Comparative testing of replacement infill materials for historic timber-framed buildings.

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Introduction

It is known that unsuitable energy retrofits of traditionally constructed buildings may lead to moisture accumulation within their external envelopes. Whilst numerical hygrothermal modelling can assist in identifying these threats, it is acknowledged that physical testing is still required [1]. Research in the UK to date has focused on solid masonry construction [1&2]. The work presented in this poster therefore focuses on the previously under-researched area of the impact of energy retrofits on historic timber-framed buildings, of which approximately 68,000 survive in the UK [3]. Specifically, the project aims to establish the risk of interstitial condensation and increased moisture content within replacement infill panels for timber-framed buildings, and the risk posed to surrounding historic fabric. The methodology utilised for this project is the construction of a physical test cell, enabling the monitoring of mock-up infill panels of 4 types of insulation. This overcomes the limitations of computer simulations, which model only idealised, homogeneous, continuous layers, with limited material data for traditional building materials in the UK, whilst at the same time avoiding many of the physical constraints in monitoring within real walls and buildings,

Methodology: Design and Construction of Test Cell

A physical test cell has been constructed (fig.1), with the test panel dimensions determined by a review of a representative sample of 100 UK historic buildings with exposed timber-frames (fig.2). The test cell with its internally controlled climate, allows the comparison of four replacement infill panel materials, wattle-and-daub, wood fibre, expanded cork board and hempcrete replacement infill panels within a reclaimed oak frame (fig.3), with one of each panel finished in natural hydraulic lime (NHL 3.5) and another in lime hemp plaster. Over a minimum monitoring period of two years, interstitial temperature and moisture content will be monitored, both within the panels and more importantly at their interface with the oak frame, in addition to their thermal performance.

Figure 1.. North façade of Test cell, Cardiff University. *Source (Whitman, 2020)*

Figure 2. Representative sample of 100 UK historic buildings with exposed timber-frame

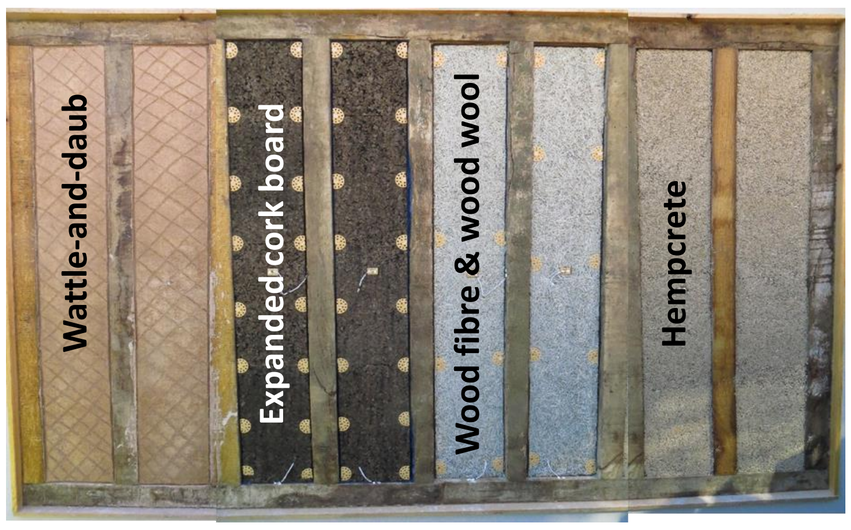

Figure 3. Test panels showing insulation prior to rendering. *Source (Whitman, 2019)*

Type T thermocouples and electrical resistance sensors for monitoring moisture content have been installed at three depths (at the interface of insulation and internal plaster, at mid-depth of the insulation, and at the interface of insulation and external render). These three depths are repeated at the midpoint of the panel, at the horizontal junction between panel infill and cill-beam, and at the vertical junction between the panel infill and the upright stud. All sensors are wired back to a Campbell Scientific® CR1000™ data logger with readings at 30 minute intervals. The internal and external climatic conditions are also recorded to enable future comparison between recorded hygrothermal behaviour and digital hygrothermal simulations. In situ U-value measurements have been undertaken over the first heating season using Hukseflux® HFP01™ heat flux plates and type T thermocouples. Further U-value measurements will be carried out over subsequent heating seasons to study the change in thermal performance with moisture content.

Initial Results

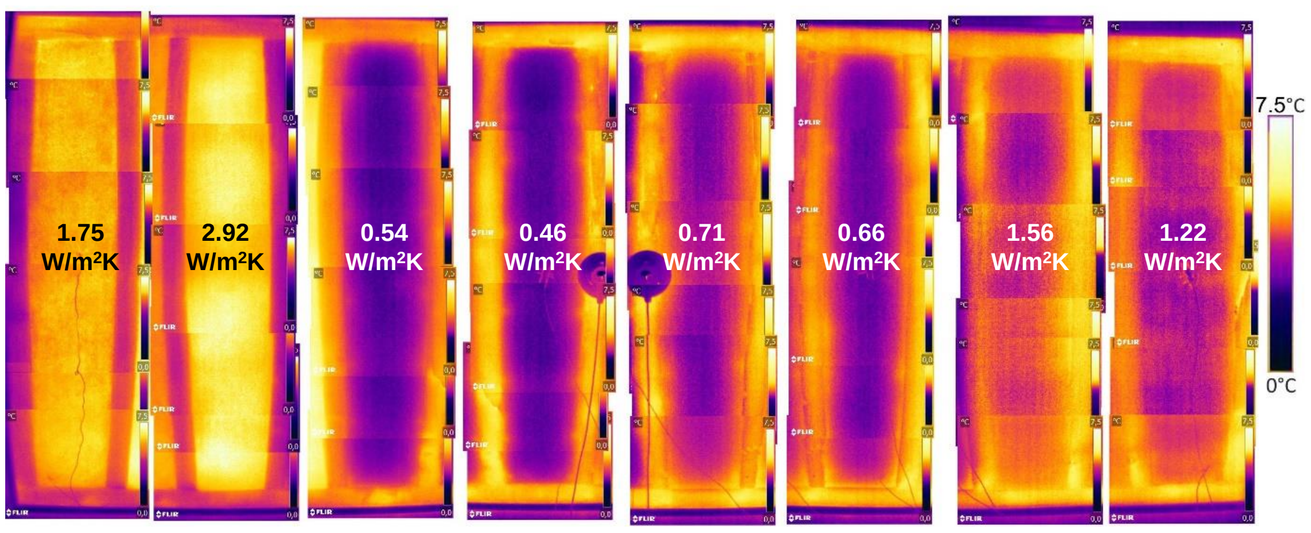

Figure 4. External thermography and measured U-values. Left to right, wattle & daub (WD) + lime-hemp plaster (LP), WD + NHL 3.5, cork + NHL 3.5, cork + LP, wood fibre (WF) + NHL 3.5, WF + LP, hempcrete (HC) + NHL 3.5 and HC + LP. Internal temp. 21°C, external temp 4 °C.

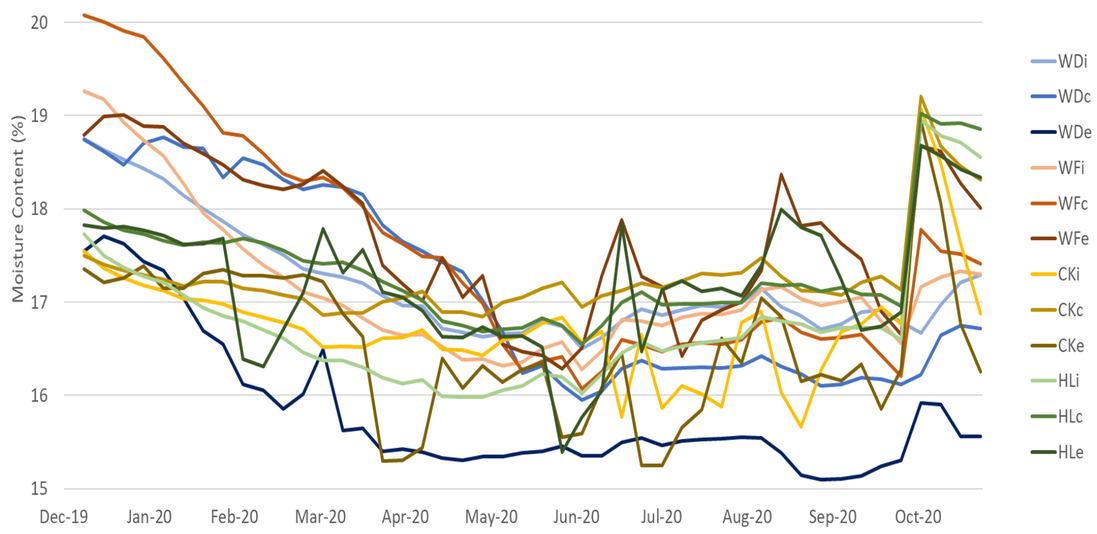

Figure 5. Initial moisture content results 13/12/19 – 30/10/20 at horizontal junction between panel infill and cill-beam for panels finished in NHL 3.5. (WD- wattle-and-daub, WF- Woof fibre, CK- Cork, HL- Hempcrete. i-internal, c-centre, e-external)

The initial U-value measurements and thermography (fig.4) showed the cork board with lime-hemp plaster to have the best thermal performance (0.46W/m^{2}K), followed by the wood fibre, then the hempcrete, with the traditional wattle-and-daub the worst. However, those insulation materials with a low moisture permeability such as the cork are seen to produce a concentration of moisture in the external render during events caused by wind driven rain. In the case of the latest wetting event, the product of Storm Alex, UK's wettest day on record [4] the results appear to suggest that the cork insulation may be trapping the moisture within the centre of the vertical and horizontal junctions. The measurements and the analysis of the results are ongoing.

Conclusions

The initial results indicate significant differences between the hygrothermal performance of the different replacement panel infills and reinforce the balance required between thermal performance and moisture permeability. It is hoped that the final results will inform best practice guidance for the energy retrofit of historic timber-framed buildings in the UK. The research, funded by Historic England, is being carried out at Cardiff University, in collaboration with the University of Bath, Ty Mawr Lime Ltd, Royston Davies Conservation Builders and UK Hempcrete.

References

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