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Hygrothermal Monitoring of Replacement Infill Panels for Historic Timber-Frame Buildings: Next Steps

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Abstract

As highlighted by Publicly Available Standards (PAS) 2030 and 2035, buildings of traditional construction require special consideration when undertaking energy retrofits, as unintended consequences may arise from changes to the moisture movement through the building fabric. For historic timber-framed buildings, retrofitting replacement infill panels poses the risk that moisture accumulation may result in accelerated decay. Since 2019 the authors have been undertaking monitoring of eight mock-up replacement infill panels, with the initial results reported at ICMB2021 and the full results of the first two years subsequently published. Funding has now been approved for further work. This paper presents the next steps: continued monitoring of the panels and detailed material characterisation to improve simulation and understand durability. Preliminary results will be presented at the conference.
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Keywords: Interstitial Hygrothermal Behaviour; Moisture Content; Monitoring; Material Characterisation

1. Introduction

For the purposes of this paper, historic timber-framed buildings refer to those built pre-1850 with an exposed timber structural timber frame, infilled with non-loadbearing panels. These panels were traditionally constructed using wattle and daub, brick nogging, stone or lath and plaster. When infill panels have to be replaced because historic materials are beyond repair, have already been replaced with inappropriate C20th materials or must be removed to facilitate the repair of surrounding timbers, there exists the opportunity to use materials with a higher thermal resistance [1]. However, as noted by PAS 2030 [2] and PAS 2035 [3] the retrofit of traditional buildings may result in unfavourable changes in moisture movement. For historic timber-framed buildings this may result in the creation of hygrothermal conditions which promote fungal decay and insect infestation. In order to assess this risk, the authors, with funding from Historic England, monitored four replacement infill panel materials: wattle-and-daub, expanded cork, wood fibre/wood wool, and hempcrete. Two panels of each material were mounted in a test cell, one finished internally and externally in an NHL3.5-based render and the other with a non-hydraulic lime/hemp mix. These were initially monitored for 27 months. The results showed that the cork infill panels provided the best thermal performance, followed by wood fibre and then hempcrete [4]. Those panels finished in the more moisture permeable lime hemp plaster demonstrated reduced drying times. No occurrence of interstitial condensation was measured, with moisture increases resulting only from wind driven rain. Problems with moisture accumulation were however noted at the junction between panel and frame of those infills with non-moisture permeable perimeter seals. Nevertheless, 27 months is a relatively short time when considering the age of the buildings in question, the anticipated service life of the panels, and the slow rate at which hygrothermal conditions change. Further funding has now been granted that will extend the monitoring for a further 24 months.

The initial measured results were compared with dynamic interstitial hygrothermal simulation with WUFI® Pro 5.3, using the measured internal and external climatic data. The results corroborated the measured results, indicating the major changes in moisture content arising from wind driven rain events [5]. However, there were considerable differences in moisture profiles between simulated and measured results. Among other factors, this potentially arises from substitute material data being used due to limitations of the software's databases. The new funding will allow for detailed characterisation of the materials being monitored, the results of which will be used for further simulations. Comparing these new simulations with the ongoing monitoring data will allow further interrogation of similarities and difference. At the same time, durability testing will inform

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guidance on both installation and future maintenance of those solutions identified to be of least risk. There follows an overview of the material characterisation testing, the preliminary results of which will be presented at the conference.

2. Methodology

For the test panel measurements, the same methodology as used in the initial 27 months of monitoring will continue to be followed [4]. Moisture content (%) and temperature (˚C) will be measured using thermistors and electrical resistance sensors embedded within the panels and at their junction with the oak timber frame. Hygrothermal conditions within the test cell and external climate (temperature (˚C), Relative Humidity (%), precipitation (mm), windspeed (m/s) and direction, and direct solar radiation incident on the panels (W/m^2) will also be measured. In addition, in situ U-value measurements of the panels will be undertaken during the heating seasons, according to BS ISO 9869-1:2014 using Huxeflux heat flux plates, and measurement of internal and external temperatures adjacent to the flux plates. Thermography will also be used to assess the panels' thermal performance.

The methodologies shown in Table 1 will be used for the measurement of both steady state and dynamic hygrothermal properties of the constituent materials of the infill panels. These are: NHL 3.5 base coat (2.5:1); NHL 3.5 top coat (3:1); Ty Mawr pre-mixed Lime-hemp render; clay daub; expanded cork board; woodwool board; wood fibre board; Hempcrete; reclaimed oak. The mechanical properties of materials will be determined as shown in Table 2.

Table 1 Hygrothermal material properties to be tested and methodology to be followed

	Properties	Methodology according to
Steady State	Bulk Density	BS EN 1936:2006
	Porosity	BS EN 1936:2006
	Porosity and pore size distribution- MIP	BS ISO 15901-1:2016
	Heat Capacity	ASTM D5334-14
	Thermal Conductivity	ASTM D5334-14
	Diffusion Resistance Factor	BS EN ISO 12572: 2016
Dynamic	Liquid Transport Coefficient- Suction	BS EN 1925:1999 or ASTM C1585
	Liquid Transport Coefficient- Redistribution	BS EN 1925:1999 or ASTM C1585
	Water Vapour Diffusion Resistance Factor- Moisture Dependent	BS EN ISO 12572: 2016
	Thermal Conductivity Moisture Dependent	ASTM D5334-14

Table 2 Mechanical material properties to be measured and methodologies to be followed

Property	Methodology according to
Flexural and compressive Strength	BS EN 1015-11:2019
Shrinkage	BS EN 12390-16:2019
Drying properties	BS EN 16322:2013
Durability- Freeze/thaw	BS EN 12371 or BS EN 12390-9

3. Conclusion

It is hoped that the extended monitoring period of the test panels will allow further analysis of their hygrothermal behaviour over a longer time frame and establish if the behaviour and problems already identified persist, change or if new issues arise. The detailed material characterisation will enable the creation of new materials for the WUFI® database, may achieve a closer correlation between measured and simulated data or may highlight other reasons for discrepancies. This may allow simulation over a longer period to be undertaken, and in future projects, the use of predicted future climate data. It is intended that these new additions to the WUFI® database will be made publicly available to facilitate improved hygrothermal simulation by others. At the same time, durability testing will inform guidance for the retrofit of historic timber-framed buildings, enabling their continued use and survival. Both the initial and follow-on projects have been funded by Historic England, with participation of Ty Mawr Lime Ltd.

References

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