Energy and Buildings 86 (2015) 754–765

Contents lists available at ScienceDirect

Energy and Buildings

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

Factors affecting the in situ measurement accuracy of the wall heat transfer coefficient using the heat flow meter method

Xi Meng[a], Biao Yan[a], Yanna Gao[b], Jun Wang[a], Wei Zhang[a], Enshen Long[a,c,*]

[a] *College of Architecture and Environment, Sichuan University, Chengdu 610065, PR China*
[b] *Faculty of Environmental Engineering, The University of Kitakyushu, Kitakyushu 808-0135, Japan*
[c] *Institute of Disaster Management and Reconstruction, Sichuan University-Hong Kong PolyU, Chengdu 610065, PR China*

ARTICLE INFO

Article history:
Received 2 August 2014
Received in revised form 31 October 2014
Accepted 2 November 2014
Available online 8 November 2014

Keywords:
Heat transfer coefficient
Measurement location
Measurement accuracy
Heat flow meter method

ABSTRACT

This paper aims at determining the combined influence of the location of thermocouples and heat flow meters, the size, shape and pasting angle of the heat flow meters on the measurement accuracy of the wall heat transfer coefficient (*U*-value) using the heat flow meter method. A three-dimensional wall heat transfer model is established, including the thermal bridge effects of mortar joints, and validated by thermoelectricity analogy theory. The results show that the measurement error can be up to 6% when the thermocouples are improperly pasted, and up to 26% when the heat flow meters are improperly pasted. It clearly demonstrates that correct layouts obviously improve the measurement accuracy. For a symmetrical structural wall, a higher accuracy can be obtained when the heat flow meter is located on the inner surface, while for an asymmetrical structural wall, the measurement accuracy can be much higher when the heat flow meter is located on the side with greater thermal resistance. The positive error is a maximum when the meter location is at the mortar joint intersection, while the negative error is a maximum when the meter location is exactly at the center of a block. The best distance is 20–32 mm away from the mortar joint edge. Moreover, the size, shape and pasting angle of the heat flow meters have influence on the measurement accuracy with different degrees.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

With the improvement in living standards and indoor comfort requirements, building energy consumption is steadily increasing. As the heat transfer loss in building envelopes accounts 60–80% of the building total heat transfer loss [1], it is of vital importance to create a good indoor environment, and to improve the indoor comfort of occupants and decrease building energy consumption by bettering the thermal performance of the building external envelopes, especially the wall body [2,3]. Therefore, the thermal performance indices of building envelopes are essential and compulsory provisions in the current energy efficiency design standards of China [4–7]. However, there are uncertain factors for completed buildings as to whether the heat transfer coefficients (*U*-values) of building walls can achieve the stipulated design value. For example, the construction contractors' failure in choosing building materials whose thermal performance cannot meet the design standard or he designed scheme, or the effect of cutting corners and allowing construction defects during the construction [8]. All these phenomena, which are common in developing countries like China, result in the wall *U*-value of actual buildings being higher than that of the design standards. For this reason, the in situ measurement in the wall *U*-value is an important auxiliary measure to guarantee the actual thermal insulation of building envelopes and is also an indispensable link in energy auditing, efficiency evaluation and consumption rating, for both new buildings and existing buildings undergoing energy-saving reforms.

In recent years, the measurement method for the *U*-value in lab is relatively mature, and a large number of ISO standards [9–11] and ASTM standards [12,13] have been formulated, and China has also issued relevant standards [14]. So far, the measurement methods are based on one-dimensional heat transfer by establishing a stable temperature gradient over a known thickness of a sample wall in order to control the heat flow from one side to another. The *U*-value is simply determined by measuring the temperature on the surfaces and the heat flow through the sample [15]. The three main methods used in the lab are the heat flow meter method, the guided hot box method and the calibrated hot box method [16,17].

---

* Corresponding author at: Room 112, Administration Building, Sichuan University, No. 24, First Loop South First Section, Chengdu 610065, Sichuan Province, PR China. Tel.: +86 028 85401015; fax: +86 028 85401015.
E-mail address: longes2@163.com (E. Long).

http://dx.doi.org/10.1016/j.enbuild.2014.11.005
0378-7788/© 2014 Elsevier B.V. All rights reserved.

The guided hot box method and the calibrated hot box method are often used to the wall's *U*-value in the lab and have the high measurement accuracy, but they do not suit to the in situ measurement due to the heavy measurement equipments or the complex in situ environments [18–20]. However, the heat flow meter method is most widely applied to measure *U*-values in situ due to the simplicity of the test equipment and system, but there remain concerns about the low measurement accuracy [21,22]. How to increase the measurement accuracy of the heat flow meter method has been a research focus for many scholars.

Desogus et al. [21] conducted a comparative analysis about the measured and theoretical *U*-values for a three-layer wall, containing one layer of the 100 mm fired perforated brick and two layers of 15 mm cement plaster. Their findings showed that the measurement uncertainty was 10%, with temperature difference of 10 °C between outer and inner surfaces, and the higher the temperature difference, the higher the measurement accuracy. Wang et al. [22] investigated the influence of wind speed on the in situ measurement of the *U*-value of the interior insulation wall. Their research showed that wind speed had little impact on temperature but significant influence on the heat flow measurement on the inner and outer surfaces. A data processing method was proposed in consideration of the influence of the wind speed, which was theoretically and experimentally validated. In addition, the research of Peng and Wu [23] showed that the measurement error of the heat flow is the main source of *U*-value errors, and on this basis, the dynamic response method was proposed eliminating the need for measuring the heat flow, yet this method requires an accurate knowledge of the frequency response factor of the wall inner surface in absorbing heat [24].

Cesaratto and Carli [25] and Cesaratto et al. [26] measured the *U*-value of an exterior insulation wall over a period of four years by the heat flow meter method. Their study found that the measurement location had great influence on the measurement accuracy for the same wall. The maximum error was up to 46% relative to the theoretical values. The temperature fluctuation caused by occupant behavior and the outdoor temperature variation also had obvious impacts on the final measurement result, however an increase in the measurement temperature difference between the indoor and outdoor environment can weaken the influence of the temperature fluctuation. Therefore, the measurement accuracy can be improved by deliberately filtering the test data during the periods having larger temperature differences. The variation in the different data processing methods can be up to 20% for the same set of test data.

Aiming at the present data processing methods of the heat flow method, Jiménez et al. [27,28] compared these methods and discussed the achievable agreement when different analysis approaches are applied to the same and different datasets to find the thermal transmittance value of a given building component. Cucumo et al. [29] proposed a method for the experimental determination of the in situ building wall conductance, which can be easily implemented and could also allow the evaluation of the equivalent thermal capacity. This method was applied to a test wall in different periods of time, finding results in agreement with values obtained by means of progressive method. In addition, the heat flow meter method is used to measure the thermal performance of the complex multilayered wall [30]. Gracia et al. [30] created a new equipment to test thermal performance of multilayered building envelopes with PCM based on the heat flow meter method and had an accurate estimate.

Although above studies [21,23,25,26] have mentioned that the location of heat flow meters on the wall surface has a large influence on the measurement accuracy of the *U*-value (or thermal resistance), they did not give convincing explanations as to why were such large errors and how to decrease them. However, there are many factors which influence the in situ measurement accuracy of the *U*-value other than the heat flow meter locations, such as various wall structures, the thermal bridge of mortar joints, the thermocouple pasting location, the pasting angle, shape and size of heat flow meters, etc. These effects still lack in systematic study and due attention.

In this paper, for four typical block wall structures, a three-dimensional wall heat transfer model is established, including the thermal bridge effects of mortar joints around a block validated by the thermoelectricity analogy method. The heat transfer rules are also investigated, taking into account the influence of the thermal bridge of mortar joints. On this basis, the research is conducted on the influence of the thermocouple location, the pasting location, pasting angle, shape and size of the heat flow meter on the in situ measurement accuracy of the *U*-value. Meanwhile, the optimization choice of the pasting wall surface, pasting location and pasting angle of the heat flow meter and the selective purchase of the heat flow meter with the rational shape and size are proposed to improve the in situ measurement accuracy of the heat flow meter method.

2. Physical description and heat transfer model of the wall

2.1. Physical description of the wall

A common wall is often a multilayer structure containing the base wall, the insulation layer or the plaster layer. The base wall is joined by blocks and cement mortar which will become mortar joints after drying up. It is feasible for the wall to be assumed as a multilayer structure composed of the homogeneous material in each layer, without considering mortar joints in conservation design and simulation of building energy consumption. However, the effect of mortar joints must be fully considered for the in situ measurement of the wall *U*-value, because the width range of mortar joints is about 8–12 mm and its volume ratio in the wall varies from 5% to 22% with a single block size according to the relative standards [31] and the practical engineering. However, the thermal conductivity of mortar joints is about 0.87–1.12 W/(m K) [32], which is higher than that of the block. Therefore, the distributions of temperature and heat flow are non-uniform on wall surfaces due to the thermal bridge of mortar joints, and there is more non-uniformity on wall surfaces corresponding to mortar joints. Therefore, when thermocouples are "randomly" pasted on a wall surface, there are errors in temperature measurements since the size of the induction temperature head is much smaller than the width of mortar joints.

On the other hand, the heat flow meters on the market have widths of 10–65 mm, very close to the width of mortar joints. When heat flow meters are "randomly" pasted on wall surfaces near or far away from mortar joints, there are bigger differences in the heat flow measurement. For this reason, the measurement accuracy of the *U*-value will be affected. Therefore, the existence of mortar joints is a key factor affecting the in situ measurement accuracy of the *U*-value.

In order to better understand the physical nature of *U*-value measurement, physical models of four typical block wall structures containing blocks and mortar joints are established. Fig. 1 shows the sections of the four typical block walls along the height direction. Fig. 1a shows the block wall (Wall 1), which consists of blocks and mortar joints and is the core part of any wall; Fig. 1b shows the plastered wall (Wall 2) containing one base wall layer and two plaster layers, which is a typical pattern of traditional interior and exterior walls; Fig. 1c and d shows the exterior and interior insulation walls (Walls 3 and 4) respectively, which contain one base wall layer, one insulation layer and two plaster layers, and are typical patterns of insulation walls. Although the above four typical structures of block

Download English Version:

https://daneshyari.com/en/article/6733029

Download Persian Version:

https://daneshyari.com/article/6733029

Daneshyari.com