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Experimental Analysis of Transparent Insulation Based on Polycarbonate Multi-Wall Systems: Thermal and Optical Performance

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Abstract

The way for a new ideas and latest developments in research of various innovative materials are becoming the basis for a variety of potential combinations in future building components and facade concepts. Transparent insulation materials (TIMs) could predominantly be used with current concepts that are trying to replace conventional insulating materials in addition. Various polycarbonate multiwall systems are analyzed from thermal and optical point of view. Thermal and solar transmittance are experimentally determined. For the thermal transmittance, an inclined angle dependence is investigated with laboratory methods. On the other hand, the solar transmittance depending on the incident angle is observed, both at spectrophotometric laboratory and in-situ outdoor level. Obtained results demonstrate a relation between both material parameters studied and their real angular modes. Based on presented analysis, multi-wall polycarbonate building components may have a relevance for future facade concepts, especially when specific solar angular dependencies and certain thermal properties need to be considered.

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Keywords: Solar transmittance; Thermal resistance; Polycarbonate systems; Transparent insulation; Angular dependence; Spectrophotometry

1. Introduction

Currently, research and development is in great demand in the field of comprehensive building solutions and the implementation of advanced forms of materials in construction. Furthermore, the challenge is to achieve flexibility in the manufacturing of building façade components in order to adapt them to different types of facades and meet our current needs. Recently, a wide range of progressive solutions have been investigated. Another related research topic is development and evaluation of different technical solutions and integration of new materials. It could be the one of

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the ways to improve thermal and energy performance of current building and including of new technologies [1] [2]. Possible way of development of solar technology includes even development of materials based on various optical performance. The transparent insulation materials (TIMs) [3] could predominantly be used for current concepts that are trying to replace conventional insulating materials in addition. However, their involvement in building envelope is specific; therefore, application in our building practice is currently rather rare. Several studies describe benefits of TIMs, disadvantages and possibilities of their application [4]. One of these approaches is related to various Polycarbonate systems, that may be applied nor as direct transparent form of building envelope, but also as the part of potential solar façade concepts. Here, various types are already developed specifically from thermal aspect point of view. On the other hand, their optical variety needs to be investigated in detail, both from spectral, angular and real outdoor perspectives, that might primarily be used in order to adapt parameters easily and flexibly into simulation models. As the application of Polycarbonate systems are increasing, it is necessary to analyze in detail data for the materials which are already available.

One of the assumptions in the field of experimental approach is based on appropriate quantifying an angular optical and thermal properties of the analyzed materials. Therefore, this issue related to presented concept should be quantified, in terms of thermal and optical performance, at several specific fields. The first area focuses on the transparent material character, solar transmittance needed to be determined at angular and spectral optical level. From thermal aspects point of view, thermal resistance is analyzed at temperature dependence and inclined angle level.

2. Methodical approach and analyzed systems

The key intention of this study resides in investigating the optical properties and thermal performance of Polycarbonate components that are primarily based upon multi wall systems. The main objective relies on:

i. Thermal performance studies of selected systems. Based on determining the parameters of thermal resistance and equivalent thermal conductivity, standardized measurement procedures are applied, the dependency of thermal conductivity on temperature and the inclined angle is conducted (selected sample inclined angle of 0°, 45°, 90°),

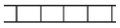
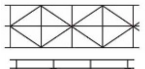
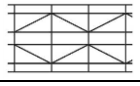
ii. Optical performance studies. Based on determining the parameters of spectral, incident angle and total solar transmittance of Polycarbonate multi wall systems, dynamic outdoor principles and spectral methods were applied and confronted at laboratory and outdoor level.

For laboratory analysis: The samples were prepared directly from existing polycarbonate systems: standard two wall system and several representative multi wall systems of different internal structure. Polycarbonate samples were prepared into particular dimensions specifically needed for each measurement phase respectively.

The table (Tab. 1) shows all the measured samples and typical characterization. As can be seen, the main difference between all applied is in their overall thickness and structure of their internal division.

For outdoor studies: polycarbonates were analyzed on two different modes. First corresponds to short-term measurements based on randomly obtained angular observation, whilst second employs long-term measurements applied on vertical south-west and north-east oriented full-scale components located at the research center AdMaS of Brno University of Technology [5] (longitude 16°34´, latitude 49°14´, altitude 297.23 m). Finally, comparison with declared values by the producers is discussed as well.

Table 1. Sample description

Sample	Type	Thickness [mm]	Weight [kg.m^{-2}]	Declared U value [W.m^{-2} K^{-1}]	Declared Solar Transmittance [-]	Internal structure
PC10	Clear 2walls	10.3	1.7	3.0 (*0.165**)	0.82	
PC20	Clear 7walls	20.7	3.0	1.6 (*0.457**)	0.62	
PC25	Clear 3walls /diagonals	25.1	3.4	1.6 (*0.457**)	0.63	
PC32	Clear 6walls combined	32.5	3.6	1.3 (*0.601**)	0.53	

* Calculated thermal resistance from U value based on surface transfer coeffitient 0.168 W.m^{-2}K^{-1}