Abstract

Buildings are currently responsible for 40% of final energy consumption and 35% greenhouse gas emissions, highlighting the need of effective strategies to improve energy efficiency in the context of climate mitigation. Among the available solutions, passive indoor climate control approaches based on building envelope components with thermal and moisture buffering capabilities offer an effective means to stabilise indoor temperature and humidity, enhance indoor comfort and reduce energy demand. Despite the increasing interest in these solutions, the assessment of their performance still presents significant methodological challenges. Existing evaluation approaches are often based on simplified indicators or steady-state properties, which are not fully representative of the dynamic thermal and hygrothermal behaviour of building components under realistic operating conditions. These limitations affect result comparability and complicate the reliable upscaling of experimental evidence from material to component and building scale.

The aim of this PhD thesis is to increase knowledge and awareness on the assessment of thermal and moisture buffering building components for passive indoor climate control, with a specific focus on Phase Change Material (PCM)-based systems for thermal buffering and highly hygroscopic materials for moisture buffering. The research adopts an application-oriented perspective, focusing on the characterisation and modelling of transient hygrothermal behaviour to support the performance assessment, design, and effective integration of buffering components within the building envelope.

Experimental activities were carried out at multiple spatial scales, including material, component and room scale. For thermal buffering applications, PCM-based materials and components were characterised through laboratory testing and dynamic experimental methods based on a Dynamic Heat Flow Meter (DHFM) apparatus, allowing the investigation of their effective thermal behaviour under boundary conditions representative of building operation. For moisture buffering applications, hygroscopic performance was assessed using adapted and modified laboratory protocols implemented in climatic chambers, complemented by inter-laboratory comparison activities and in-field monitoring under real operating conditions. Experimental results were used for the empirical validation of hygrothermal models and building performance simulation tools, enabling the upscaling of buffering effects from material and component level to room scale. The outcomes of this research provide methodological insights, validated assessment approaches and quantitative evidence to support the use of thermal and moisture buffering components in passive indoor climate control strategies, contributing to both research and construction materials practice.