiguous and incomplete commercial sheets provided by manufacturers. They could be used as input for building energy and lighting analyses, reducing the calculation uncertainties and removing the simplifications often associated to usual calculation tools [18–22] with more reliable results.

2. Materials: Polycarbonate panels

Polycarbonate plastic is mouldable, durable, lightweight, flame resistant, and shatterproof. One of its best properties is high-impact resistance, which can be more than 200 times greater than tempered glass. Polycarbonate panels for building applications are weather resistant and UV protected, making them an efficient solution for non-residential buildings: they could be used as fenestration systems, continuous windows, shed, roofs, walls, and finally indoor partitions.

Polycarbonate sheets can be as clear as glass, translucent, or completely opaque, depending on the specific use. The panels can be flat or corrugated, rigid or flexible, thick or thin. Moreover, different colours are available for vertical façade panels and custom colours or texts could be used in buildings. Indeed, light and colour in architecture are two important aspects deeply investigated in the literature [23].

A lot of products with different cell geometric characteristics, colours, thicknesses and kind of application are available in the market. They have been spread both in the USA and Europe, above all in commercial and industrial buildings (Fig. 1).

In the paper three types of multiwall panel in co-extruded polycarbonate were investigated considering different alveolar structures. They could be considered representative of a wide range of polycarbonate systems: few chambers, many chambers, intermediate number of chambers with major geometry complexity and they could represent a possible and cheaper option for non-residential buildings instead of standard glazing façades.

They present different geometric characteristics of the cell, but they have the same total thickness (0.04 m). Type S3 consists of three walls, two external layers (about 1 mm thickness) and an internal one (0.14 mm thickness), with and a double-chamber with air. The polycarbonate panel S5 has a multi-wall section, with triangular shape of the internal structure. Finally, Type S9 consists of nine walls and eight chambers. In all cases, the outdoors layer is UV protected.

The panels are manufactured with a maximum width of 0.435 m, so they need to be installed in buildings thanks to male–female joints that could be a weak point for the façade.

Table 1 shows the main characteristics of the examined samples.

3. Experimental facility and methodology

3.1. Conventional spectrophotometer for optical measurements

Optical measurements were carried out using a Perkin Elmer Lambda 950 spectrophotometer. It is a double beam type and is equipped with a 150 mm Spectralon coated integrating sphere: measurements were carried out in the 300–2500 nm wavelength range, with a spectral resolution of 5 nm, covering the whole solar spectrum as defined in the relevant standards [24,25]. The slit aperture was set to 2 nm in the visible range and in servo mode (slit size variable according to the optimal energy input) in the near infrared range.

Because of the thickness and the geometry of the samples, preliminary measurements showed that the instrument is not adequate for complex assembled components. The spectrophotometer was used to measure reflectance and transmittance of the single PC layers used to assemble the component. Reflectance measurements were carried out versus a calibrated reference in Spectralon. Broad band values were calculated starting from the spectral data in compliance with EN 410 standard [25–27].

3.2. Large diameter integrating sphere facility for optical measurements

As stated in the previous section, commercial spectrophotometers are not suitable for the characterization of complex transparent systems, because of geometrical and constructive limitations. For these reasons accurate measurements are not possible for samples characterized by complex geometry, high thickness or bulk scattering properties. A large diameter integrating sphere apparatus is needed to perform accurate measurements on such materials [14]. The schemes in Fig. 2 show the system configuration of the optical facility used for the characterization of the PC samples described