

Effect of orientation on the hygrothermal behaviour of a capillary active internal wall insulation system

Valentina Marincioni, M.Sc. ¹

Hector Altamirano-Medina, Ph.D. ¹

¹University College London, UK

KEYWORDS: *internal insulation, capillary active, relative humidity, orientation, solar radiation*

SUMMARY: *UK authorities are promoting energy efficiency schemes to improve the performance of buildings as a result of the high levels of energy consumption and consequent CO₂ emissions. A quarter of these emissions are due to requirements for space heating. Installation of insulation is one of the most common alternatives to thermally improve buildings, especially on buildings built of solid masonry (~20 percent of the housing stock). However, the thermal improvement of buildings located in conservation areas, listed buildings, decorative façades, or traditional buildings could be only achieved through the use of internal wall insulation. Solid masonry walls with high surface water absorption coefficients have a higher dependence on external climate conditions (e.g. rain, solar radiation), which are likely to affect the performance of internal wall insulation. This paper examines the effect of walls orientation on the hygrothermal behaviour of an internally insulated 16th century building. External walls have been insulated with a capillary active system that allows moisture movement towards indoor environments. Sensors to monitor relative humidity and temperature between the existing brick wall and the insulation were installed in the north-facing and south-facing walls of the building. Both walls are exposed to the same internal environmental conditions (teaching area). The study showed that drying of the south-facing wall occurred faster than drying of the north-facing wall and that drying of the south-facing wall was enhanced by the effect of direct solar radiation.*

1 Introduction

Improving the energy efficiency performance of the building stock is a priority if the UK is to meet at least 80% carbon reduction by 2050. Wall insulation is one of the measures considered for buildings built of solid masonry (~20 percent of the housing stock) (DECC, 2011).

Due to planning requirements, traditional buildings built before 1920 (generally buildings located in conservation areas, listed or with decorative façades) and characterised by solid walls are likely to be thermally improved through the installation of internal wall insulation. However, internal wall insulation can undermine the durability of a building, increasing the risk of mould growth and timber decay. Solid walls would be exposed to lower temperatures and, depending on the insulation system applied, there may be an increase in the vapour resistance of the building envelope.

This paper presents the results of a case study where the effect of orientation on the heat and moisture transfer within internally insulated solid walls was assessed. The building analysed is a grade II listed barn, with 330 mm solid brick walls and internally insulated with a capillary active insulation system made out of dense woodfibre.

2 Methodology

2.1 The building

The building studied is a grade II listed 16th century barn located in Maidenhead, west of London. The building was refurbished in 2011 and converted into an education centre, featuring a large teaching area, open-plan offices and one exhibition area.

The external walls (solid brick) were insulated internally with 100 mm of Pavadentro, a composite board formed by woodfibre and a mineral layer that creates a light vapour diffusion resistance; the total equivalent air layer thickness of the dry composite board is $s_d = 1.6$ m.

The existing wall was levelled with a lime-based coat before the insulation was applied and then a bonding coat was used to provide full contact between the insulation and the existing wall. External façades were left exposed, without any impregnation treatment or installation of damp proof courses; therefore not limiting moisture penetration into the building. The building durability could be maintained if potential moisture accumulation were counterbalanced by subsequent moisture drying (a process formed by evaporation and vapour transfer).



FIG 1. Building and external walls insulated a) north facing wall; b) south facing wall (access to teaching area)

TABLE 1. Wall assembly

Wall construction (outside to inside)	Thickness (mm)	
Brick	330	
Levelling coat (3:1 NHL and sand)	0 to 6	
Bonding coat (Lime plaster)	5	
Pavadentro (composite insulation)	woodfibre board	20
	mineral layer	1
	woodfibre board	80
Internal finish (Lime plaster)	8	

2.2 Monitoring method

The aim of the study was to estimate the effect of orientation on the hygrothermal behaviour of internally insulated walls. Four thermocouples and resistive probes (sensors) to measure temperature (T) and relative humidity (ϕ) respectively were installed at the interface between the existing wall and the insulation; sensors (NH, NL) were installed at 30 cm (low – L) and at 200 cm from the ground (high – H) on the north-facing wall and on the south façade (SH, SL) respectively, as shown in figure 1. Sensors were set with a sampling interval of $\Delta t = 30$ min and an accuracy of $T = \pm 0.7$ °C and $\phi = \pm 5$ % at 21 °C. Data were collected for 22 months starting on 01/11/2011 and ending on 11/09/2013.

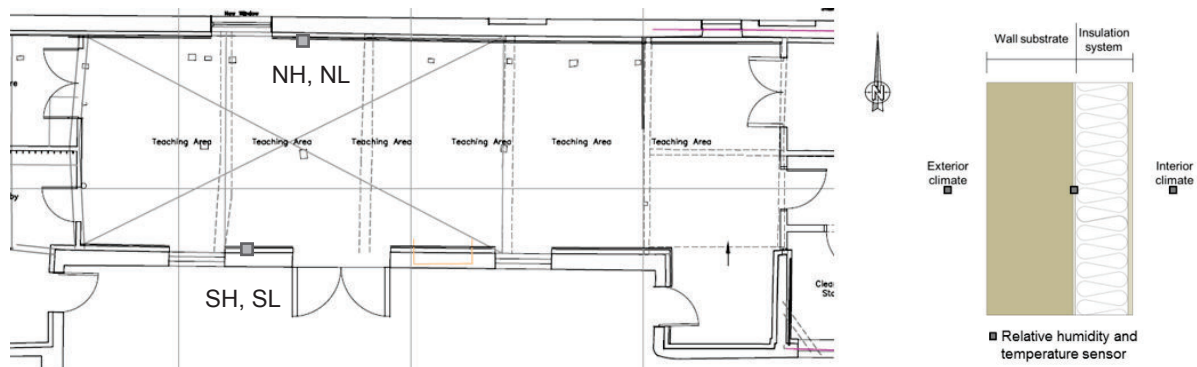


FIG 2. Building plan with focus on the teaching area and locations of sensors

2.3 Climate

The building is located within the Wind Driven Rain zone 2 (where $33 \text{ l/m}^2 < \text{WDR} < 56.5 \text{ l/m}^2$ per spell) in an area where the prevalent wind direction is WSW. Minimum and maximum mean daily temperatures (data from the period 1971-2000) vary from 1 °C to 9 °C and from 7 °C to 23 °C respectively. Monthly average sunshine fluctuates from 50 to 200 hours. (Met Office, 2013a)

The main source of internal moisture comes from the people occupying the teaching room, generally large groups for short periods of time; occupation patterns depend on the frequency of school visits. The room is naturally ventilated (all windows are openable).

3 Results and discussion

Temperature and relative humidity at the interface between the existing wall and the insulation were collected and the profiles related to the north and south orientations compared. The reduction and increase of relative humidity (drying and wetting period respectively) at the interface were analysed and the causes of such events identified.

Profiles of relative humidity at the four interstitial locations studied are shown in Figure 3. The initial relative humidity varied from 82 % to 94.6 % as sensors were applied on the surface of the insulation board and surrounded by the bonding coat (wet when applied). The initial moisture of the construction system started drying out after 2 months on the south elevation and 4 months on the north elevation.

As shown in Figure 3, there was a reduction of the interstitial relative humidity in both insulated walls, however with a higher reduction observed in the south-facing wall. In both walls, the relative humidity was lower at the end of the study at high level (NH and SH). Drying occurred approximately from January to September, whereas wetting occurred from September to January.

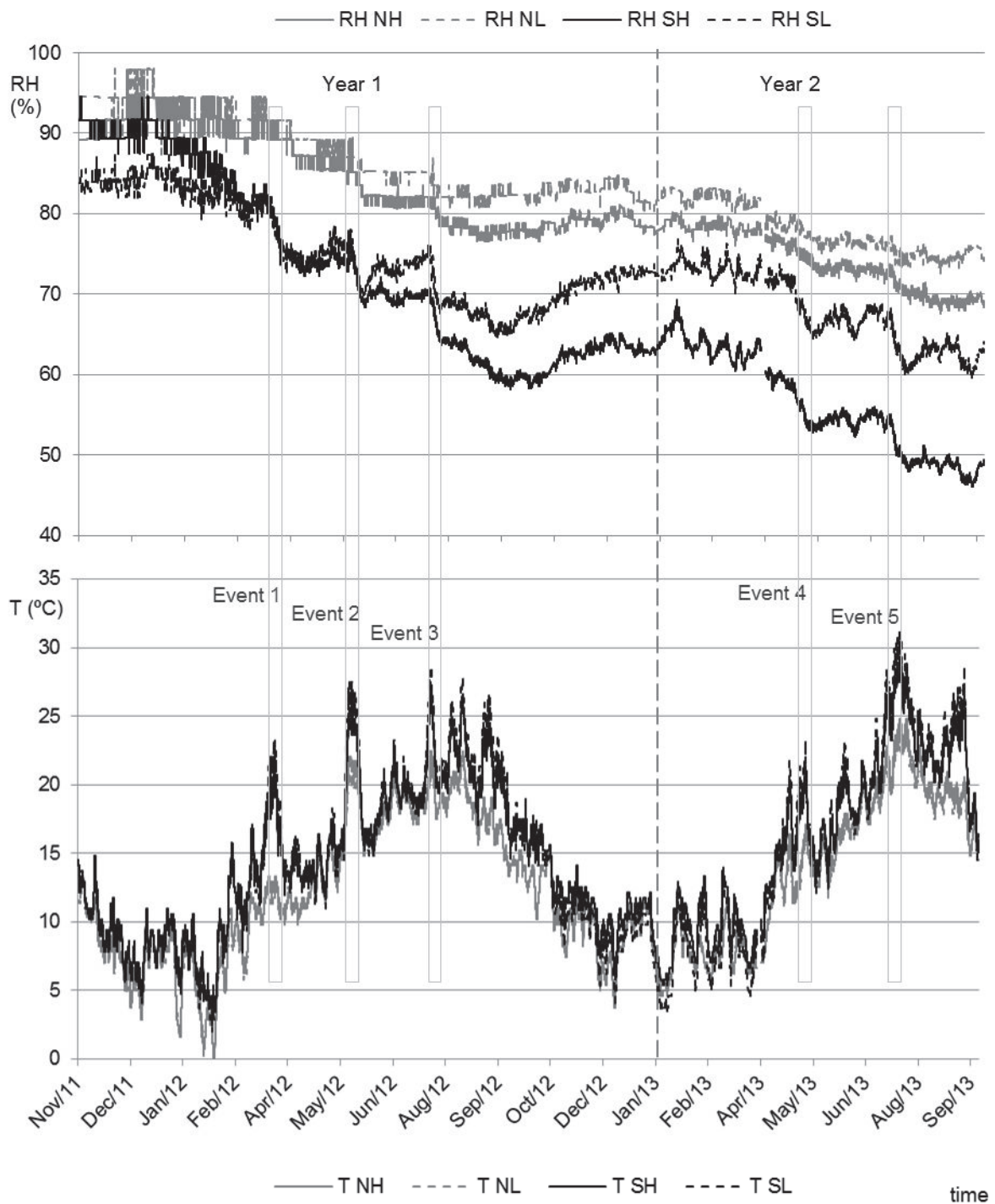


FIG 3. Relative humidity and temperature measured at four location of the existing wall-insulation interface.

Drying periods in 2012 and 2013 were characterised by events of sudden relative humidity reduction; sudden reductions were defined as events when at least one sensor shows a decrease of relative humidity ϕ (%), in function of time t (d), for minimum 7 days and with an average rate of 0.5 % per day or above:

$$\frac{\Delta\phi}{\Delta t} \geq 0.5 \% / d \quad (1)$$

According to these criteria, three major events occurred on year 1, followed by two on year 2.

TABLE 2. Events of sudden decrease in relative humidity ($\Delta\phi/\Delta t$) and difference in the temperature averages

Event	Start date	End date	Duration (days)	$\Delta\phi/\Delta t$ south wall (%/d)		$\Delta\phi/\Delta t$ north wall (%/d)		$T_{\text{south wall}} - T_{\text{north wall}}$ (°C)
				High	Low	High	Low	
1	24/3/12	6/4/12	13	0.62	0.77	0.15	0.15	6.1
2	23/5/12	3/6/12	11	0.64	0.82	0.37	0.37	3.6
3	23/7/12	1/8/12	9	0.67	0.78	0.22	0.33	3.6
4	25/4/13	9/5/13	14	0.43	0.5	0.22	0.14	4.3
5	6/7/13	20/7/13	14	0.43	0.57	0.29	0.14	4.8

The events of sudden relative humidity reduction lasted from 9 to 14 days, with a rate of decrease from 0.43 to 0.82 % per day in the south-facing wall and from 0.14 to 0.37 % per day in the north-facing wall.

A difference in temperature at the interface of the existing wall and insulation was noted during the events of sudden relative humidity reduction (Figure 3, below), which was not observed during the wetting period. Temperatures at the four locations were comparable; however in the drying period, and in particular during the relative humidity reduction events, the temperature at the interface of the existing wall and the insulation on the south-facing wall was higher than the temperature within the north-facing wall. Table 2 shows the average difference of interstitial temperature between the sensors located in the south wall and the ones in the north wall.

The difference in temperature seems to be related to orientation and more specifically to solar radiation. Direct radiation would allow an increase in surface temperature in the south-facing wall and a higher rate of evaporation compared to the north-facing wall, which is only affected by diffuse radiation. The observed sudden reductions in the internal humidity of the south-facing wall coincided with events reported by the Met Office (2013b) as “remarkably sunny” periods: from the 23rd to 30th March 2012 and from the 21st to the 28th May 2012. The same happened in July 2012, a cold and wet month until the 21st, when the weather became warmer and sunnier. In Figure 4, the monitored relative humidity for the period November 2011 – August 2012 was plotted along with daily averaged solar radiation intensity (W/m^2); events of sudden relative humidity reduction match periods of consistently high solar radiation intensity.

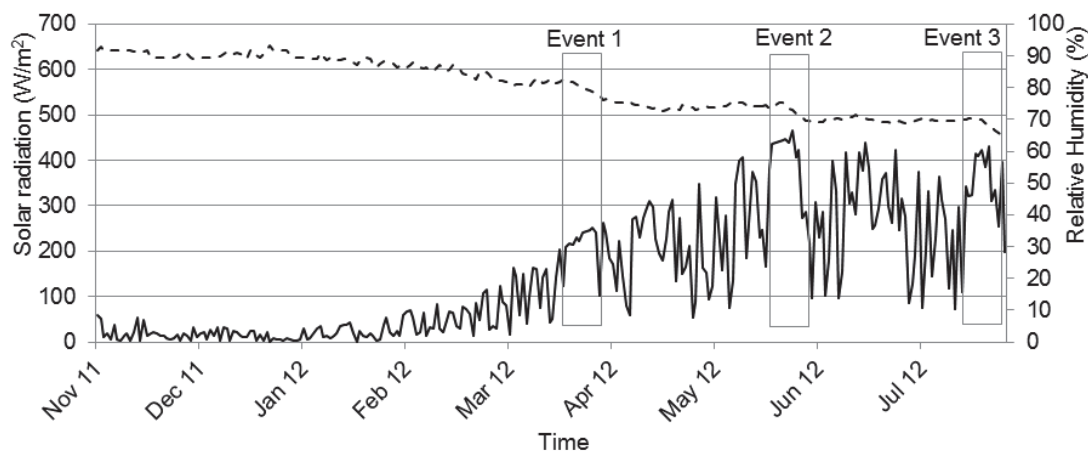


FIG 4. Events of sudden relative humidity (dashed line) reduction and solar radiation (solid line)

4 Conclusion

This paper examines the effect of walls orientation on the hygrothermal behaviour of internally insulated walls of a traditional building.

Temperature and relative humidity at the interface between the existing wall and the insulation were monitored for a period of two years. It was observed that the walls have a different hygrothermal performance. The south-facing wall presented a faster reduction in relative humidity compared to the north-facing wall. Discrepancy in the performance was found to be associated to wall orientation; in particular solar radiation.

The hygrothermal performance of a capillary active internal wall insulation system was found to allow dry-out of moisture within the building envelope enhanced by changes of temperature in the external wall due to longer and constant periods of solar radiation. Other studies have shown that capillary active insulation is beneficial to the building structure helping to reduce the risk of mould growth (Häupl, Fechner et al. 2006, Wegerer and Bednar, 2011).

The effect of solar radiation and wind driven rain on the performance of various conventional and capillary active insulation systems is being further investigated.

Acknowledgments

The authors would like to thank Natural Building Technologies and Technology Strategy Board who funded the research project and Oxley Conservation for providing the case study building.

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