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Thin Internal Wall Insulation (TIWI)

Measuring Energy Performance Improvements in Dwellings Using Thin Internal Wall Insulation

Annex D; Moisture Risks of TIWI

Laboratory Investigations

BEIS Research Paper Number: 2021/016

LEEDS SUSTAINABILITY INSTITUTE

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LUCIDEON

Department for Business, Energy & Industrial Strategy

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Executive Summary

As part of a wider project to investigate the benefits and risks associated with internal wall insulation (IWI) and thin internal wall insulation (TIWI), Leeds Beckett University and Lucideon Ltd, undertook a series of laboratory investigations on uninsulated and insulated solid brick test walls. The test walls were built inside a frame that could be moved into hygrothermal chambers. To investigate the effects of breathability on any moisture risks, two versions of each insulated wall were tested, one installed on lime-based plaster (vapour open), and one on gypsum-based plaster (vapour closed). The tests were designed to mimic the weathering effects of the UK climate and investigate how this affected heat loss, moisture accumulation, moisture transfer, surface condensation risk and interstitial condensation risk. After being equipped with sensors for measuring temperature and moisture, the walls were installed into Lucideon's hygrothermal chambers where they were exposed to accelerated weathering cycles to represent the impact on the *outside* wall face of homes, while the *inside* wall face was exposed to conditions representative of homes in the UK.

In initial trials, wetting test bricks resulted in excessive salt deposition meaning it was not possible to measure the moisture transfer through the walls. An alternative method based on shorter periods of weathering and relying on temperature measurements and heat flux measurements was developed to evaluate heat loss as well as surface and interstitial condensation risk. Core samples of the bricks also confirmed the water content of each wall after testing.

The tests showed that wetting bricks results in highly irregular heat loss patterns, though generally it was observed that wet bricks had higher U-values and heat loss than dry bricks. This indicates that the impact of rain on brick thermal performance may warrant further study.

When looking at the dry brick wall performance, a slight performance gap was observed between predicted and measured U-values of the IWI and TIWI, particularly for the Cork Lime Render. However, this may be due to inconsistencies in the thickness at which this product was applied.

Internal wall surface condensation risk was observed to be reduced following the installation of both TIWI and IWI by around a similar margin. This indicates a potential benefit to households may be achieved regardless of which insulation option is installed.

Conversely, interstitial condensation risk was observed to be somewhat introduced when TIWI was installed, though this risk substantially increased when IWI was installed.

There was some evidence to suggest that breathable plasters tended to result in lower levels of moisture accumulation in the internal bricks compared to non-breathable plasters, however, no trends were observed suggesting that breathable insulation products result in lower water accumulation. This may be because the accelerated weathering tests do not adequately mimic real world conditions. Indeed, values of water content of the external brick were not correlated with the plaster or insulation product that was used. Further investigation into the benefits of breathable wall insulation and waterproofing systems is required.

1 Annex D; Introduction to Laboratory Tests

1.1 Research Project Overview

Thin internal wall insulation (TIWI) could play a role in UK energy policy, though the extent to which it can contribute to emissions targets, increase retrofit rates of solid wall homes, reduce fuel poverty, improve thermal comfort and mitigate unintended consequences is not fully understood.

On behalf of the Department for Business, Energy and Industrial Strategy (BEIS), Leeds Beckett University have investigated the potential of TIWI to achieve warmer homes and lower fuel bills with fewer unintended consequences than conventional internal wall insulation (IWI).

Five output reports describe the research and results from this project, these are:

1. Summary Report
2. Annex A, Introduction to TIWI: Literature, Household & Industry Reviews
3. Annex B, TIWI Field Trials: Building Performance Evaluation (BPE)
4. Annex C, Predicting TIWI Impact: Energy & Hygrothermal Simulations
5. Annex D, Moisture Risks of TIWI: Laboratory Investigations

1.2 TIWI Annex D Overview

This report presents the results of the laboratory investigations.

This report is structured as follows:

- Section 2, Introduction to the Laboratory Research
- Section 3, Methodology
- Section 4, Impact of IWI and TIWI on Heat Transfer and Moisture Risk
- Section 5, Impact of TIWI on Wall Moisture Content
- Section 6, Conclusion

2 Introduction to the Laboratory Research

2.1 Laboratory Research Project Aims

The laboratory research compares how moisture and the thermal properties of solid walls change when internally insulated with a conventional 70mm internal wall insulation (IWI) and 5 novel thin internal wall insulation (TIWI) products with thicknesses below 30mm. The products were:

• Phenolic	70 mm
• PIR	27 mm
• Aerogel	14 mm
• Cork render	20 mm
• Latex rolls	10 mm
• Thermo-reflective paint	1 mm

The scope of the project involved exposing solid brick walls, clad with IWI and TIWI materials, to weathering cycles, equating to 25 years in the UK climate. The walls were constructed from Warwickshire Olde English Bricks, which were chosen to replicate the construction typically found in older properties in the UK. The aims of the laboratory research were:

- to establish if accelerated weathering of internally insulated solid walls had a detrimental effect on their thermal properties (U-value)
- to determine how IWI and TIWI affects moisture accumulation and the risk of surface and interstitial condensation in solid walls.
- to evaluate the impact of breathable and non-breathable internal plaster on moisture accumulation in internally insulated walls.

To answer these aims, the following measurements approaches were used:

1. Thermocouples and moisture probes were inserted into the walls at varying depths in a dice pattern and on the surface of walls in a diagonal pattern to measure the changes in brick moisture and temperature following and during the cycles.
2. Thermocouples were placed on the internal wall surface and behind the insulation layers to measure surface and interstitial condensation risk.
3. Heat flux was measured through the wall during “dry” and “wet” steady state conditions to measure the impact of damp walls on heat flux.
4. Core samples of the walls were taken from the walls to analyse moisture accumulation post wetting.
5. Walls were constructed and insulation was tested using breathable and non-breathable plaster to compare how these systems performed.

3 Methodology

This section outlines the initial testing undertaken to track moisture movement in solid walls and then describes the further investigations undertaken in the hygrothermal laboratory to measure thermal performance, moisture accumulation and condensation risk in the insulated and uninsulated walls.

3.1 Tracking Moisture Through Bricks During Accelerated Weathering

Moisture movement through brickwork walls has historically been monitored over extended periods of time, often over many months. Attempting to measure this during accelerated weathering cycles therefore was a novel approach, since these run over hours, not months.

3.1.1 Thermistor Trials

Trials were undertaken to establish a method to enable moisture tracking through the brick wall during the weathering cycles. Before equipping the walls with sensors, thermistors, which are frequently used to monitor temperature and humidity, were installed into holes drilled into three test bricks at depths of 15mm, 50mm and 75mm. The brick was then placed into water to a depth of 10mm and data from the thermistor recorded on a digital logger. Once the brick was saturated, it was removed from the water, and placed in ambient air conditions to dry. However, the data from the experiment suggested that once the brick became saturated, a constant relative humidity reading of 100% from the thermistor was recorded even after the brick had fully dried, indicating something to do with the brick being soaked was affecting the thermistors from recording accurately. To attempt to overcome this problem, the experiment was repeated, this time the thermistor was placed inside a rigid plastic sheath, and the hole was filled with rapid curing mortar to isolate the thermistor from the brick and moisture. However, the thermistor readings after drying the brick were again reading 100% and somehow being affected by the soaked brick. This meant that an alternative approach was required to track moisture in the brick.

3.1.2 Electrical Resistance

Electrical resistance posed a possible alternative approach to monitoring moisture tracking through the brick. Attempts were made therefore using a) a copper wire and b) a wooden dowel. These were installed into test bricks and then this was soaked in the water. Measurements of conductivity on the wire and the wooden dowel were taken, but in both instances erratic readings were again recorded, and no correlation between conductivity and moisture content could be made.

The cause of these unreliable readings was investigated further, specifically in relation to the soluble salts within bricks. When soaked, the salts in the brick go into solution and travel through the body of the brick and on drying form a white deposit on the brick surface. Trials were therefore conducted to determine if the Warwickshire Olde English Bricks used for the construction of the test walls contained unusually high levels of soluble salts. A container was filled with de-ionised water, and the conductivity of the water was measured. The bricks were submerged in water for a period of 72 hours and then removed. The conductivity of the water was re-measured and was found to have increased significantly suggesting that salts from the brick had leached into the water. This would offer an explanation as to why the resistance measurements were found to be so erratic, as salts leaching from the bricks would interfere with the resistance measurements. The bricks were allowed to air dry, and significant salt deposits were noted on the exterior of the bricks again, indicating high levels of soluble salts in the bricks as shown in Figure 3-1.

Figure 3-1 Salt Deposit Leached from Bricks

To further investigate suitable approaches to measuring moisture movement in bricks, research papers were sourced looking at methodologies for monitoring temperature and humidity movement in bricks. Most pointed to undertaking measurement over an extended period on walls that had been *in situ* for many years whose salts will have diminished over time. Changes in the climate that the brick is exposed to occur over weeks and months allowing time for the moisture within the brick to be tracked. Conversely, with accelerated weathering cycles there is little time for moisture in the brick to escape between each cycle. This appears to result in moisture gathering in the void where the instrumentation is located and a reading of 100% is obtained. The reading remains at 100% until the brick around the void dries and the reading drops. Unfortunately, the time between the accelerated weathering cycles does not give enough time for the brick to dry.

Thus, accurate monitoring of moisture movement was not be possible during the programme of accelerated weathering. The next sections describe the data collection that could be relied upon from the laboratory testing, included monitoring of surface and internal brick temperatures using thermocouples, heat flux across the insulated wall, and core samples taken from the walls to evaluate water accumulation.

3.2 Hygrothermal Laboratory Tests

The walls to be tested in the hygrothermal laboratory were built using Warwickshire Olde English Bricks. Six walls were built in stretcher bond, 9 inches thick (229 mm), inside 2.6m x 3.2m metal frames. Three of the walls were plastered using a non-breathable thistle bonding coat and gypsum plaster, and three were plastered using a breathable Limelite renovating plaster. Each wall was split in half vertically and insulated with one of the six insulation products meaning each product was tested on a breathable and non-breathable plaster.

Thermocouples were inserted at five positions in a dice pattern to provide an even spread of measurements over the brickwork face of two of the walls. The thermocouples were inserted at three depths in the brickwork at 50 mm 100 mm and 150 mm depths from the external face of the wall exposed to the weathering. A second set of three thermocouples were adhered to the plaster face of the walls in a diagonal pattern on the internal and external surface. Two heat flux plates were fixed to the internal surface of each half wall to allow the wall U-values to be calculated. It is not known if the two insulated half walls interfered with heat or water transfer at the boundaries, however, the sensors and core samples were located far enough away from the boundaries to avoid any edge effects.

Before all the walls were insulated, two of the walls were placed into a hygrothermal chamber and exposed to the weathering cycles to provide the uninsulated baseline data as can be seen in Figure 3-2. The plastered faces (internal conditions) of the walls were enclosed in a climatic box to enable the temperature at the plaster face to be controlled at 18°C to replicate conditions in a home.

Figure 3-2 Hygrothermal Chamber

The initial tests involved subjecting the walls to hygrothermal cycles, which resulted in the walls being heated to 50°C for a period of three hours, and then subjected to a water spray for one hour. However, these parameters appeared to be too severe with both the brickwork and plaster quickly becoming completely saturated and having little time to dry between weathering cycles. A large volume of salt was also washed from the bricks depositing on both the plaster and brickwork face as can be seen in Figure 3-3.

Figure 3-3 Salt Deposits on both Plaster Face and Brickwork

The programme was therefore modified, to reduce the amount of time that the walls were exposed to the water spray with a period of 2 hours chosen to represent a typical rain shower in the UK. The control walls were exposed to 50°C over an extended period in order to dry the walls prior to commencing a new cyclic regime. Cores were taken from the walls, dried and the moisture content calculated in order to ensure that the walls were *dry* prior to commencement of the new regime.

Following the baseline data collection, the six insulated walls were tested in the hygrothermal chamber and exposed to the following climatic conditions until a steady state was achieved for a period of at least five days which allowed heat flux measurements to measure the U-value of the dry wall.

- *Exposed Brickwork Face* — *Air Temperature 6^{o}C*
- *Internal Plaster Face* — *Air Temperature 18^{o}C*

Once a steady state had been achieved, the walls were the subjected hygrothermal cycles for a period of five days. The cycles consisted of the following:

- *Exposed Brickwork Face* — *Air Temperature 50^{o}C falling to -2^{o}C 3hr Cycles*
- *Internal Plaster Face* — *Air Temperature 18^{o}C*

Following this the walls were exposed to the 2hr soaking and the wall was again exposed to the following climatic conditions again until a steady state was achieved and held for five days which allowed the U-value of the *wet* wall to be measured and compared to that of the *dry* wall.

- *Exposed Brickwork Face* — *Air Temperature 6^{o}C*
- *Internal Plaster Face* — *Air Temperature 18^{o}C*

On completion of the accelerated weathering programme, cores were taken from the samples, and moisture content of the brickwork calculated. On completion of the accelerated weathering, two cores were taken from each wall at a depth of 100mm to determine moisture content. Two cores were taken from the same location on each wall, one from the plaster face and one from the brick face.

Table 3-1 Description of the two insulation products applied to each test wall

Wall	Product 1	Product 2
Limelite Wall 1	14mm Aerogel board	10mm Latex Roll
Limelite Wall 2	1mm Thermo reflective paint	70mm Phenolic board*
Limelite Wall 3	20mm Cork lime render	27mm PIR board
Gypsum Wall 1	14mm Aerogel board	10mm Latex Roll
Gypsum Wall 2	20mm Cork lime render	27mm PIR board
Gypsum Wall 3	1mm Thermo reflective paint	70mm Phenolic Board*

The insulation products were applied to the plaster face of the wall according to manufacturer's guidelines, as summarised in Table 3-1. As stated, the two control walls, after drying, were used for the final insulation trials. However, cores were taken from the baseline walls on completion of the drying process prior to insulating and the moisture content was calculated to show they had sufficiently dried to below the desirable 3% water content. Although the two walls had been previously weathered it was felt that this would have little negative impact on the trials as examination of the cores removed to establish moisture content revealed no signs of degradation.

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* Conventional IWI

4 Impact of IWI and TIWI on Heat Transfer and Moisture Risk

This section describes how heat transfer through the wall was affected by the insulation and weathering cycles, including an assessment of changes to U-values. Following this, the impact of insulation on internal surface and interstitial condensation risk between the insulation and brick wall is discussed and finally, an assessment of how breathability of the wall affects moisture accumulation is presented.

4.1 Impact of IWI, TIWI and weathering on heat transfer

Table 4-1 presents the temperatures recorded through the brick during the different test phases.

Table 4-1 Mean Recorded Temperatures in Test Walls

		Dry						Wet					
		External face	50mm	100mm	150mm	Plaster	Internal face	External face	50mm	100mm	150mm	Plaster	Internal face
Limelite Plaster	Control	7.92	8.23	10.68	10.99	20.65	19.1	7.54	8.57	10.69	10.79	21.85	21.08
	14mm Aerogel Board	7.26	8.32	8.48	9.6	11.61	18.03	8.88	9.29	9.26	12.35	15.55	16.16
	10mm Latex Roll	10.21	14.52	15.65	16.64	13.95	17.43	8.82	9.76	11.38	12.51	13.29	15.35
	1mm Thermo Reflective Paint	7.36	7.57	9.5	10.22	13.35	14.74	8.05	8.99	9.51	12.16	14.32	16.47
	70mm Phenolic Board	6.87	7.21	7.92	8.04	9.28	16.24	8.32	9.63	9.64	10.05	15.53	16.63
	20mm Cork Lime Render	8.79	8.7	9.94	10.19	15.99	17.41	6.56	5.38	6.86	10.01	10.85	17.17
	27mm PIR Board	9.1	13.85	14.78	15.05	13	17.68	11.06	6.98	7.48	6.98	8.86	17.21
Gypsum Plaster	Control	7.14	7.83	11.24	11.20	20.22	19.05	7.29	9.24	9.79	9.93	20.00	19.53
	14mm Aerogel Board	7.6	8.42	9.13	9.69	14.33	17.02	9	9.37	10.16	12.7	17.91	18.98
	10mm Latex Roll	10.02	13.88	15.05	16.98	14.09	17.1	8.86	10.02	11.86	13.19	14.35	17.42
	1mm Thermo Reflective Paint	7.36	9.63	9.64	10.05	13.5	14.88	8.35	8.12	8.55	10.81	13.44	19.75
	70mm Phenolic Board	8.36	7.87	7.81	7.87	9.33	16.01	8.18	9.43	9.53	9.57	16.15	19.36
	20mm Cork Lime Render	8.66	10.73	12.8	13.15	21	26.27	6.9	7.52	7.61	9.69	10.28	25.5
	27mm PIR Board	8.54	14.65	15.2	15.31	15.01	26.86	15.38	8.27	9.54	9.57	14.5	30.84

An average of the Gypsum and Limelite temperature profiles through the brick, for the Dry and Wet conditions are presented in Figure 4-1*Figure 5-1* and Figure 4-2 respectively. As can be seen, when the bricks are dry, they may be generally slightly warmer, though the trend is not particular strong, and in both wet and dry bricks the temperatures increase from the external to the internal sides as would be expected. However, the type of insulation installed does not appear to consistently impact temperature profile of the bricks.

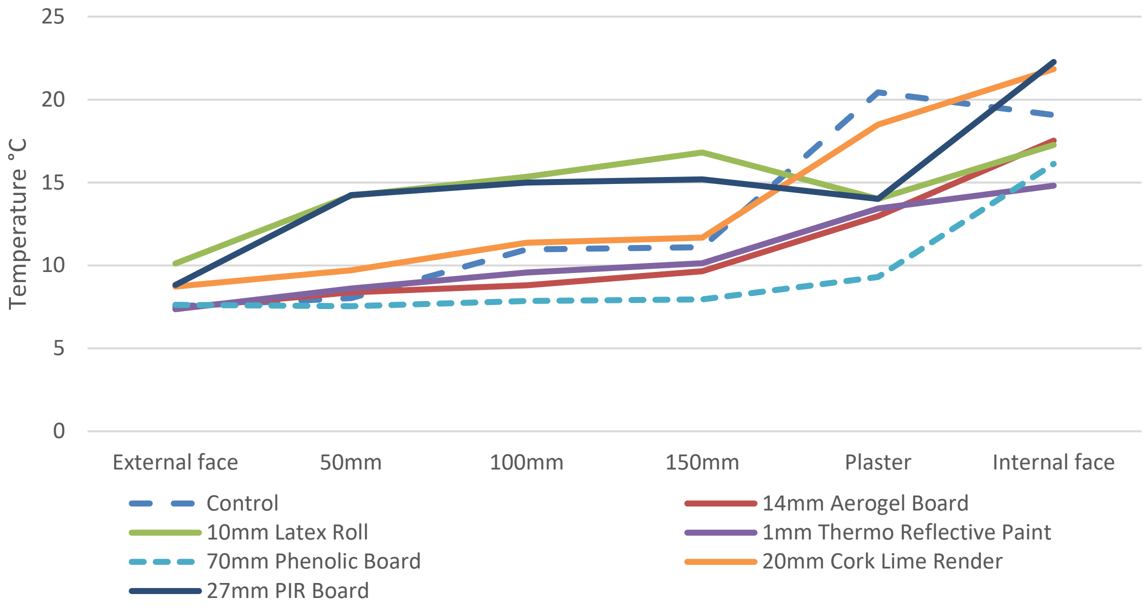

Figure 4-1 Dry Brick Temperature Profile

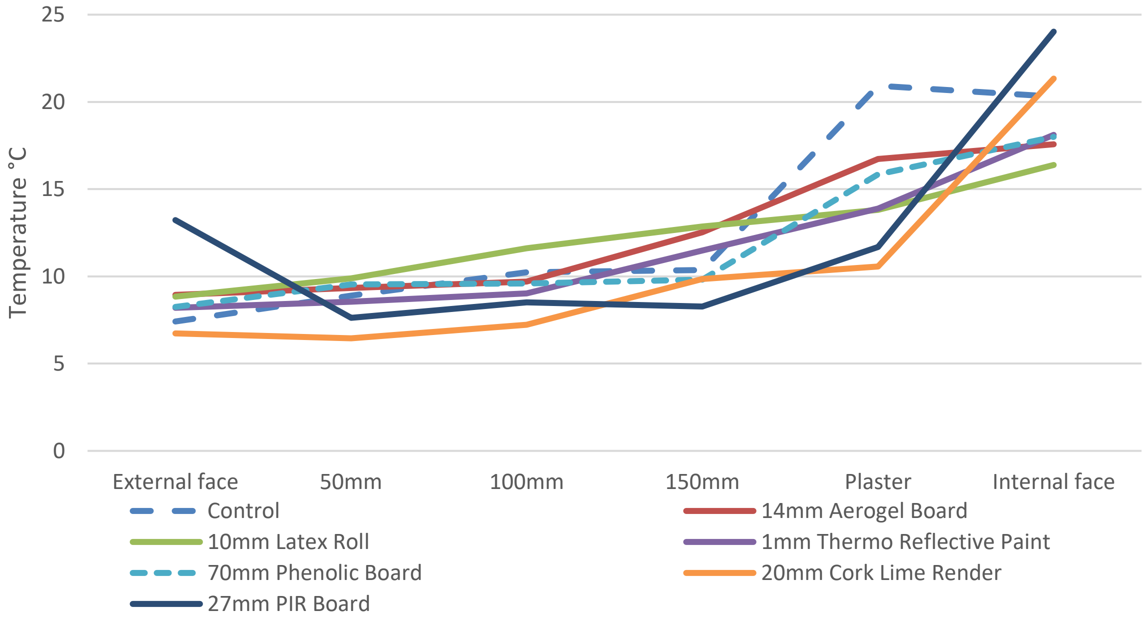

Figure 4-2 Wetted Brick Temperature Profile

4.2 Impact of IWI, TIWI and Weathering on U-values

This section discusses the how heat flux through the wall changed when the insulation was installed and when the wall was wetted. To calculate the U-values, the ISO 9869:1994 method was used which assumed an uncertainty of ±10%. This relies on quasi-steady state conditions, which it was possible to create in the hygrothermal chamber and uses the equation below.

$$U = \frac{\sum_{j=1}^{n} Q_j}{\sum_{j=1}^{n}(T_{in,j} - T_{ext,j})}$$

Where Q is the heat flux, T_{in} the internal temperature and T_{out} the external temperature. U-values were calculated both before and after the wetting occurred and a dramatic difference in the flow of heat through the wall was apparent after the wetting had occurred as shown in Figure 4-3. The moisture both dramatically increases the heat flux through the wall and makes it more variable. Moisture will decrease thermal resistance in a wall, however the extreme fluctuations in heat flow were not expected and heat flow appears to be more complex during evaporation and drying. This may be particularly relevant when evaluating the benefits to heat loss and wall U-values of water repellent coatings.

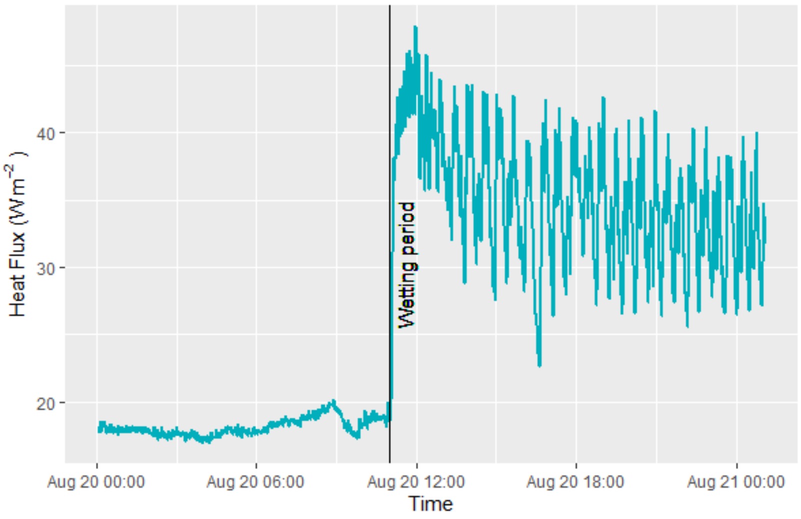

Figure 4-3 Time series plot of heat transfer before and after wetting

As a result of this chaotic heat flux, the system does not adhere well to the steady state conditions required by ISO 9869:1994. U-values were still calculated however, and included here to illustrate the impact moisture can have on heat flux through walls, though caution should be taken in interpreting the numbers. All calculated U-values are displayed in Table 4-2.

Table 4-2 Comparing U-value predictions of insulated the walls during dry and wet conditions in the Laboratory

Wall Description	Predicted U-value	Dry U-value	Wet U-value
Gypsum 70mm Phenolic Board	0.23	0.21	0.43
Limelite 70mm Phenolic Board	0.23	0.16	0.29
Gypsum 27mm PIR Board	0.46	0.59	1.23
Limelite 27mm PIR Board	0.46	0.51	1.16
Gypsum 20mm Cork Lime Render	0.64	1.06	2.27
Limelite 20mm Cork Lime	0.64	1.36	3.07
Gypsum 14mm Aerogel Board	0.51	0.54	0.91
Limelite 14mm Aerogel Board	0.51	0.61	0.71
Gypsum 10mm Latex Roll	0.87	0.89	1.54
Limelite 10mm Latex Roll	0.87	1.07	1.34
Gypsum 1mm Thermo Reflective Paint	1.02	1.23	2.88
Limelite 1mm Thermo Reflective Paint	1.02	1.15	2.31

Table 4-2 shows the predicted U-values of the walls based on typical thermal resistances of wall components. As can be seen, the dry U-values match relatively well with the predicted values, given the 10% uncertainty in the ISO method, except in the case of the thermo reflective paint. This may be due to a prediction gap in the U-value of the uninsulated base case wall. For this calculation, a thermal resistance of 0.59 m^2K/W was assumed for the solid wall, 0.062 m^2K/W for the Limelite plaster, 0.067 m^2K/W for the gypsum plaster, 0.17 m^2K/W for the inner surface resistance and 0.13 m^2K/W for the outer surface resistance. The thermal resistances for each TIWI was taken from the manufacturers' specifications.

Figure 4-4 shows the effect on U-values that the moisture is having. In all cases, the U-value increases as a result of the moisture. In some cases, the U-value more than doubles. The variation is not easily understood: the largest difference was observed in the thermo reflective paint and the cork lime render, however these products were tested on different walls so it is unlikely to be a methodological effect related to the conditions on one wall being more extreme than the others. Whilst the walls in the laboratory tests are wetter than you would typically find in a real home, this shows the effect that rain and moisture can have on heat loss in domestic dwellings. The smallest variation between wet and dry measured U-value is seen generally when more insulating products are used, which may have been expected because the largest resistance and contribution to U-value was provided by the insulation which is unaffected by the wetting cycles.

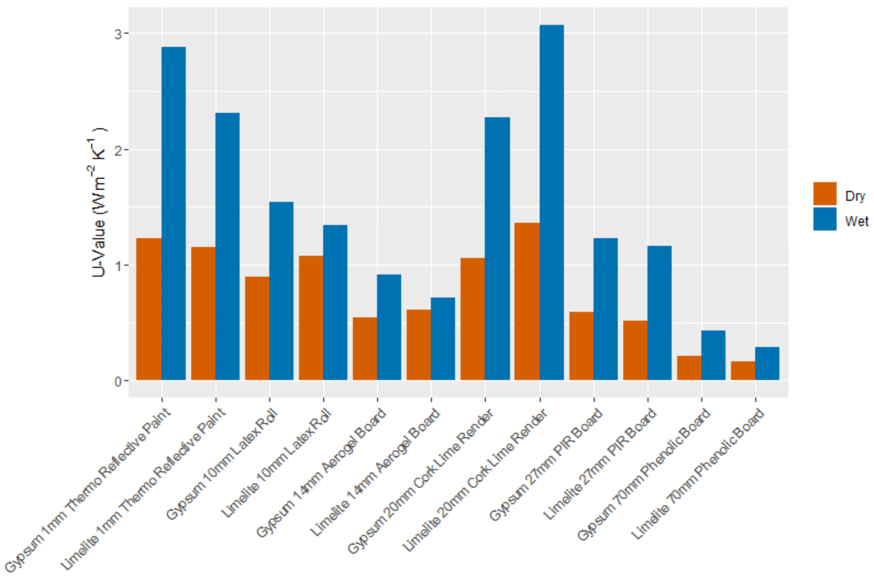

Figure 4-4 Influence of Wetting on measured U-values

Figure 4-5 plots the performance gap between the U-values measured dry in the lab and predicted U-values. In all situations the measured performance is lower than the prediction except in the case of the 70mm Phenolic board, however in all cases the result is not large and almost always within the 10% uncertainty in the ISO standard. The exception is the lime render; however, this may have greatest error because the exact thickness the that render was applied is not known and may vary, affecting its insulating potential.

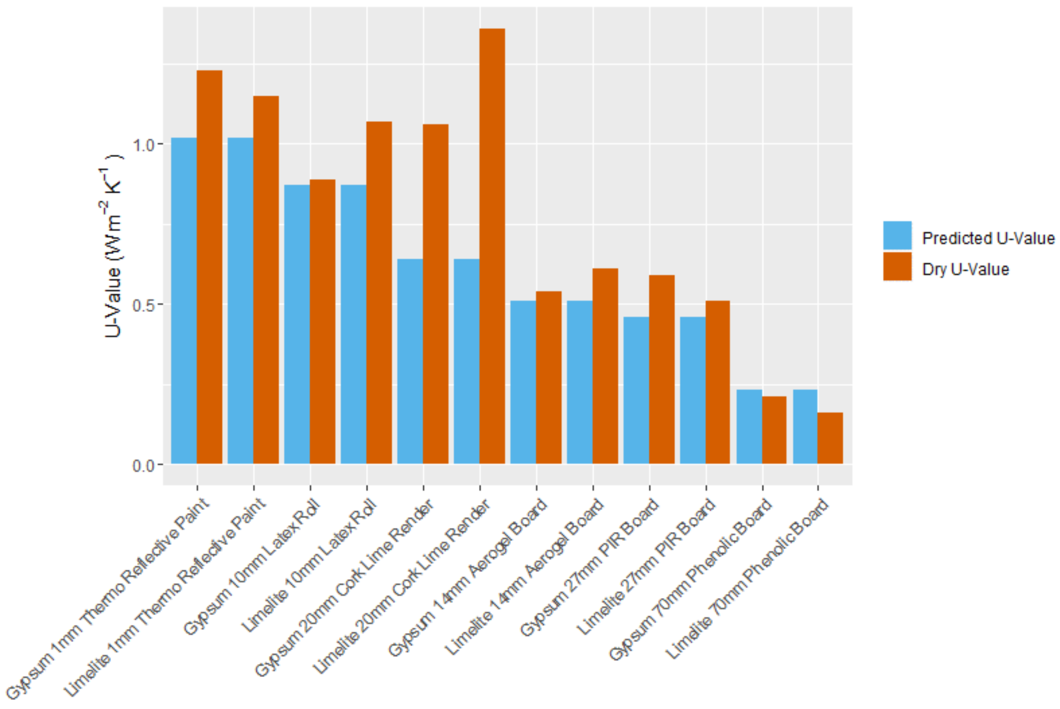

Figure 4-5 Performance gap in IWI U-values

4.3 Impact of IWI, TIWI and Breathability on Surface and Interstitial Condensation risk

We have seen that the heat loss through the walls was tremendously affected by the wetting cycles but that when dry the performance gap for the U-values was small. This section assesses surface and interstitial condensation risk using *temperature factor* calculations, which use the following equation:

$$f_R = \frac{T_{si} - T_e}{T_i - T_e}$$

Where T_{si} is the internal surface temperature, T_e the external temperature and T_i the internal temperature. The temperature factor, f_R, will then take a value between 0 and 1, with higher values being associated with less condensation risk. For domestic properties, any value of f_R below 0.75 is considered as having an appreciable risk of condensation.

Another method of assessing condensation risk is to use dew point. However, the temperature factor has an advantage over the dew point as the dew point depends on the relative humidity of a space. The humidity in the laboratory tests were not those typically found for domestic properties and, therefore, dew point would not be representative of condensation risk in typical properties.

The temperature factor at each timestep during the dry test period was calculated for each of the five TIWI and one conventional IWI, and the mean of these was then calculated and is plotted in Figure 4-6, which compares the values when installed on the breathable Limelite plaster compared to the non-breathable gypsum plaster. Temperature factors calculated during the wet phase do not represent realistic conditions, since bricks are unlikely to remain soaked for extended periods. Moisture in the walls allows the surface to be at a higher temperature, thus appearing to reduce condensation risk.

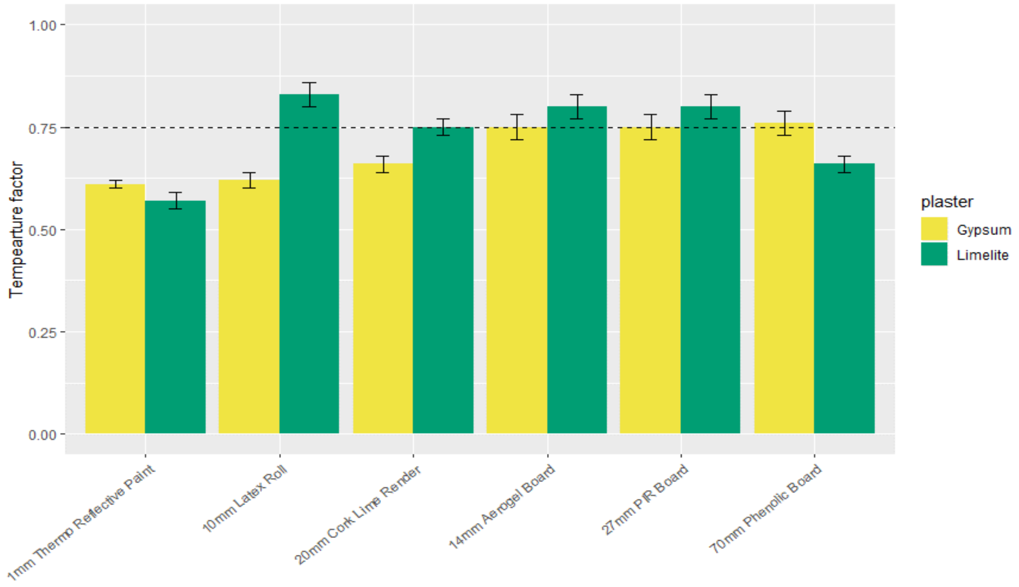

Figure 4-6 Surface condensation risk reduces when IWI and TIWI are installed

Data were collected for the uninsulated baseline wall, and although not robust indicated there was not a risk of surface condensation.

Figure 4-6 suggests that adding IWI and TIWI products tend to increase the temperature factor and thus reduce the risk of surface condensation since insulation should increase the surface temperatures of walls. The baseline wall was not analysed for condensation risk; however, since the thermo-reflective paint had little effect on U-values, this may be reasonably taken as a representative baseline value.

Although surface condensation risk may be reduced by reducing the flow of heat into the walls, the insulation may have caused a new risk of interstitial condensation. To assess this, the temperature factor calculations were repeated, this time using the temperatures on the surface at the interface between the insulation and the plaster. The results of this are displayed in Figure 4-7 showing that the products that are more insulating introduce a greater risk into homes. This is not surprising, as the more insulation that is applied the less heat is transferred to the brick, causing colder areas behind the insulation. Thus, there appears to be a balance in installing insulation to reduce heat loss through walls and reduce surface condensation risk versus not introducing too much interstitial condensation risk. The cork lime render, aerogel boards, PIR boards and to some extent the latex foam rolls appear to improve surface condensation risk by as much as conventional IWI yet they introduce substantially less interstitial condensation risk into walls (the PIR boards to a lesser extent) and so may be considered more appropriate for wide scale retrofit in homes where risk is a primary concern.

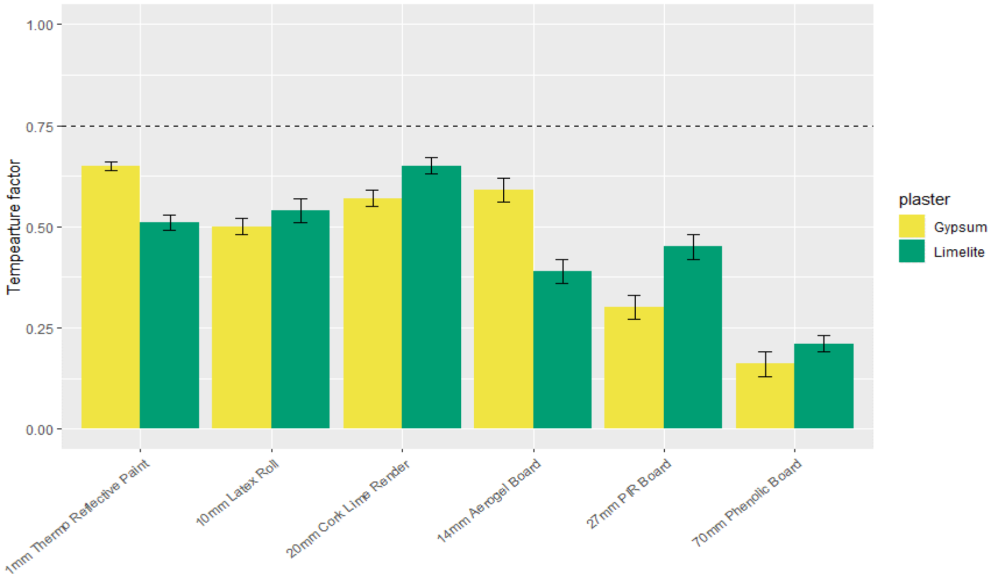

Figure 4-7 TIWI somewhat increases, and IWI substantially increases, interstitial condensation risk

This assessment assumes that the interstitial region will experience similar conditions to the internal surface. It is important to note that exceeding the critical temperature factor threshold is doesn't mean that condensation will not occur, it is just considered unlikely, however risk is also influenced by local factors, but this method does allow comparisons in performance between products is a useful exercise in risk mitigation. Regardless of what insulation is used, moisture management is essential, and the next section discusses the potential of breathable products to reduce moisture risk further.

5 Impact of TIWI on Wall Moisture Content

The previous section discussed how all the TIWI and IWI products were successful in reducing the risk of internal surface condensation risk. Additionally, all the TIWI introduced a slight risk of interstitial condensation while the IWI introduced a substantial risk. Moisture management may therefore be key to low risk internal wall retrofits and this section discusses how the breathability of the product may contribute to this. The breathable insulation products assessed include the Thermo-reflective Paint, the Cork Lime Render and the Aerogel Board which were tested with a breathable plaster (Limelite) and a non-breathable plaster (gypsum). The non-breathable products were the PIR board, the Latex roll and the Phenolic board, which was the only IWI tested. Again, these were tested when installed on the breathable and a non-breathable plaster.

At the end of the laboratory tests, core samples were taken of the products on each type of plaster. The moisture content of the cores was calculated by weighing the sample before and after drying and these are given in Figure 5-1 and Figure 5-2 for the inner brick leaf (including the plaster layer) and the outer brick leaf respectively. As can be seen, when considering the moisture content in the inner brick and plaster there is no trend in the amount of water accumulation in the brick regardless of whether a breathable or non-breathable insulation were installed. However, the breathability of the plaster used did appear to influence the moisture content of the external brick; in 5 out of 7 cases the gypsum plaster tended to result in a wetter inner brick. Thus, there is some evidence that the breathable plaster could reduce the water accumulation in walls. This suggests there could be some benefit in using breathable plasters to reduce moisture related unintended consequences such as surface condensation and mould growth. However, no measurement of moisture content of the walls was taken in advance of the testing and so it is not known if all the walls had the same starting moisture content.

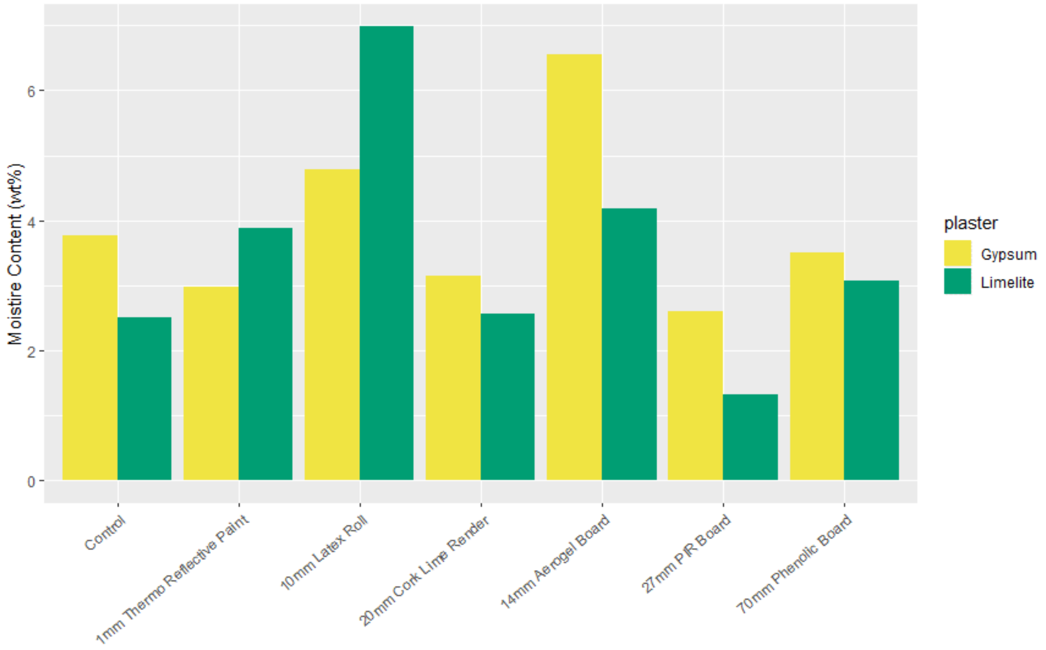

Figure 5-1 Moisture Content of the plaster face brick after weathering

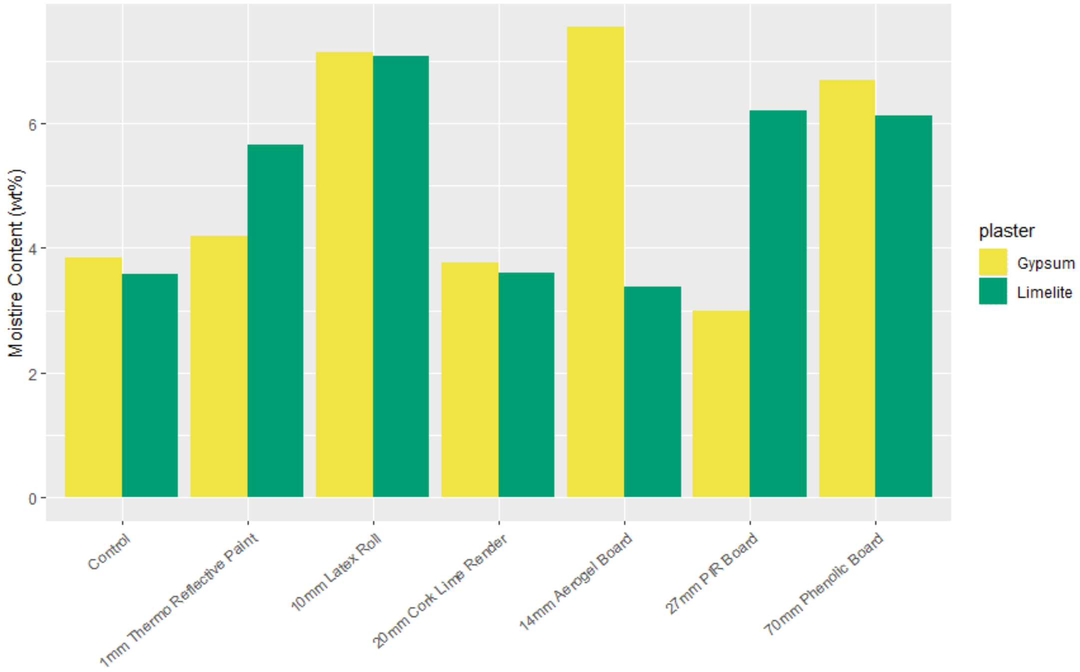

Figure 5-2 Moisture Content of the external brick after weathering

It can be seen in these figures that the external brick was always wetter than the internal brick, as may have been expected as it was exposed to the wetting cycles. However, it appears that breathability of the insulation or plaster did not substantially influence moisture accumulation in the external brick, except in the case of the aerogel board, where the non-breathable wall had more than twice the water content of the breathable wall, and for the PIR board where the reverse was true. This suggests that the wetting cycle was the driving influence behind the moisture content of the external brick.

On completion of the testing, the walls were deconstructed and inspected for signs of condensation and mould. None of the bricks had any signs of mould, indicating moisture accumulation may not be a risk of insulation though this is perhaps because mould requires longer time frames than the laboratory tests to manifest. Additionally, a blot test for moisture was undertaken at the interface between the plaster and insulation, though no moisture was detected.

6 Conclusion

It was not possible to directly measure the transfer of moisture through the brick, and so the analysis of IWI and TIWI performance and moisture risk was assessed using analysis of temperature recordings and heat flux measurements.

The temperature profiles through the wall were somewhat affected by the addition of insulation and wetting though there was no strong trend regardless of which plaster or insulation was installed.

Wetting of the brick had a much more marked impact on the heat transfer measured across the wall, with recordings becoming erratic after the wetting period. Generally, wetter bricks had higher U-values, and the impact of rain on brick thermal performance may therefore warrant further study.

A slight performance gap was observed between predicted and measured U-values, particularly for the Cork Lime Render, however, this may be due to inconsistencies in the thickness at which this product was applied.

Surface condensation risk was shown to be reduced by similar degrees following the installation of both TIWI and IWI. Interstitial condensation risk was only somewhat introduced when TIWI was installed but substantially introduced when IWI was installed.

Moisture content was calculated using core samples of the walls and it was observed that for the internal brick in 5 out of 7 walls the breathable solutions had lower moisture content. The extreme nature of the wetting of the external brick meant that no trends related to breathability could be observed in the external brick moisture content following the tests. It is recommended that further investigation into the benefits of breathable systems is undertaken using field trials since laboratory experiments are limited in their ability to replicate real world conditions.