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Long-term field measurements of moisture in wooden walls with different types of facades: Focus on driving rain tightness

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Abstract

Moisture damage has been found in houses having well-insulated, rendered (ETICS) wooden stud walls. However, there is no well documented experience from subsequent long-term monitoring of moisture conditions in such walls or indeed in other walls, for instance in ventilated facades. Long-term measurements show rain leakage within the exterior walls in five of a total of seven buildings during 2009–2011 and extended measurements until 2015 show continued leakages. We have not seen any difference in the number of leakage occasions when we compare ventilated and unventilated facades. It is also clear that the detailed solutions are not verified with regard to driving rain.

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Keywords: moisture; driving rain; precipitation; wood; wall; façade; weather barrier; measurement; field test; ETICS

1. Introduction

Moisture damage has been found in houses having well-insulated, rendered (ETICS) wooden stud walls that are unventilated and undrained, which was revealed in Sweden in 2007. A national survey has been carried out in order to determine the extent of the problem [1,2]. It became clear during the survey that it would be important to monitor the moisture conditions in walls that were built or renovated, in order to check that moisture performance was as intended. However, there is no well documented experience from subsequent long-term monitoring of moisture

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conditions in such wall structures in Sweden. Representatives of contractors and materials manufacturers were asked during the survey to make renovated or new buildings available for monitoring of moisture conditions behind the rendering of exterior walls. Buildings in two areas of Helsingborg in south western Sweden, where the facades were in need of rebuilding, were made available for monitoring. Additionally, around the same time, two Swedish research projects (WoodBuild and Wood Frame Buildings of the Future) were initiated in order to study the durability associated with the use of wood in the building envelope. One purpose has been to investigate the actual moisture and temperature conditions in external walls.

Measurements from these studies have now been extended for four of the buildings until 2015. This paper presents results from long-term field measurements of RH, T, and MC, in external walls, over a period of nearly six years, together with climate data of rain, wind speed and wind direction.

Nomenclature

EPS	expanded polystyrene
ETICS	external thermal insulation composite system
MC	moisture content
MW	mineral wool
RH	relative humidity
T	temperature

2. Method and site measurements

The resulting field studies have continuously (once an hour) monitored RH, T and MC conditions in residential buildings of one-, two- and seven-storey height, see Table 1. Two buildings were renovated, rebuilt facades, in 2009 retaining the ETICS design and wooden stud walls, although with improved detailing, see Fig. 1. These parameters have also been monitored in one 2-storey house that was renovated to incorporate a ventilated façade outside the wooden frame wall and one more change using stiff mineral wool slabs mounted outside the wind barrier board. The other buildings were new-built around 2008 to 2009 with ventilated facades and weather barrier, and the structures are of wooden frame or massive wooden elements (multi-layer cross-laminated timber) and wooden studs.

The sensors were distributed over all four facades, with 10–20 measurement points per house due to building size, with some of them being placed underneath windows mounted mainly in the outer part of the wooden frame and in the sill/bottom plate, see Fig. 1 and Fig. 2, or underneath other facade details.

Measurements were taken using wireless sensors (Protimeter HygroTrac). These were attached with two stainless steel screws (covering an approximate surface area of 5x40 mm) into wooden studs and sills/bottom plate and also acted as electrodes to measure the MC. The screws penetrate the wood material to a depth of 10 mm. The RH and T sensor is at a distance of 30 mm from the wooden surface and inside the plastic casing, see Fig. 2. The MC is usually measured approximately 5 mm inside the exterior of the stud or sills. In addition, reference sensors were placed far from facade details, near the internal air and vapor barrier, indoor and outdoor. Approximately over 100 sensors in total have been distributed over seven buildings, being calibrated prior to construction with traceability to a normal and a national standards laboratory. They have not, however, been calibrated afterwards, as they were built in. The MC has been adjusted for Swedish spruce and current T. Measurement uncertainty is estimated to be less than ±1.5% for MC, less than ±5% for RH and less than ±0.5ºC throughout the entire measurement period 2009–2011. Our experience of these sensors is that the MC and T appear to be relatively stable over time, but the RH may possibly have a slight drift, which has been included. Weather data is taken from observations from weather stations [3] that are close by or located in the same city as the present building sites.

Table 1. Type of building, structure, facade, site location, leakage occasions and maximum value of rain and wind speed during leakage.

Type of building	Structure	Facade	Site	Leakage occasion *(Measurement point, Date)*	Rain (mm) and Wind speed (m/s) *(Maximum value for an hour on average for rain and 10 minutes on average, once per hour, wind speed)*	Number of buildings/site with extended measurements 2012–2015
Two residential buildings of 1-storey height	Wood frame	Ventilated, wooden panel	Växjö	(1, 2010-07-25)	7 mm and 11 m/s	
			Växjö	(6, 2011-01-01)	0.2 mm and 5 m/s	
			Falkenberg	(23, 2010-07-30)	7 mm and 6 m/s	
Two residential buildings of 2-storey height	Wood frame	ETICS	Helsingborg A	No	-	
			Helsingborg B	(6, 2010-11-12)	2.5 mm and 8 m/s	1
			Helsingborg B	(6, 2014-12-12)	3 mm and 8 m/s	
			Helsingborg B	(6, 2015-01-09)	4 mm and 10 m/s	
One residential building of 2-storey height	Wood frame	Ventilated, plaster on mineral-based board	Helsingborg C	(1, 2009-11-18)	2.5 mm and 12 m/s	
			Helsingborg C	(1, 2010-11-12)	2.4 mm and 8 m/s	1
			Helsingborg C	(1, 2014-12-12)	3 mm and 8 m/s	
			Helsingborg C	(1, 2015-01-09)	4 mm and 10 m/s	
Two residential buildings of 7-storey height	Massive wood element and wood frame	Ventilated, cement fiber board, see Fig. 2. (Växjö)	Växjö	(16, 2010-08-17)	3 mm and 5 m/s	
			Växjö	(16, 2011-03-31)	3 mm and 5 m/s	
			Växjö	(16, 2011-07-14)	5 mm and 7 m/s	2
			Växjö	(8, 2011-11-25--)	3.5 mm and 7 m/s	
		Ventilated glulam timber panel (Skellefteå)	Skellefteå	No		

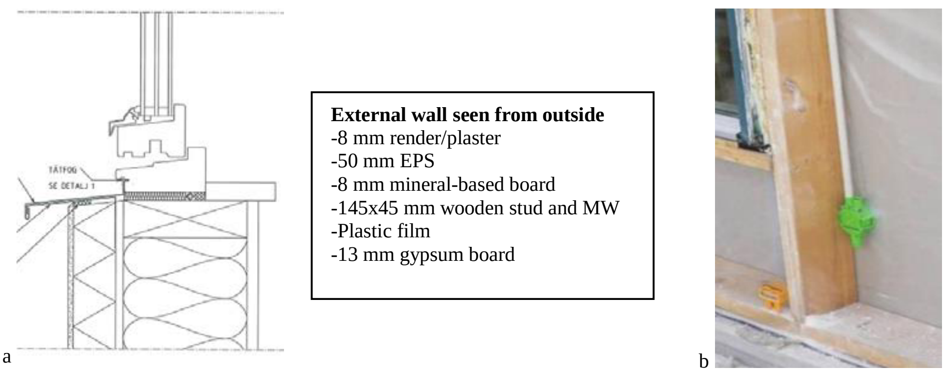

Fig. 1. (a) Vertical cross-section of wooden stud wall with rebuilds ETICS. (b) Position of measurement point 6 (Helsingborg B) in the outer part of the sill, facade facing southeast.

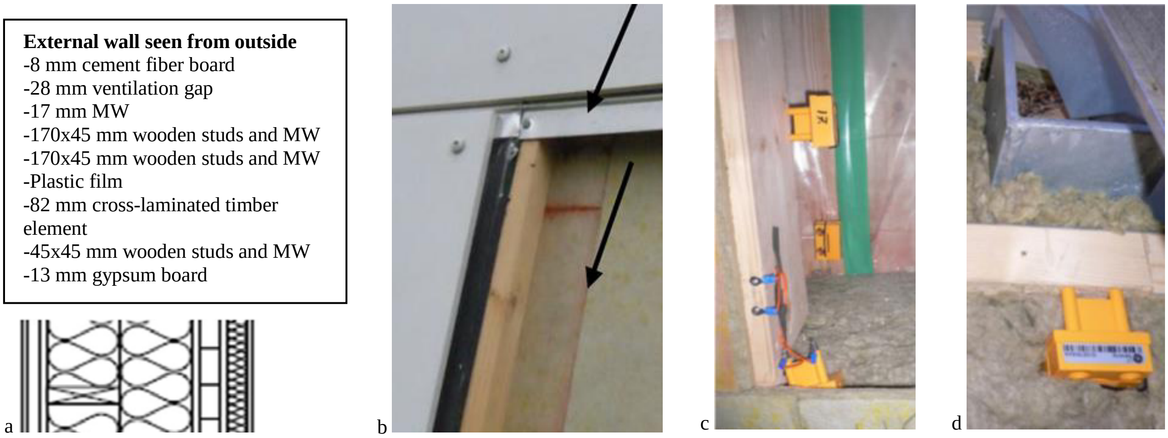

Fig. 2. (a) Cross-section of wooden stud wall with ventilated facade. (b). The facade board is opened up in point 16, arrows show pass way for water flow. (c) Position of measurement point 16 and extension cables for MC bolted onto the outside of the stud.(d) Position of measurement point 8 bolted near the outside of the stud and underneath the fastening of a balcony.

3. Results and comments

This chapter shows weather observations and the measurement results in detail for only two measurement points distributed over two buildings, Helsingborg B and Växjö of seven-storey height. The summary of the total number of leakage occasions is shown in Table 1. In five of a total of seven buildings there are moisture indications deriving probably from rain leakage during the sampling period 2009 to 2011, see Table 1, which were reported previously [4].

Measurements in point 16 show RH around 80–90% at most, briefly over 90% during the construction phase and thereafter for occasional hours over 90% RH, see Fig. 3. The higher humidity level appears to have occurred in connection with inward leakage, during MC peaks, or during the colder months when outdoor RH is at its highest.

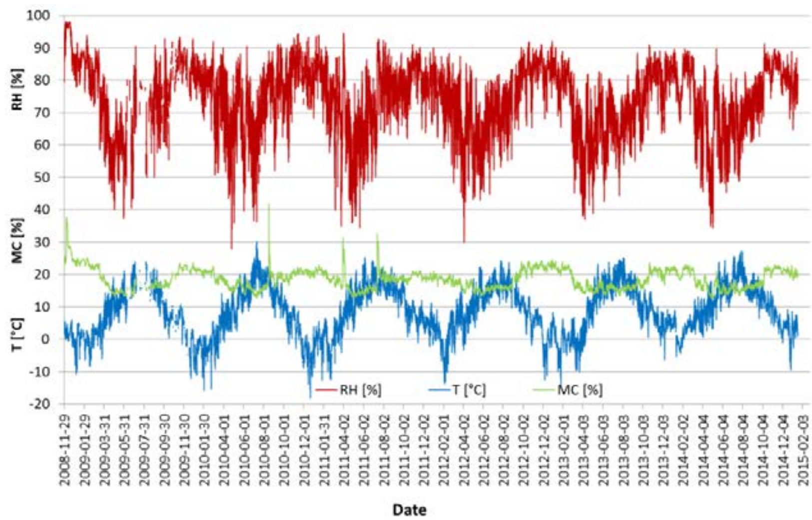

Fig. 3. Measured RH, T and MC for measurement point 16 during the period 2008-11-29 to 2015-01-25. The MC is measured using extended electrodes, for only this point and with a large contact surface, which is why the values are somewhat higher than in reality.

There were sudden increases in MC of over 30% on around 17 August 2010, 31 March 2011 and 14 July 2011, which were probably caused by inward leakage. The MC appears to have dropped over time, despite recurring inward leakage, which means that the humidification that has occurred at the measurement point seems to have been able to dry out within the following weeks. Climate observations show rain at these times and with wind direction from the southeast and east, and the facade is also east-facing.

In 2012, the wall was opened up from the outside to investigate the cause, see Fig. 2. Above the measurement point, there is a horizontal joint in the facade board, where water could have penetrated between the board and the joint profile. This could explain the problem, together with the fact that there was a joint in the weather barrier, which consists of stiff mineral wool slab, where water could have penetrated into the wall.

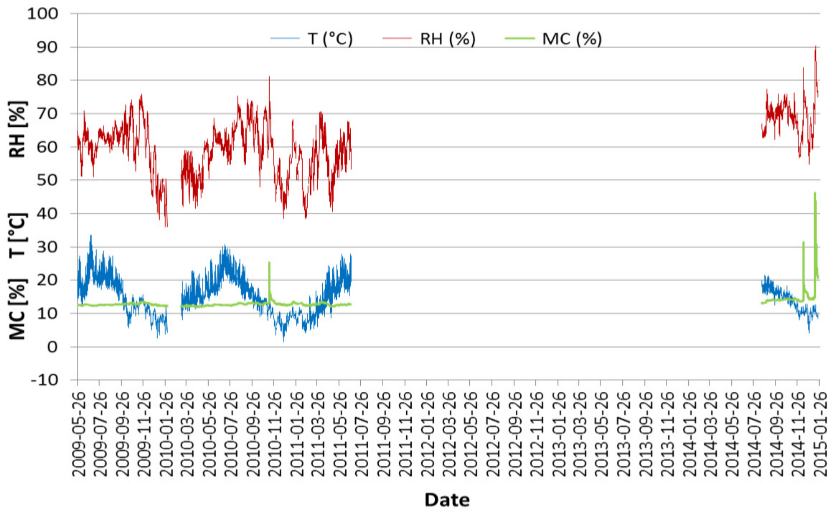

Fig. 4. Measured RH, T and MC for measurement point 6 (Helsingborg B) during the period 2008-11-29 to 2015-01-28. There is no data for 2012–2013.

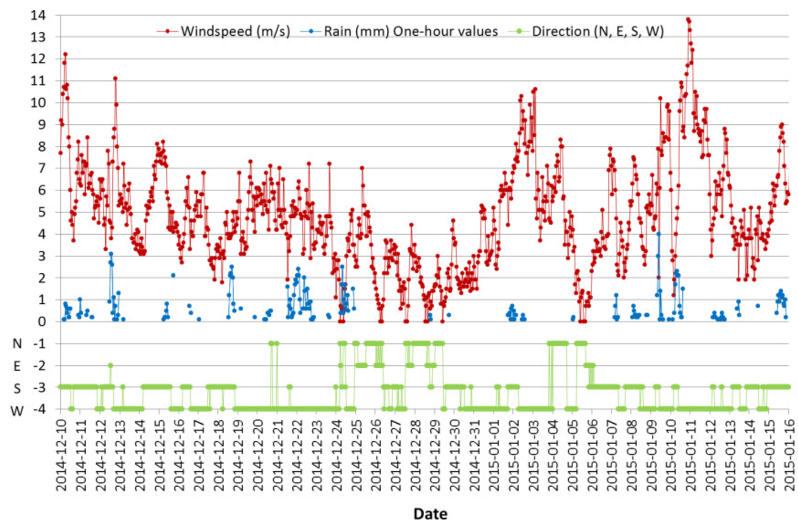

Fig. 5. Each point represents the average value for a period of one hour for precipitation and 10 min average (one time per hour) for wind speed and direction [3].

However, we do not know if the inward leakage has worked its way further down or somewhere else in the wall. The wall surface that was opened has reportedly been restored with wind barrier fabric inside the air gap, which could possibly explain why leakage appears to have ceased at this measurement point.

The measurements in point 6 (Helsingborg B) behind the ETICS in the stud walls show normal values: at most, about 75% RH, i.e. no elevated moisture conditions that could result in moisture damage, see Fig. 4. However, there were some exceptions: the measurements indicating high MC of 25%, or higher, on 12 November 2010, 12 December 2014 and 9 January 2015 when there was particularly heavy rain and wind load on this facade, see Fig. 5. There is no data for 2012 to 2013 due to interruption in measurements. Additionally, there were some additional points where there were minor indications of leakage.

4. Conclusion and comments

In the building site measurements, it has not been possible to detect inward leakage over entire wall surfaces; instead measurements have been carried out on a very limited scale. Some sensors have been placed beneath selected facade details, and have covered an approximate area of 5x40 mm. Nevertheless, in five of a total of seven houses there are moisture indications derived probably from rain leakage during 2009 to 2011, and extended measurements until 2015 show continued leakages. We have not seen any difference in the number of leakage occasions when we compare ventilated and unventilated facades. The general site inspection has not shown any obvious flaws or unusual deviation from construction practice. Based on these results we are quite sure that leakage appears when these four factors appear at the same time as flaws in the facade, wind direction toward the facade, significant amounts of rain (2.5 mm per hour or higher) and wind speed (5 m/s or higher), see Table 1. We do not know if leakage appears with lower values, because we cannot separate it from the highest value. The resulting weather data is limited to an average of 15 minutes for rain and 10 minutes for wind speed. When we compare 15-minute values with one-hour values we get at least double the rain rate for 15 minutes. Probably the wind gusts are much higher, maybe double the wind speed, compared to the average for 10 minutes. All walls are more or less vapor-open to the outside part, and a vapor-open solution is surely important to prevent water accumulation within the wall over time. In these types of construction it is difficult or nearly impossible to detect small moisture leakage by RH or vapor-content measurements but possible with MC measurements. Bearing in mind their relatively short durations, these measured moisture conditions ought not to result directly in broad moisture damage. However, we do not know if inward leakage has worked its way further down or somewhere else in the wall where it may be trapped and cause extensive moisture damage.

Results from these site measurements and other studies [1,2,4,5] confirm that leakage at windows and other connections and details in facades or external walls is fairly common. It is also clear that the solutions for penetrations, joints and connections being used are not verified with regard to driving rain. One reason is that most products are not manufactured and verified to provide an overall or system function.

Acknowledgements

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