The use of hygrothermal and bio-hygrothermal simulation to inform envelope design for residential buildings in southern Australia

Mark Dewsbury\textsuperscript{a}, Freya Su\textsuperscript{a}, Liqun Guan\textsuperscript{a}, Hartwig Künzel\textsuperscript{b} \textsuperscript{*}

\textsuperscript{a} School of Architecture & Design, University of Tasmania, Launceston, Australia
\textsuperscript{b} Fraunhofer Institute for Building Physics, Holzkirchen, Germany

Abstract

Recent enhancements to energy efficiency regulations, combined with exterior water control layers and minimal changes to decades old external wall system construction for stand-alone and multi-residential buildings in Australia has led to an apparent increase of interior and interstitial condensation and mould. Since 2014 researchers from the university of Tasmania have been utilizing non-transient and transient calculation methods to provide forensic analysis of existing buildings and to provide guidance on changes that should be considered for the design and construction of external envelope elements for Australian dwellings. This paper discusses recent research conducted for the State of Victoria, Australia, that has included traditional hygrothermal and bio-hygrothermal simulation of 6 Star and 7 Star building regulation compliant external wall systems.

1. Introduction/Background

Since 2003, the Australian national building regulations have included minimum insulation and airtightness requirements as a method to reduce the significant greenhouse gas emissions that are created through the heating and cooling of residential and non-residential buildings \cite{1}. These requirements were enhanced for residential buildings in 2004, 2007, 2010 and 2022\cite{2}. Parallel regulatory development has also included the use of exterior membranes to protect the structural frame system from moisture during construction \cite{3}. The combination of the energy efficiency requirements and the types of pliable membranes applied to manage exterior moisture during construction have led to significant industry and consumer concern regarding the increased presence of condensation and mould in new housing\cite{4-7}.

Since 2008, architectural science researchers from the University of Tasmania have been collaborating with state and federal government agencies regarding what was considered a future risk, through to forensic and hygrothermal simulation-based research to provide ‘better-than-code’ design and construction solutions for residential buildings \cite{8-11}. This article discusses research funded by the Victorian Building Authority, CSIRO and Master Builders Victoria, to assess simulation-based risks of interstitial moisture accumulation and/or mould growth in national building regulation compliant 6 Star and 7 Star external wall systems.

2. Method

To establish a credible data-set to inform regulatory change and provide advice to the design and construction professions required the establishment of several processes and the application of recently published hygrothermal (heat and moisture) and bio-hygrothermal (mould growth) simulation methods. This included the establishment of exterior climate data, interior climate conditions and the physical properties of construction materials. The research included three stages, namely

- Stage 1 – 6 Star residential external wall systems, with standard RMY climate data
- Stage 2 – 7 Star residential external wall systems, with standard RMY climate data
- Stage 3 – Variations to the material properties of the 6 Star and 7 Star residential external wall systems until suitable mould growth indices were achieved.

In this research the reference meteorological year (RMY) climate data sets developed for the Australian government for the Nationwide House Energy Rating Scheme (NatHERS) \cite{12} were reformatted to enable their use in the WUFI Pro software suite. These climate datasets are the required for building envelope thermal performance simulation. The selection of these climate datasets follows similar trends in other nations, where the first generation of hygrothermal simulation has used Building Energy Rating climate data sets. It should be noted that the RMY data-sets available during this stage of the research only included calendar years 1970 to 2005. As the RMY data sets do not include rain data, the first stages of this research did

* Corresponding author. +61417290807 mark.dewsbury@utas.edu.au

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not include rain data in the external climate data. Stage 3 of this research included the reformatting of NatHERS Gen 2 climate data-sets (1990-2015) and the addition of hourly precipitation data. The precipitation data available included a mix of once a day (9am to 8am), and hourly observations. The state of Victoria includes thirteen NatHERS climate zones, covering 1,682 postcodes. As some locations had very few buildings constructed, the number of climates to be simulated were reduced to eight. In this research the interior climate applied a mix of principles from ASHRAE 160, DIN 4108, the NatHERS Protocol and NCC 2022 [12-15]. These governed the interior temperature, relative humidity cap, water vapour generation and airtightness.

The external wall systems were established through an analysis of data collected by the CSIRO, as a component of the NatHERS certification portal. Sixteen external wall systems were identified. Based on quantities of building approvals, this was reduced to nine external wall systems. An analysis of the published data for density, conductivity, thermal capacitance and water vapour diffusion resistivity was conducted. Existing materials within the WUFI Pro data-base were modified to better represent the Australian products [16].

Hygrothermal and mould growth simulations were completed for a period of ten years

3. Results

The first stage of the research explored the simulation-based risks of interstitial moisture accumulation and mould growth in the 6 Star residential external wall systems. 880 hygrothermal and 880 bio-hygrothermal simulations were completed. Whilst most wall systems demonstrated nil moisture accumulation, a significant percentage demonstrated mould growth indices (MI) that indicated the wall systems may be climatically inappropriate.

The second stage of the research explored the simulation-based risks of interstitial moisture accumulation and mould growth in the 7 Star residential external wall systems. 594 hygrothermal and 594 bio-hygrothermal simulations were completed. Whilst most wall systems demonstrated nil moisture accumulation, a significant percentage demonstrated mould growth indices (MI) that indicated the wall systems may be climatically inappropriate.

The third stage of the research investigated options regarding vented and drained cavities, water control layers with a lower water vapour diffusion resistance and the application of interior vapour control layers. These measures showed a pathway to construct modern wall systems that may minimise interstitial moisture accumulation and mould growth.

4. Conclusion

The simulation results demonstrated significant risks for interstitial mould growth, which resembles experiences documented by members of the design and construction professions and building occupants from new residential buildings constructed in the last decade. Recognising the significant lag that occurs for regulatory development, the Stage 3 simulations are being used to provide ‘better-than-code’ guidance for the design and construction professions. The next stage of this research for the Victorian government will explore impacts from varying the interior conditioning patterns.

References

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