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Total Solar Transmittance Quantifying of Transparent Insulation Building Materials Based on Real Climate Outdoor Measurements

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Abstract

Solar transmittance belongs to the optical properties that are more frequently required in the field of buildings as those specifically related to solar energy and thermal aspects point of view. A possible method for the measurement of solar transmittance of building's systems and materials was introduced and tested. The method is based on an outdoor climate conditions and two pyranometers setup applying of comparative in-situ measurement approach. The experimental setup was contrasted by spectrophotometer method and its validity was tested by measurements comparison with different options to obtain the best solar transmittance determination in an outdoor uncontrollable condition. Although, these measurements are applicable only for the particular measurement environment, they can easily provide an information about studied parameters. A good agreement was found and the introduced method was verified for a typical building's transparent and translucent systems like simple glass pane and Plexiglas. This was also implemented for the solar transmittance determination of a particular transparent insulation material in the form of honeycomb on Poly Methyl Methacrylate basis. Coupling of the two pyranometers (or photodiodes) with the monitoring of solar intensity behind and in front the measured materials and its ratio estimation enables its applicability as an alternative, integrated and less cost consuming method towards the characterization by more sophisticated spectrophotometer or solar simulator method.

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Keywords: Solar transmittance; Outdoor measurements; TIMs; Spectrophotometry; Transparent; Translucent; Pyranometer

1. Introduction

Currently in the building sector, there are continuously needs for determining building physical and optical properties of structures, systems and components. Transparent and translucent building structures form an important part of building envelopes. Besides thermal quantification of transparent and translucent systems, optical properties

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are equally important parameters, particularly optical properties such as solar transmittance etc. There are several ways for measuring solar transmittance, such as laboratory spectrophotometric or indoor solar simulator methods applying of a spectrophotometer or solar simulator for determining the optical properties respectively. For this purpose, various types of devices are developed, e.g. UV/VIS/NIR spectrophotometers or specific solar simulators, whose acquisition costs have a higher requirements and less available character in this sense. The possible limitation of spectrophotometer method is that it can measure obviously certain materials of limited homogenous structure and maximum thicknesses. More thicker materials or specific types of texture based are very difficult to measure or finally it cannot be done at all, thus special prototypes usually need to be used. Another way concerns on solar simulator utilizing, where uniformed, controlled and standardized solar distribution can be exposed to the measured sample and finally determines the solar transmittance as ratio of monitored solar intensities behind and in front of measured sample. The initial idea of this purpose was to obtain solar transmittance parameters of various transparent insulation systems whose internal structures, dimensions and overall thicknesses are specific to measure by available methods, such as spectrophotometry [1]. Several studies aimed to measure the directional-hemispherical (also sometimes called direct-diffuse) solar transmittance for several different honeycomb-type structures with an indoor solar simulator and a 40 cm diameter integrating sphere for incidence angles up to 70° [2, 3]. In this relation, outdoor measurements using the sun as the source might be the option. Platzer [2] point out that it is not an option for Central European climate. Although there are many specific issues to take into account, such as inclined angular dependence, fluctuations of solar irradiation and overall solar distribution as well as cardinal point aspect, we tried to test and verify the using of solar transmittance estimating by real outdoor measurements. This is already implemented in standard test method for solar transmittance of sheet materials using sunlight with detailed specification and procedures according to ASTM E1084-86(2015) [4]. Overall, there is lack information regarding real outdoor measurements in literature as typically used for solar transmittance measurements. This may represent very simple and well available way of measuring the total solar transmittance parameter.

2. Objective and method

The object of this study demonstrates an availability and simple use of two pyranometers setup and/or alternatively two small photodiodes [4] as a solar detector for possible substitution of measuring a total solar transmittance using the sun as the source. During measurements were obtained data with aim to develop and optimize final experimental setup as contrasted with spectrophotometry results. Own measurement apparatus was proposed taken fundamental specification of ASTM E1084-86(2015) into account. Finally, two pyranometers implemented in square boxes and third additionally opened to the outdoor conditions were applied in order to determine the total solar transmittance of typical building transparent and translucent materials, such as transparent insulation material etc. All results were taken during measurements where maximum sun height above horizon has been achieved during midday at 60° conducted at the research center AdMaS of Brno University of Technology (longitude 16°34´, latitude 49°14´, altitude 297.23 m).

Two different methods were contrasted. First based on laboratory spectrophotometer measurements, a Perkin Lambda 1050 UV/VIS/NIR spectrophotometer with a 150mm Spectralon integrating sphere was used to measure solar spectral transmittance. This apparatus can register spectral properties ranging from 200 nm to 3300 nm. Spectral curves and integrated Total Solar Transmittance (TST) values from 280 to 2 500 nanometers are obtained. Second method is based on proposed outdoor experimentation applying of comparative in-situ measurements approach using the sun as the source.

3. Presented concept and procedure of test setup development

As aforementioned, the initial idea of this research was to obtain solar transmittance parameters of transparent insulation material in the form of honeycomb on Poly Methyl Methacrylate basis as well as Polycarbonate systems that are strongly specific to measure by available methods, such as spectrophotometry. The first concept of measuring was simply based on two pyranometer sensors, one implemented into square cardboard box covered by white office paper including measured sample to obtain required data. Overall, we integrate three pyranometer sensors for this study, whose mutual accuracy were contrasted. Only at their maximum peaks, some deviations were measured,