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The Implications of Future Wind-Driven Rain Exposure on the Hygrothermal Performance of Internally Insulated Solid Walls in London

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Abstract

With approximately 40% of the London building stock built before 1919, internal wall insulation (IWI) is one of the likely measures for deep retrofit to meet carbon emissions targets. However, IWI can lead to moisture accumulation and associated unintended consequences, especially in walls highly exposed to wind-driven rain (WDR). Climate change is predicted to exacerbate WDR exposure. This paper presents a comparative analysis between the hygrothermal performance of IWI under current and far future (2080) climates. Historic weather station data and UKCP18 climate projections were used to develop weather files for simulating current and future climate, respectively. Hygrothermal simulations were performed using DELPHIN. Assemblies include calcium silicate, phenolic foam, and wood fibre systems. Future climate predictions are associated with a rise of interstitial relative humidity, leading to patterns more favourable to mould growth.

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Keywords: Internal wall insulation; climate change; hygrothermal simulations

1. Introduction/Background

With approximately 40% of the London building stock built prior to 1919, reaching net-zero carbon emissions in refurbishments will likely require internal wall insulation (IWI) where exterior alterations are limited by aesthetic preference or conservation principles. IWI will improve thermal performance, but it will also alter hygrothermal behaviour: introducing extra vapour and thermal resistance reduces inward drying and poses a risk for interstitial condensation. In addition, the changing climate will present more challenging environmental loads experienced by external walls with a major one being wind-driven rain (WDR), which has been studied to be the most critical to moisture risk [1]. Under a high emissions RCP 8.5 scenario, a 27% increase in average winter precipitation and increase in hourly extremes may be seen [2]. The aim of this paper is to understand current and future WDR exposure in London and analyse moisture behaviour within internally insulated solid walls.

2. Methodology

Observed weather data was used to simulate current climate conditions. The London Weather Centre (LWC) was chosen for its proximity to the Borough of Westminster (67,000 traditional pre-1919 buildings [3]) and data availability; the most recent UKCP18 climate projections along with weather morphing were used to produce weather files for simulations under future climate conditions. The quantification of WDR exposure under current and future climate was performed according to BS EN ISO 15927-3 [4]. In line with BS EN 15026 [5], simulations under current climate conditions and a far (i.e. 2080) future climate used the year with 90th percentile rainfall. The method for the development of climate files is described in [6].

One wetting and drying cycle (e.g. Oct 1999 – Oct 2000) was used to analyse yearly rainfall; each cycle was repeated three times to reach dynamic equilibrium in the simulations. A total of 16 hygrothermal simulations were carried out on a vertical south-facing wall in DELPHIN 6.0, using materials from the software database. The original brick wall was modelled along with three different insulation materials: phenolic foam, wood fibre and calcium silicate. The s_d value for each assembly (excluding the brick layer) was 100.3m, 0.52m, and 0.63m respectively. Each IWI system was modelled to achieve two U-values; one ‘low’ of 0.35 W/(m^{2}K) and ‘high’ of 0.6 W/(m^{2}K). A comparative analysis concerning interstitial temperature and relative humidity between existing brick and insulation was carried out to evaluate the influence of future climate on interstitial condensation and mould growth risk.

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3. Results and Discussion

3.1. Wind-driven Rain Exposure Analysis

Climate analysis showed an overall trend of cooler, wetter winters and hotter, drier summers in London in 2080 compared with the current climate. This is in line with UKCP18 MetOffice findings [2]. Using the semi-empirical WDR equation from ISO 15927-3:2009 [4], the total intensity of annual WDR doubled to approximately 200 mm during the wetting season (October – March). WDR spells will, on average, increase in intensity and duration by 24% and 5%, respectively. This brings London from a sheltered to moderate exposure level. This would also result in shorter periods for potential drying between them. Another index [7] resulted in a 63% increase in the 95th percentile of WDR intensity, representing more extreme (intense) short-term WDR events.

3.2. Predicted Hygrothermal Performance of Insulated Walls

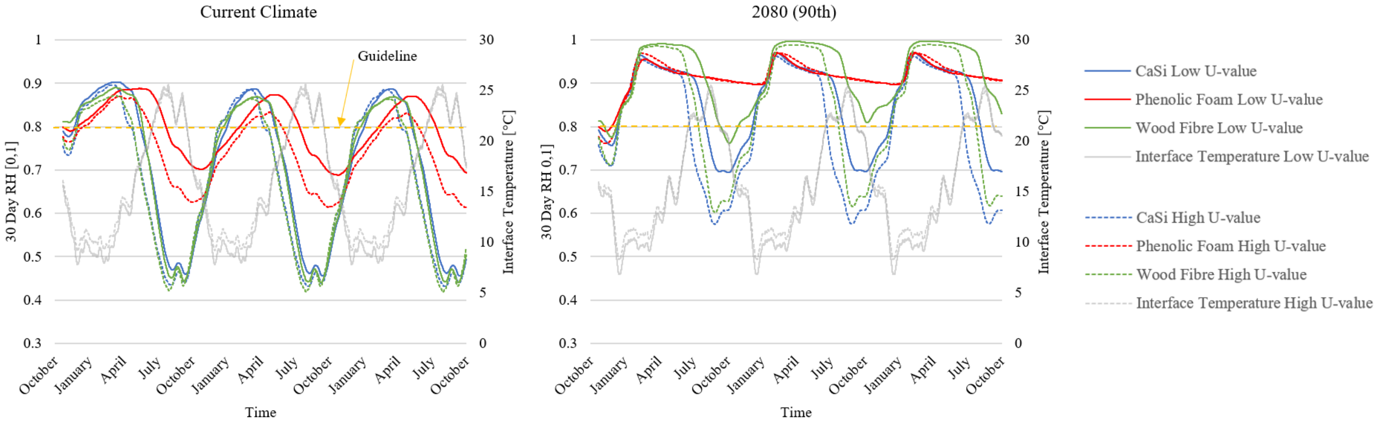

Figure 2. 30-day moving average of interface relative humidity and temperature for low and high U-value assemblies: (left) current climate (90th percentile); (right) future 2080 climate (90th percentile) with an 80% RH guideline for moisture risk.

Figure 2 shows a 30-day moving average of interface relative humidity and temperature of the three different insulation materials. Interface temperature behaved the same across the three systems. In 2080, there is a significant rise in RH throughout the year. Due to increased moisture loads, wood fibre and phenolic foam assemblies stay above 80% with wood fibre hovering at 100% for the entire wetting season. Consistently higher RH in the summer months also delays the speed and extent of drying, with assemblies reaching their driest point approximately one month later. In 2080, sustained high relative humidities also coincides with periods of warmer temperatures, increasing the conditions suitable for mould growth. Calcium silicate performed best, with the lowest RH throughout the year. From the graphs it is also noticeable that the dotted lines representing the thinner insulation option reach lower RH levels, particularly in the drying months of the year. With internal wall insulation systems, a higher U-value than what is currently required in the building regulation should be considered as the increased moisture risk may compromise the wall's integrity.

4. Conclusion

The future climate in London is predicted to bring higher exposure to WDR, both in intensity and duration. In hygrothermal simulations of three various IWI systems, increased moisture loads of the future result in a significant rise to interstitial RH combined with temperatures higher than 10°C throughout the year, leading to patterns more favourable to mould growth. The calcium silicate material performed the best and thinner insulations in all three systems allowed the most drying. This highlights a potential need to change building regulations where a higher U-value could result in less moisture related risk.

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