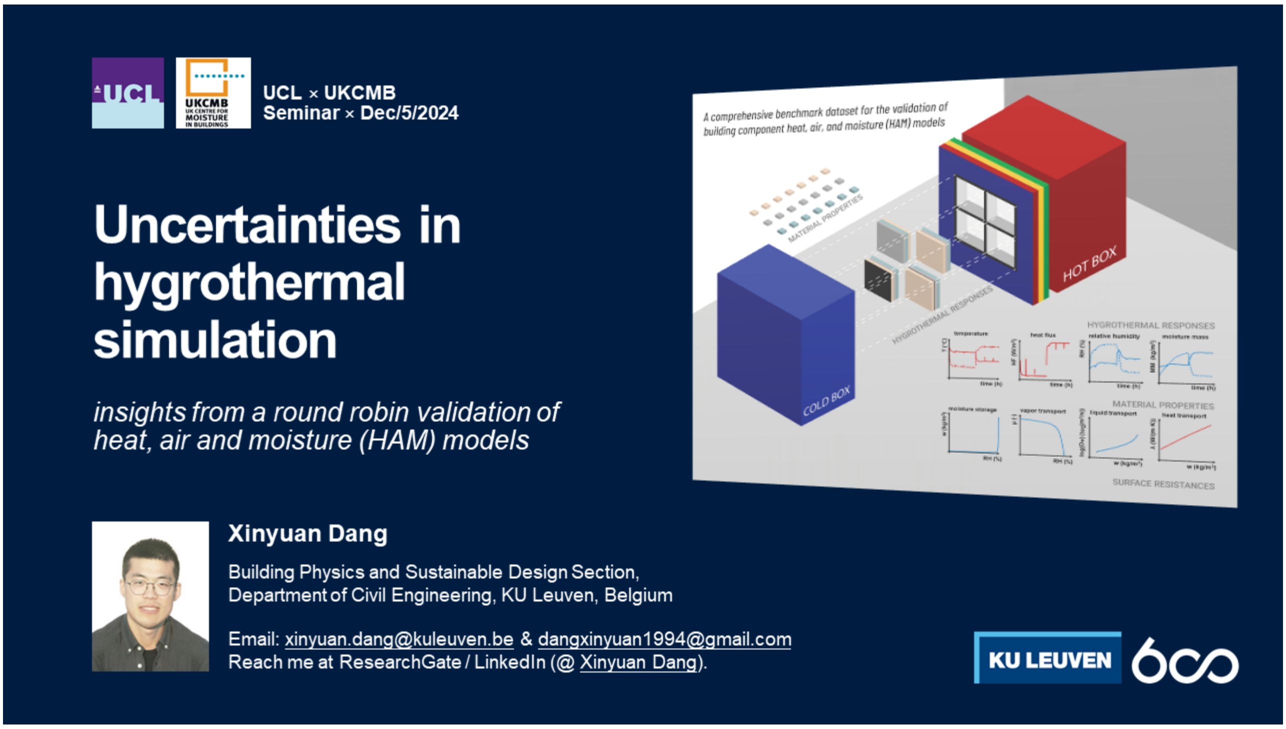

Topic:	Uncertainties in Hygrothermal Simulation: Insights from a Round Robin Validation of Heat, Air, and Moisture (HAM) Models
Presenter:	Xinyuan Dang, PhD candidate, KU Leuven, Belgium
Date and Time:	December 5, 2024, 13:00–14:00 GMT

Purpose:

- ✓ Raise awareness of uncertainties in HAM modelling and their impact on hygrothermal performance prediction
- ✓ Introduce the methodology and resources for validation and quality assessment of HAM models in the round robin exercise.

Learning Objectives:

- ✓ Identify key uncertainties in HAM modeling (e.g., material properties and boundary conditions).
- ✓ Understand the impact of variations in inputs on simulation outcomes.
- ✓ Gain familiarity with round-robin validation methodologies.
- ✓ Access newly developed benchmark datasets for future research or practical applications.

Contact Information:

- ✓ Email addresses: xinyuan.dang@kuleuven.be / dangxinyuan1994@gmail.com
- ✓ LinkedIn: https://www.linkedin.com/in/xinyuan-dang-b83327249
- ✓ ResearchGate: https://www.researchgate.net/profile/Xinyuan-Dang

- ✓ Join our LinkedIn Group **“Heat, Air, and Moisture (HAM) Modelling”** for more updates!
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0. Overview

- Heat, air, and moisture (HAM) models allow efficient simulation of hygrothermal performance of building components. However, inaccuracies and incorrectness often stem from assumptions, simplifications, and approximations in implementing material properties, boundary conditions, etc. Despite their extensive use, HAM models lack robust quality assessment frameworks. Previous studies failed to establish standardized criteria for answering the critical question: “Can the model correctly predict reality?” Most available experimental datasets may not accurately reflect real-world complexity, limiting the representativeness of the benchmark, while pure inter-model comparison based on hypothetical scenarios similarly limits the effectiveness of assessment process.
- This webinar presents groundbreaking findings from a recent global initiative “Empirical Validation of HAM-Models Based on a Dedicated HB-CB Experiment” led by the Building Physics and Sustainable Design Section at KU Leuven (2023-2024). Building on prior EU HAMSTAD and IEA Annex 24 efforts, this unprecedented collaboration involved over 70 researchers/practitioners across 38 groups from 19 countries, assessing HAM models against a dedicated benchmark dataset. The session delves into key uncertainties in hygrothermal modelling, particularly the implementation of material properties, and explores their impact on simulated hygrothermal responses. Attendees will gain valuable insights into enhancing the robustness and reliability of HAM models while accessing newly available datasets for future research or practical application.

1. Problem Statement

1) Background of HAM Models

- HAM models simulate heat, air, and moisture transport, critical for durability, energy efficiency, and resilience of building components. Unlike time-consuming and resource-intensive laboratory tests or field measurements, HAM models offer efficient and quick simulations.

2) Common Uncertainties in HAM Models

- Material Properties (MP): Issues arise from variability in moisture storage, liquid transport, and vapor transport parameters due to differing experimental methods, approximations, and database entries.
- Boundary Conditions (BC): Deviations result from diverse standards (e.g., ASHRAE 160 vs. ISO 15927) and specific simplifications in wind-driven rain or surface transport coefficients implemented in HAM models.
- Other Factors: Grid discretization, geometric configurations, initial conditions, etc. contribute to output variability.

3) Limitations in previous Validation & Quality Assessment

- Prior validation benchmarks are mainly limited by the “sample” scale, use of single materials or materials with similar hygric properties, simple hygrothermal transport processes, and incomplete datasets.
- Prior inter-model comparisons are often simplified and lack experimental evidence, potentially masking common inaccuracies among HAM models.

2. The Round Robin "Empirical Validation of HAM-Models Based on a Dedicated HB-CB Experiment" led by the Building Physics and Sustainable Design Section at KU Leuven (2023-2024)

1) Overview

- Scope: Involved 38 groups and 19 countries; Built on prior EU HAMSTAD and IEA Annex 24 efforts.
- Methodology: Validation performed in three stages: Stage 1: Robustness Test—Only basic material parameters from technical sheets are provided; Stage 2: Reliability Test—Measured material properties and surface transport coefficients are provided; Stage 3: Fine-Tuning—Participants optimized models using measured hygrothermal responses and simulation results from all groups in stage 2.

2) Experimental Setup

- HB-CB Configuration: Four wall assemblies using calcium silicate, mineral wool, and wood fiber boards in different configurations. Aluminum foil vapor barrier is attached to different interfaces in two wall assemblies.
- Indicators: Monitored temperature, relative humidity, heat flux, and moisture mass.
- Boundary Conditions: Cold box: 2°C, 80% RH. Hot box: 28°C, 54% RH. Boundary conditions switched mid-experiment for diverse scenarios.

3) Key Findings

- Heat Transport Predictions: Consistently accurate across stages.
- Moisture Transport Challenges: Variations in implemented moisture storage and transport causes significant deviations.
- Improvements Over Stages: Quantitative indicators (e.g., RMSE, Pearson correlation) showed better agreement in later stages.
- Material Database Issues: Materials with similar names but differing properties in databases led to output inconsistencies.

4) Recommendations

- For Model Users: Be cautious when selecting material properties from databases; Validate model outputs using comprehensive datasets and sensitivity analyses.
- For Researchers: Focus on moisture mass as a benchmark validation indicator due to its sensitivity to inaccuracies; Perform more precise material characterization and implementation.

3. Resources and Publications

We published a journal paper for the HB-CB experimental dataset [1] and raw data of measured material properties, surface transport coefficients, boundary conditions and hygrothermal responses [2], which is dedicated to the round robin empirical validation exercise as initially described in the call for participation [3]. We collected and analyzed the three-stage simulation results from the participants, and also worked independently on more in-depth studies on the uncertainties in the implementation of material properties in WUFI and DELPHIN. The preliminary round robin results [4] and our own results [5] were presented at IBPC24 and NSB23 respectively. A joint journal paper on comprehensive summary and insights from the round robin results is currently under review, and we are working on extending our own in-depth analysis to different strategies for implementing hygric properties in hygrothermal simulation for another journal paper – stay tuned! In parallel to uncertainties in the implementation of material properties, we dealt with uncertainties in the implementation of wind-driven rain (WDR) as a crucial boundary condition [6].

[1] Dang, X., Janssen, H., & Roels, S. (2024). A comprehensive benchmark dataset for the validation of building component heat, air, and moisture (HAM) models. Building Simulation. 17(11): 1893–1907. https://doi.org/10.1007/s12273-024-1176-8.

[2] Dang, X., Janssen, H., & Roels, S. (2024). Empirical validation of HAM-models based on a dedicated HB-CB experiment_datasets [Data set]. Zenodo. https://doi.org/10.5281/zenodo.10998834.

[3] Empirical validation of HAM-models based on a dedicated HB-CB experiment Call for participation. (2023). https://doi.org/10.13140/RG.2.2.10053.83682.

[4] Dang, X., Janssen, H., Roels, S. (2025). User Impact as an Uncertainty in Hygrothermal Simulations: Insights from a Round Robin Test. In: Berardi, U. (eds) Multiphysics and Multiscale Building Physics. IABP 2024. Lecture Notes in Civil Engineering, vol 552. Springer, Singapore. https://doi.org/10.1007/978-981-97-8305-2_9. *(presented at the 9th International Conference of Building Physics (IBPC2024), Toronto, Canada)*.

[5] Dang, X., Janssen, H., & Roels, S. (2023). Hygrothermal Modelling of one-dimensional Wall Assemblies: inter-model Validation between WUFI and DELPHIN. Journal of Physics: Conference Series, 2654 (1): 012040. https://doi.org/10.1088/1742-6596/2654/1/012040. *(presented at the 13th Nordic Symposium on Building Physics (NSB2023), Aalborg, Denmark)*.

[6] Dang. X., Vereecken, E, Janssen, H., Roels, S. (2024). Impact of semi-empirical methods implemented in heat, air, and moisture (HAM) models on predicted wind-driven rain (WDR) loads and hygrothermal responses. Building and Environment, 111770. https://doi.org/10.1016/j.buildenv.2024.111770.