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New measurement procedure for U-value assessment via heat flow meter

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Abstract

Methods for building envelope inspection are well known since 70's. However, measurement instruments and software improve, making methods for building envelope inspection susceptible to further improvements. In particular, the present paper deals with building envelope assessments performed via heat flux meters and reports the outcomes of a monitoring campaign verifying a measurement procedure proposed by the authors. Such a procedure is aimed at the improvement of the accuracy and reliability in the on-field measurement of the U-value of building constructions. In detail, the proposed method exploits an experimental device providing controlled local heating aimed at speeding up the measurement process and limiting temperature fluctuations, with possible improvements over the calculation of the final U-value. The advantages and limits of this measurement procedure are explained in this paper, together with possible future improvements.

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Keywords: heat flow meter; measurement procedure; U-value

1. Introduction

The assessment of building envelope thermal characteristics is critical for the reliable assessment of building energy performances, for energy certification, energy audits and design in case of renovations. Moreover, the reliable assessment of the thermal performances of building constructions is necessary in the case of field verification for the fulfilment of design U-values or for litigations about building construction quality level. The U-value is the parameter

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that mostly characterizes the thermal behaviour of the building construction, especially if ventilation is limited by heat recovery [1]. The assessment of the U-value may take place through standard calculation methods. These methods are based on the calculation of building construction thermal parameters starting from the material layers (and related thermal properties) present in the building construction, according with ISO 7345 [2] and ISO 6946 [3]. In this case, mainly 3 sources of data may be used in U-value assessment. The first uses Abacus: the material layers constituting the building construction and consequent thermal properties are defined by basing on abaci of typical building constructions in analogous buildings, by considering the year of construction or renovation, location and intended use of the building, as well as the building construction's thickness. The second uses design data. The assessment of the material layers constituting the building construction derives from design technical sheets, where available. The third uses endoscopy. The series of layers composing the building construction is assessed by visual inspection and measurement of building construction material layers via endoscopy. Another way to obtain the U-value is the hot box method [4]. It consists in measuring the thermal parameters of the building construction in laboratory, by imposing well-defined boundary conditions taking place in two contiguous thermally controlled rooms sharing the building construction itself. This method is used in testing laboratories for the evaluation of reference building constructions.

Another experimental method uses heat flow meter, for on-site measurement [5, 6] of the thermal behaviour of the building construction and consequent derivation of the main thermal parameters.

Moreover, also assessment procedures based on thermography are used under specific conditions [7]. In order to avoid uncertainties consequent to the actual building realization and the thermal properties of material layers, the heat flow meter method should be preferred, when existing buildings are considered. Anyway, this method requires long measurement periods and the reliability of the derived results is relevantly affected by the presence of fluctuations of internal heat gains and indoor and outdoor temperatures. In particular, the measurement procedure currently used in the frame of the heat flow meter method is characterized by the many sources of uncertainty and the consequent uncertainty contributions (ISO 9869-1 [8]):

- $u_{Sensors}$. This uncertainty is due to the calibration of the heat flow meter and temperature sensors and is equal to about 5 %, after a correct calibration;
- $u_{Data\ logger}$. This uncertainty is related to the accuracy of the data logging system and is usually negligible;
- $u_{Contact}$. This uncertainty is due to the contact thermal resistance between the heat flow meter plate and the internal side of the building construction, approaching about 5 % after a careful installation;
- $u_{Superposition}$. This uncertainty is due to the influence of the thermal field consequent to the superposition of the heat flow meter over a limited area at the internal side of the building construction and is equal to about 2–3 %;
- $u_{Boundary\ conditions}$. This uncertainty is due to the random variation of the temperatures and heat flows consequent to indoor temperature variation and heat gains and to outdoor weather conditions. It can be lowered down to ± 10 %;
- $u_{Temperature\ distribution}$. This uncertainty is due to uneven temperature distribution in the room air and to the difference between air and radiant temperatures, approaching about 5 %.

As a consequence, in case of well performed in-situ measurements, the minimum expectable combined (in quadrature) accuracy is around 14 %. Under real applications, considering the presence of people, heat gains, indoor temperature fluctuations and other differences from desirable measurement conditions, the total accuracy may be far worse, especially because of higher uncertainty due to boundary conditions.

Moreover, the standard heat flow meter application takes long time, according to the recommendations present in (ISO 9869-1 [8]), usually from 3 days up to 7 days and more, in the case of high-inertia walls.

Finally, the conventional measurements via heat flow meter are reliable only when relevant temperature differences are present between the internal and the external environments. In this regard, Desogus et al. [9] show the HFM measurement uncertainty is about 10 % with temperature difference of 10 K between external and internal surfaces, and the measurement accuracy increases with the temperature difference. Moreover, the application in summer conditions is usually not recommended. In literature, Ahmad et al. [10] had accurate results also in summer conditions, but in very particular conditions: very hot summer days, and indoor set-point temperature equal to 22 °C.