Experimental works based on active and passive thermography for measuring the thermal resistance of building walls

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10.21611/qirt.2020.145

15th Quantitative InfraRed Thermography Conference

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Abstract

This study presents the experimental part of RESBATI project. Several measurements based on active thermography were launched on a real Internal Wall Insulation. Three estimation processes proposed by project partners were applied in order to estimate the thermal resistance of this wall and its uncertainty. Moreover, the influence of some parameters (as applied heat power, convective heat transfer coefficient …) on estimation capability were also discussed. Besides, a two-week passive measurement was performed to compare with active method.

1. Introduction

The thermal resistance is one of the physical parameters which allow qualifying the thermal insulation level of a building envelop. By considering the global objective about building energy consumption, the thermal regulation requires a limit of this value for the construction of new buildings and the renovation of older ones. In 2012, this value was estimated around 4 $K.m^2/W$ [1] and will increase in the next regulation. For this reason, several methods and measurement techniques (passive, normalized …) which can estimate this kind of parameter were developed [2,3,4,5]. Being one of them, the RESBATI project (RESistance thermique de la paroi des BATIments), which is granted by French National Research Agency (ANR), was launched. The project objective consists in developing an in-situ device based on active method which works with any kind of walls in any moment of the year (winter or summer) and which requires short measurement duration in order to estimate the thermal resistance of the tested walls.

After validating some estimation methods proposed by each partners of the project via numerical studies [6], several experimental tests were performed to validate the performances and accuracy of the measurement device. Internal Wall Insulation (IWI) was chosen during this stage because of its popularity in France and of its medium resistance and weak lateral effect of thermal diffusion. Several permanent environment conditions were tested by using a climatic chamber at the CEREMA. Besides, a two-week series of passive measurement under real condition was launched to compare with the active method at the end.

2. Presentation of estimation methods

During this study, three different estimation methods proposed by CSTB, IFSTTAR and CERTES were used. Each of them is based on different approach of heat transfer modelling. The details of all methods were presented in [6].

A representation of a wall by using RC circuit was used in model of CSTB (based on the ISABELE method [7]). This approach can be considered as a gray box method. The resistances and capacities are adjusted in order to maximize the likelihood function. The complete estimation process is done by using CTSM-R package [8].

In the IFSTTAR approach, one-dimensional heat transfer differential equation and finite element method are considered. The descent gradient and Tikhonov regularization [9] play a role as main algorithm of parameter estimation.

Instead of solving directly heat transfer equation in time space, CERTES proposed the use of Laplace transform on differential equations in order to obtain a linear quadrupole relation [10]. The Bayesian inference [11] was used in CERTES model to identify the thermal resistance.

Based on numerical results, the temperature of the internal surface of the wall was chosen as minimization target in the parameter estimation process and the external temperature measurement was used as input of the direct model.

3. Presentation of experimental setup

We used a lamp box for the thermal excitation of the wall. It was developed during a previous project in the CERTES [12]. This box is made of wood and its inner facades are covered by a reflective film to homogenize heat flux leaving its front face. The tested wall was heated by a series of halogen spots fixed on the rear face of this box.

Both active and passive measurements were performed using the same experimental setup presented in figures 1 and 2. The only difference between them is that the halogen spots were turned on only during certain periods of the active tests. Several thermocouple sensors and an aluminium film were installed also on this surface to correct IR thermograms in the post-processing steps.

The determination of heat transfer coefficient on the internal surface was a challenge during this study. Some strategies for measuring this value were tried by using a normal and a radiative flux-meters which were fixed on this surface.

For controlling environment temperature effectively, we installed our experiment in a climatic chamber at the CEREMA. Then, we programmed different conditions for internal and external air temperatures. Due to the variation of thermal conductivity of materials as a function of operating temperature, these conditions helped us to verify the measurement sensitivity of the proposed prototype under different cases.

Two different levels of applied heat power were studied under each condition to reveal the influence of this factor on thermal resistance estimation.

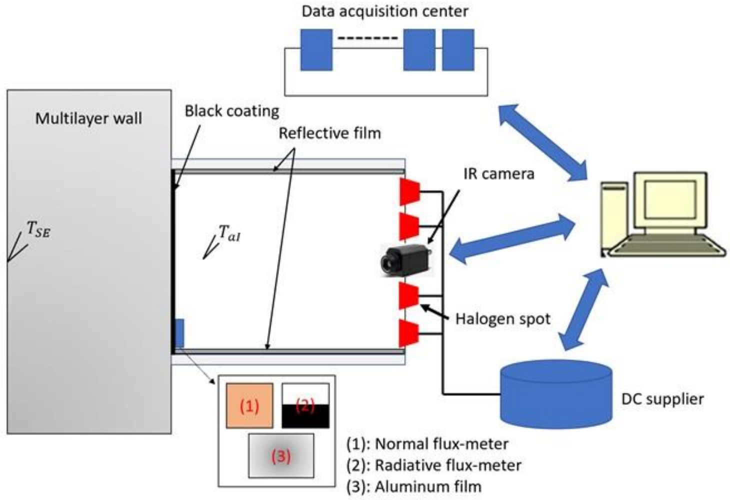

Figure 1: Schematic view of experimental setup

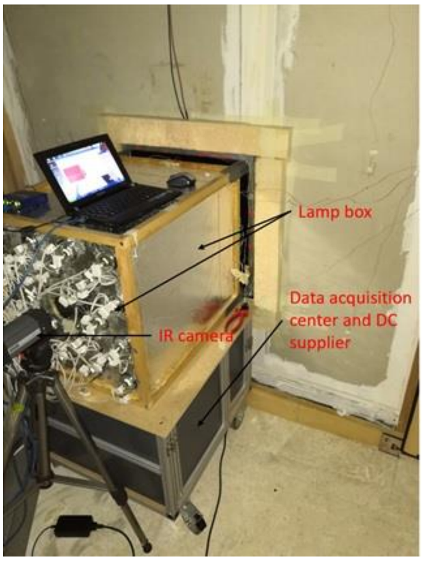

Figure 2: Real view of experimental setup at the CEREMA

Acknowledgements

The authors thank the French National Research Agency (ANR) for the financial support of the RESBATI project

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