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Published in:
NSB 2023 - Book of Technical Papers: 13th Nordic Symposium on Building Physics

DOI (link to publication from Publisher):
10.54337/aau541620389

Publication date:
2023

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Vereecken, E., Prignon, M., Tilmans, A., & Mets, T. D. (2023). HAMSTER Test Facility – Features and future Potential of a unique bi-climatic Chamber. In H. Johra (Ed.), *NSB 2023 - Book of Technical Papers: 13th Nordic Symposium on Building Physics* (Vol. 13). Article 253 Department of the Built Environment, Aalborg University. https://doi.org/10.54337/aau541620389

HAMSTER Test Facility – Features and future Potential of a unique bi-climatic Chamber

Evy Vereecken, Martin Prignon, Antoine Tilmans, Timo De Mets

Buildwise, Dieudonné Lefèvrestraat 17, 1020 Brussels, Belgium

*Corresponding author – Evy.Vereecken@buildwise.be

Abstract. The HAMSTER project (2016-2022) aimed at designing, building, and validating a bi-climatic chamber. The test facility developed within the project, called the HAMSTER test facility, is a recent versatile bi-climatic chamber that is made to study the dynamic heat, air and moisture performance of building components of realistic size. The hot chamber is furthermore thoughtfully designed to conduct accurate stationary thermal transmittance tests according to the standards. Realistic climatic conditions, like rain, sun, and pressure differences, can be reproduced in the cold chamber so that many different tests can be performed using HAMSTER. After 6 years facing numerous challenges, this new testing facility has been installed at the Buildwise laboratory in Brussels, Belgium.

1. Introduction and background

Buildings are responsible for around 40% of the energy consumption and 36% of the greenhouse gas emissions in Europe [1]. To reach carbon-neutrality by 2050, one of the ambitious goals set out in the European Green Deal, buildings should be constructed or renovated energy efficiently. Additionally, durable building components should be provided. No damage patterns may be induced by improving the energy efficiency. In this respect, the assessment of heat, air and moisture (HAM) transfer in building components is fundamental.

To study the hygrothermal performance of building components, numerical and experimental modeling can be applied. Numerical modeling offers a lot of potential, as it allows the investigation of thousands of varieties in respect to the building component's assembly and its material properties, the boundary conditions, the initial conditions, etc. [2][3]. A major drawback of this numerical approach is however the risk of neglecting important phenomena, resulting in a deviation between numerical output and practice [4]. Hence, experimental studies are indispensable in research on HAM transfer in building components. Experimental work can consist out of field measurements, studying the building components under real boundary conditions. However, a study of well-specified phenomena is often difficult in such field measurements, as e.g. outdoor climatic conditions are difficult or not controllable. Often, this also leads to a long time span needed for the measurements, due to for instance inadequate boundary conditions for the specified test; for instance, a lack of heavy rain loads, winter conditions that are not severe enough for the phenomenon that is studied, etc. To overcome these issues, laboratory measurements can come in handy, as it allows well-specified and controlled boundary conditions. From this perspective, within the HAMSTER project (2016-2022) a unique and versatile bi-climatic chamber, called HAMSTER, has been designed and built [5].

This paper first presents the HAMSTER test facility and its innovative features. Next, a concise overview of the scheduled validation campaign is given, and future research projects using the HAMSTER test facility are described. Ultimately, a conclusion is drawn.

2. The HAMSTER test facility

The bi-climatic chamber, called HAMSTER (acronym for “Heat, Air and Moisture Specialised Test facility for building Elements of Real size”), consists of a hot box, a cold box and a test frame (figure 1a) in which building components (a.o. walls, windows) with real dimensions (up to 3 m high and 3m wide) can be mounted to be analysed. Three standard test frames with a depth of 0,6 m (figure 1b) and two extended test frames with a depth of 1,5 m (figure 1c) are available. By connecting the extended test frames and a standard test frame to each other, an assembled test frame with a depth of 3,6 m can be achieved. This way, also building nodes and roofs can be analysed with the HAMSTER test facility.

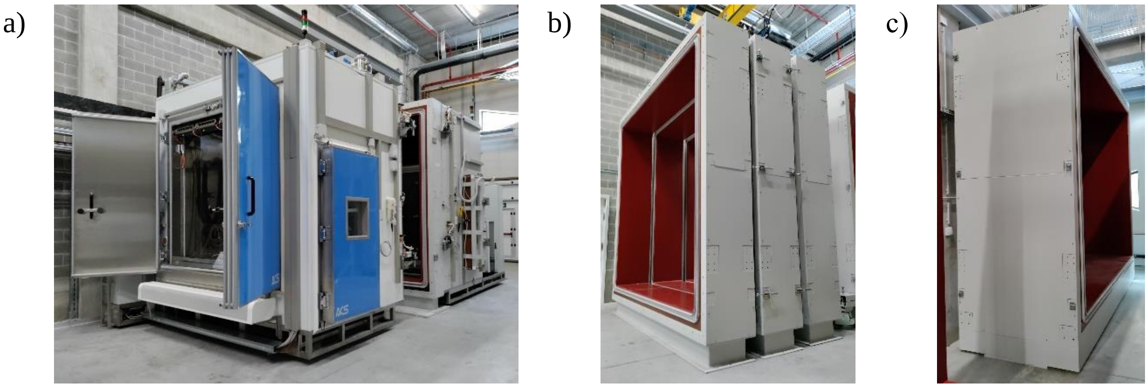

Figure 1. a) HAMSTER test facility, b) standard test frames, c) one of the extended test frames.

The HAMSTER test facility makes U-value measurements possible by use of both the guarded hot box (using the stand-alone metering box, see figure 2a) and the wall-calibrated hot box method, as described in ISO 8990 [6]. The air flow near the test component’s surfaces, and thus the heat transfer coefficients, can be regulated by use of fans and by regulating the position of a baffle at both sides of the test component (figure 2b).

To perform hygrothermal studies, dynamic temperature and relative humidity conditions can be imposed in both boxes. In the cold box, infrared lamps enable simulating solar radiation. These infrared lamps are positioned on a tiltable frame (figure 2c), enabling also measurements on (pitched) roofs. The real solar spectrum cannot be replicated with the current test facility. Though, the back wall of the cold box consists of a glazed section, made from high transmittance glass (figure 1a). When desirable, an artificial solar simulator could be purchased at a later stage and placed externally in front of this glazed section. When not using such a solar simulator, the glazed section will be protected by closing the external doors at the back wall of the cold box. To simulate a rain load, rain can be imposed to the test component by use of automatic spray nozzles mounted on a movable beam. Uniform rain distribution over (parts of) the test sample can be imposed. The movable beam can furthermore be provided with, for instance, thermocouples or relative humidity sensors to scan the test component’s spatial surface temperature and relative humidity. In hygrothermal studies, also an air pressure difference over the test sample can be imposed to simulate calm to strong wind conditions; though, the intention of the test setup is not to provide extreme conditions or to perform standardized tests on watertightness of building components.

Finally, the airtightness of the test samples can be measured prior to a hot box-cold box experiment. Thereto, an airtightness box (figure 2d) can be connected to the test frame with the test component, and a pressure difference can be imposed.

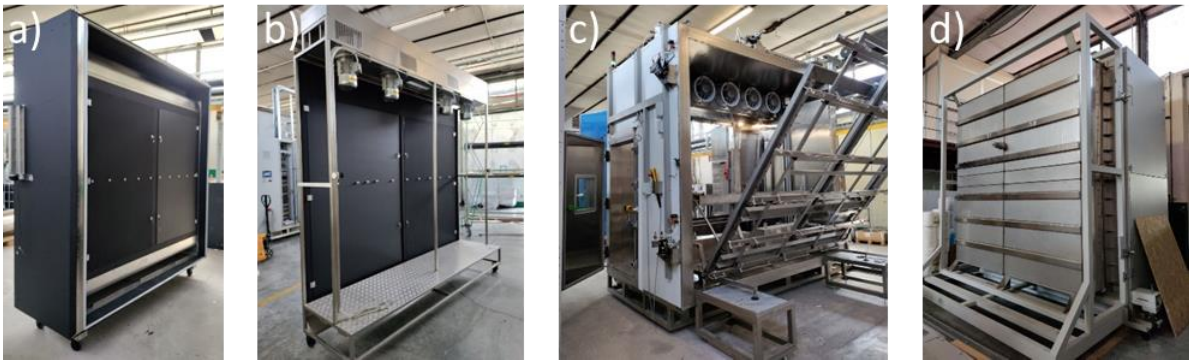

Figure 2. a) metering box, b) baffle, c) tiltable frame for infrared lamps, d) airtightness box.

An overview of the technical specification of the HAMSTER test facility, as requested from the supplier, is given in Figure 3. To achieve a good measurement accuracy, a number of actions have been taken. For instance, the walls of the hot box are provided with an active electrical guard. A thermopile installed across the walls of the hot box measures any temperature difference. By use of heating pads, temperature differences are cancelled, and thus a potential heat flow from the hot box to the laboratory environment is avoided. Furthermore, to restrict air losses induced by the many sensor wires, a flexible sealing solution for cable penetrations is applied.

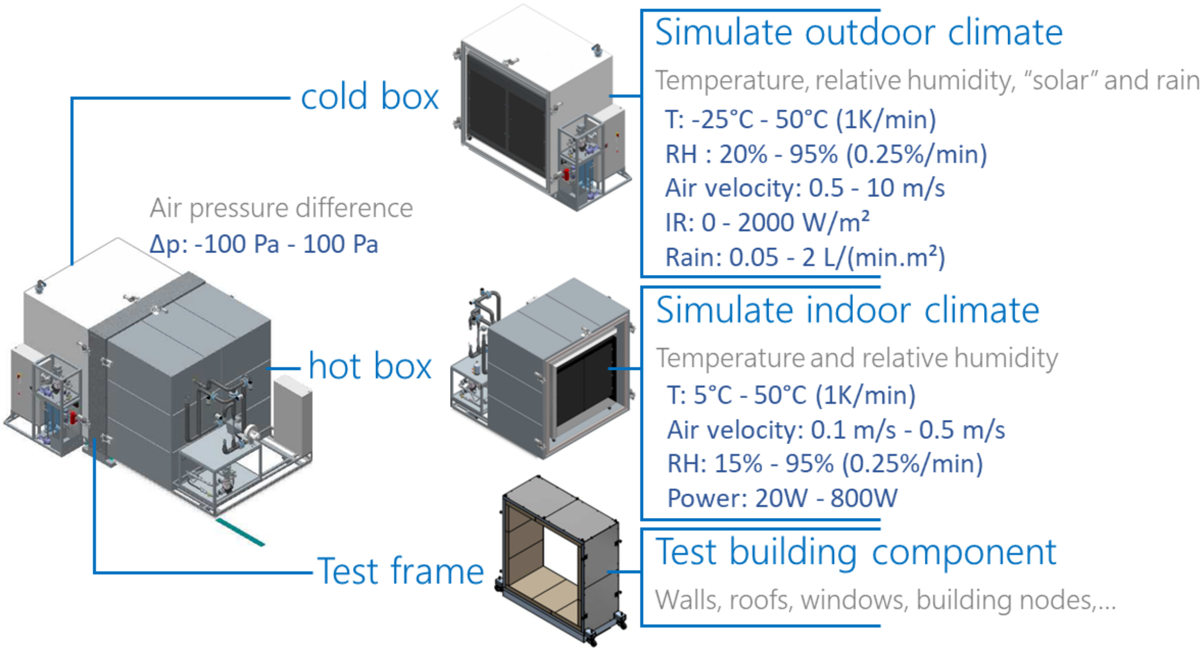

Figure 3. Technical specifications of the HAMSTER test facility, as requested from the supplier.

The HAMSTER test facility can be controlled via a constructor control system. The control system is open, so that an external control system (based on LabView for example) can be used to enables the signal acquisition from the sensors used for the monitoring of the test component and the environment in the bi-climatic chamber. Additionally, the external control system can read the inputs and outputs of the constructor control system and is able to take control of certain control loops.

3. Validation campaign

A validation campaign has currently started in order to check if the requested specifications (Figure 3) are met. In the validation campaign, first the airtightness of the hot box, cold box, test frames and stand-alone metering box has been measured by use of the airtightness box. Other validation tests in this campaign will consists of a.o. a theoretical uncertainty calculation of the power measurements in the hot box and cold box, testing the temperature and humidity ranges and its dynamic performances, analysing the capability of the air conditioning system to providing the specified power, temperature and relative humidity stability, verifying the accessible air speed range 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. Finally, the operation of the water spraying system will be tested by verifying the variation in the water flow rate, the water temperature stability and the spatial uniformity.

4. Future projects

After the validation and calibration of the HAMSTER test setup, the test setup will be used within several research and development projects. The focus within these projects will be put on energetic challenges, both in the context of constructing new buildings and in the context of renovating our existing building stock, including heritage. Both the performance of innovative and traditional materials and systems will be studied within the projects. Furthermore, the HAMSTER test setup will be used to validate numerical models and other methodologies applied to optimise the design of building components. Two recently initiated projects will be briefly described in what follows.

A first project, called PERCHE, aims to facilitate the renovation process of wooden window frames in pre-war buildings in the Brussels region. The energetic renovation of these window frames is of paramount importance, as it offers a large potential to reduce the building’s energy use and to improve the indoor comfort. Though, a possible renovation should reckon the preservation and upgrading of the architectural heritage. Within PERCHE, the HAMSTER test facility will be used to evaluate the thermal performance and the air- and watertightness for different renovation solutions for wooden window frames. A decision tree to choose the most appropriate intervention, taking into account the need for heritage preservation, will be developed.

A second project, OptHyWall, pursues the hygrothermal characterisation of materials and (layers of) building components (e.g. the diffusion resistance of a vapour barrier, the hygrothermal properties of an insulating rendering) as well the initial conditions, and this based on measurements in combination with inverse modelling. The HAMSTER test facility will be used to validate the standardised tools and optimisation techniques developed within the project for real building components. Moreover, within the project, an optimization of the hygrothermal design of building components is pursued.

A thorough scheduling of the different projects will be of huge importance in order to use the bi-climatic chamber in an efficient way and for several projects. Especially for hygrothermal measurements, often several months of testing are required. In this respect, future research will also focus on the definition of well-considered boundary conditions for the experiments, in such a way that the test periods can be shortened.

5. Difficulties

Designing and building a hot box-cold box is a challenging tasks. To reduce potential pitfalls and difficulties during the design and building process of the HAMSTER test facility, an extensive field study has taken place beforehand. Technical information on the existing hot box-cold box test setups is however often not publicly available. Therefore, several laboratories in possession of a hot box-cold box test facility have been consulted and visited. Though, the plenty and ambitious technical specifications pursued for the HAMSTER test facility still made it not possible to find a supplier familiar with all the necessary technical aspects. Therefore, it was decided to support the future supplier in the design process. For example, numerical simulations were conducted in order to assess the feasibility of the drafted specifications as well as the accuracy achieved for specific tests (e.g. U-value tests). One specific technical point that required a lot of attention is the realisation of the airtightness of the boxes themselves. Given the many connections and wires and the necessity to be able to impose low air flow rates through the tested elements, a huge effort has been dedicated to reach the needed airtightness level. Apart from the technical challenges, logistical difficulties were encountered. The test facility was built and tested in Italy, after which the test facility had to be demounted to be transported to Brussels. In the Buildwise laboratory a thoughtful positioning was necessary in order to be able to get all the components of the HAMSTER test facility in the laboratory and to make a manipulation of the test frames and the test walls in between different measurements possible.

6. Conclusion

Within the HAMSTER project, a unique and versatile bi-climatic chamber has been designed and built. The test facility offers a full test battery to measure the heat, air and moisture performance of both building components with realistic dimensions and building nodes. Well-considered (controlled) boundary conditions, with inclusion of rain and solar radiation as well as air differences across the test sample, can be imposed. Currently, a validation of the test setup's features is going on. The actual commissioning of the HAMSTER test facility in research and development projects is scheduled for September 2023.

Acknowledgment

The HAMSTER project has been funded by the European Regional Development Fund and Innoviris (Brussels Region, Belgium). These financial supports are gratefully acknowledged.

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