Infrared Physics & Technology 79 (2016) 135–143

Contents lists available at ScienceDirect

Infrared Physics & Technology

journal homepage: www.elsevier.com/locate/infrared

Set-up of an experimental procedure for the measurement of thermal transmittances via infrared thermography on lab-made prototype walls

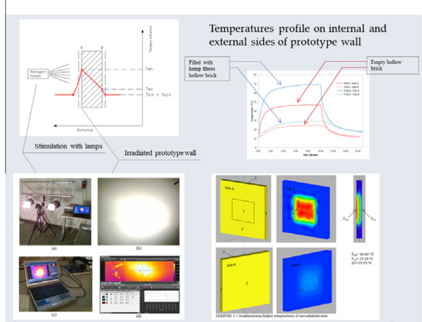
Antonio Donatelli *, Patrizia Aversa, Vincenza Anna Maria Luprano

ENEA – Italian National Agency for New Technologies, Energy and Sustainable Economic Development, SS Appia 7, km 706.00, 72100 Brindisi, Italy

HIGHLIGHTS

- Infrared thermography for thermal transmittance measurement.
- Alternative method to heat flow meter approach.
- Set-up of an experimental method to be applied both on prototype walls and partition walls in buildings.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 3 October 2016
Accepted 17 October 2016
Available online 18 October 2016

ABSTRACT

In this paper an experimental set-up measurement for the evaluation of the thermal transmittance of opaque elements has been developed. It is based on infrared thermography and it is suggested as alternative to the standard approach set by the ISO 9869:1994 based on heat flow meter (HFM) measurement which is widely accepted by scientific audience.

The proposed method has been designed in order to overcome the following restrictions of HFM method: long measuring times (about 72 h), weather conditions as constant as possible and at least a difference of 10–15 °C between the temperatures of internal and external sides of walls.

In this work, the alternative method proposed is widely described and applied on lab-made prototype walls: the results are encouraging, showing discrepancies with theoretical U-values, determined in accordance with international standard ISO 6946:2007, in the range −3.5 to 2.9%. The thermal transmittances were also calculated with a commercial software based on finite element analysis; the obtained results were in good agreement with the experimental ones. Moreover, the simulations pointed out that the values obtained on lab-made prototype walls are similar to those associated with partition walls which separate rooms with different environmental conditions.

1. Introduction

The energy efficiency of buildings plays a strategic role in achieving the target of "almost zero consumption" indicated by the European Directive 2010/31/EU [1]. For this, the analysis or

* Corresponding author.
E-mail address: antonio.donatelli@enea.it (A. Donatelli).

http://dx.doi.org/10.1016/j.infrared.2016.10.005
1350-4495/

Nomenclature

h_c	convective heat transfer coefficient (W m^{-2} K^{-1})
$\dot{Q}$	heat flow (W)
R	thermal resistance (m^2 K W^{-1})
T	temperature (°C)
U	thermal transmittance (W m^{-2} K^{-1})
v	wind velocity (m s^{-1})
V	volume (m^3)

Greek symbols

λ	thermal conductivity (W m^{-1} K^{-1})
ε	emissivity
ρ	density (kg m^{-3})

Subscript

abs	absorbed
h	hollow
hb	hollow brick
in	referring to the internal side
loc	referring to "close to the wall" position
out	referring to the external side
rad	radiated
ref	reflected
sb	solid brick
tra	transmitted
wc	referring to the cold surface wall
wh	referring to the hot surface wall
10	referring to free stream at z = 10 m

the energy audit of buildings are effective tools, and even rapid, for new building designs or to take action on the energy renovation of existing buildings, which generally are characterized by inefficiencies that lead to wasted energy. Requalification aims decreasing the energy consumption of a building and CO_2 emissions. Moreover it leads to decreasing expenses charged to the citizen and to the public administration.

An element on which the design or the analysis of a building primarily focuses the attention is the wall: a proper evaluation of the adequacy of opaque elements as thermal barriers is mandatory. The parameter that expresses how easily an opaque wall permits the heat transfer is the thermal transmittance: the lower the thermal transmittance, the greater the resistance that the opaque element opposes to heat transfer.

Thermal transmittances of opaque elements must be calculated in according to ISO 6946:2007 [2], which provides the method of calculation of the thermal resistance and thermal transmittance of building components and building elements, excluding doors, windows and other glazed units, curtain walling, components which involve heat transfer to the ground, and components through which air is designed to permeate.

To date, measurements of the thermal transmittance of horizontal and vertical opaque elements based on heat flow meter (HFM) and according to standard ISO 9869:1994 [3] are widely accepted and they provide values similar to theoretical ones, calculated in accordance with ISO 6946:2007, with differences in the range 15–40% [4–7]. Nevertheless, this technique presents some limits, hereinafter listed:

i. long measuring times (about 72 h);
ii. weather conditions as constant as possible. Unfortunately, weather changes can be frequent during the measurement and this phenomenon affects the measure that must be repeated;
iii. HFM requires at least a difference of 10–15 °C between temperatures of internal and external sides of walls; such differences are not frequently experimented in the Mediterranean Area, to which this work refers, and in particular during summer.

In order to overcome these limits, a different experimental setup measurement for the evaluation of the thermal transmittance of opaque elements has been developed. It is based on thermography applied to lab-made prototype walls, in alternative to the widespread method based on heat flow meter measurements according to standard ISO 9869:1994.

It is worth mentioning that thermography (infrared method) is already applied for the thermal analysis of buildings; indeed the international standard EN 13187:1998 [8] establishes the guidelines for the qualitative detection of thermal irregularities in building envelopes. Our aim has been the evaluation of possibility of using thermography also for quantitative analysis of opaque elements, in particular on lab-made prototype walls. Albatici and al [9,10] already performed some in-situ measurement of thermal transmittance using the infrared thermovision technique and obtaining results close to theoretical ones. They highlighted the issues related to the difference between inner and outer temperatures and the consideration that the measurement based on infrared thermovision is relatively fast, as we already observed.

Fokaides and Kalogirou [11] determined the U-value of typical building constructions in Cyprus using IR thermography and validated the results with the notional values obtained from relevant EN standards and the use of thermohygrometer for two seasons, summer and winter and with the use of heat flux metres. They found that the percentage absolute deviation between notional and the measured U-values for IR thermography was in an acceptable range of 10–20%.

The main difference of our approach compared to the previous is the possibility to carry out measurements on prototype walls and therefore can be very useful in the constructions of new buildings, in which innovative materials are involved. In this way, the thermal transmittance of a wall before its employment in building construction could be possible, avoiding the adoption of an incorrectly designed stratigraphy. Moreover, the measurement on prototype walls in laboratories could allow technicians performing measurement throughout the year, avoiding the above-mentioned restriction of a difference of 10–15 °C between indoors and outdoors.

In particular, with the perspective of implement solutions that enhance sustainability compared to state of the art, in our study we have used hemp fibres as insulating material, thus preferring vegetable and locally sourced materials.

2. Materials and apparatus

For the experimental investigation, two prototype walls were realized:

– "*Wall I*": a lab-made prototype wall, composed by 16 commercial hollow bricks purchased by Wienerberger ($80 \times 250 \times 250$ mm, with 10 hollows arranged in two rows and whose sizes are $30 \times 40 \times 250$ mm) and plastered on both