A multi-functional hot box-cold box for heat, air and moisture studies on full-scale building components: feature overview and onset to validation

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Abstract

Experimental studies on the heat, air and moisture (HAM) performance of building components can offer extremely valuable knowledge for the construction of energy efficient buildings as well as for the renovation of existing buildings. To this aim, within the HAMSTER (acronym for “Heat, Air and Moisture Specialised Test facility for building Elements of Real size”) project a unique hot box-cold box has been designed and built in Brussels, Belgium. The test facility enables well-controlled experimental studies on the HAM performance of real scale building components and nodes, and is hence highly valuable for future research projects. This work presents the features of the HAMSTER test setup and the main validation tests the facility is subjected to prior to commissioning. Peer-review under the responsibility of the organizing committee of the ICMB23.

Keywords: hot box-cold box; guarded hot box; wall-calibrated hot box; HAM; building components; monitoring; solar; wind-driven rain

1. Introduction

Knowledge on the heat, air and moisture (HAM) performance of building components is of pivotal importance in the development of new energy efficient building systems as well as for damage-free renovations. Many studies on the HAM performance of building components are performed based on numerical simulations, e.g. [1][2]. Though, numerical studies might deviate from practice. Experimental studies can give a better view on phenomena not (yet) included in numerical studies, and hence on the real performance in practice. This way, experiments can likewise serve to validate numerical models. In-situ measurements can yield interesting information in this perspective; though, are not flexible in respect to the imposed boundary conditions. In order to execute well-specified experiments, with well-considered controlled boundary conditions, laboratory experiments are preferable. In this context, within the HAMSTER project (2016-2022) a unique and multi-functional hot box-cold box test facility has been designed [3] and built at the Buildwise laboratory in Brussels, Belgium.

2. The HAMSTER test facility

The hot box-cold box test facility, called HAMSTER (acronym for “Heat, Air and Moisture Specialised Test facility for building Elements of Real size”), consists of a ‘hot box’ and a ‘cold box’ separated by a test frame (Figure 1a,b). Building components (a.o. walls, windows, roofs) with realistic dimensions up to 3 m high, 3 m wide and 3.6 m deep can be mounted in the test frame to be analysed. For U-value measurements, both the guarded hot box (by use of the stand-alone metering box in Figure 2a) and the wall-calibrated hot box method described in ISO 8990 [4] can be applied. Baffles (Figure 2b) positioned...
at both sides of the test component allow to regulate the air flow near the test component’s surfaces, and hence allow to adjust the surface heat transfer coefficients. A dynamic controllable temperature and relative humidity in both boxes furthermore allows a hygrothermal analysis. In the cold box, infrared lamps enable simulating solar radiation. These infrared lamps are positioned on a tiltable frame (Figure 2c) which makes also tests on (pitched) roofs possible. Automatic spray nozzles, mounted on a movable beam, provide a uniform rain distribution over (parts of) the test sample. Additionally, an air pressure difference over the test element can be imposed. Also, by use of an airtightness box (Figure 2d) which can be connected to the test frames, prior to a hot box-cold box test, the airtightness of the test element can be measured following EN 1026 [5]. This way, the HAMSTER test setup offers a full test battery to measure the building components’ HAM performance. An overview of the technical specifications of the HAMSTER test facility, as requested from the supplier, is shown in Figure 1b. To achieve a good measurement accuracy, a number of actions are taken. For instance, a flexible sealing solution for cable penetrations restricts air losses caused by the many sensor wires. Furthermore, an active electrical guard is present in the walls of the hot box. A thermopile positioned across the walls of the hot box measures any temperature difference. By use of heating pads, temperature differences are cancelled, and consequently also the heat flow from the hot box to the laboratory.

Figure 2. (a) metering box, (b) baffles to control the air circulation near the building element’s surface, (c) tiltable frame for IR-lamps, (d) airtightness box.

3. Validation campaign

To check if the requested specifications (Figure 1b) are met, a validation campaign is currently running. At first, the airtightness of the cold box, hot box, test frames and stand-alone metering box is measured by use of the airtightness box. Subsequent validation tests consist of a.o. a theoretical uncertainty calculation of the power measurements in the cold and hot box, a study on the capability of the air conditioning system in respect to the temperature, power and relative humidity stability, an analysis of the temperature and humidity ranges and its dynamic performances, a verification of the accessible air speed ranges and the uniformity of the air speed profile. In the hot box and metering box, also the operation of the thermopile and the electrical guard will be verified. For the water spraying systems, a.o. the variation in the water flow rate, the spatial uniformity and the water temperature stability will be verified.

4. Conclusion and discussion

A unique hot box-cold box has been designed and built. The test facility enables studies on the HAM performance of building components and building nodes with realistic dimensions, imposed to well-considered (controlled) boundary conditions, with inclusion of rain. In the coming time, the test facility will be further validated and calibrated, after which the test facility will be used in projects on, amongst others, retrofitting solutions for heritage windows and the optimization of the hygrothermal design of building components. Hygrothermal measurements can, however, take several months. Therefore, future research will also focus on how to define the boundary conditions in a way that shortens the test period.

References