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#2539

Summary There have been recent reports of interstitial condensation forming on the *back* of vapour checks of dry lined solid walls. This usually occurred within south facing walls during hot weather. A possible explanation is that water evaporates from the inside surface of the masonry, travels through the insulation and condenses on the cooler internal vapour check. Similar condensation has been reproduced in experimental walls under natural weather conditions with a variety of insulants including highly permeable mineral fibre. In these tests it was found that condensation deposited over a period of a few hours can take several days to re-evaporate.

#2559

Summer condensation within dry lined solid walls

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1 Introduction

Interstitial condensation has been reported in situations which suggest a mechanism opposite to that forecast by accepted methods of prediction in this country. The traditional concept is that interstitial condensation is caused by water vapour migrating under the influence of the higher vapour pressure inside a building through the construction, and then condensing on surfaces at temperatures below the dewpoint of the air in contact with them. However, it is also possible for water to evaporate from the inside surface of a damp warm solid outer wall. Where the temperature of a vapour check behind a dry lining falls below that of the wall then condensation is possible on the *back* of the vapour check.

Such condensation has been observed on a few occasions. It typically forms within south facing walls in late spring or early summer. The problem has presented as rust and damp stains on the surface of the lining or as water emerging from the bottom of dry lined walls. On investigation, water has been discovered on the back of the aluminium foil or polythene vapour check. Wet insulation in contact with the vapour check has also been found. This type of condensation has been called 'summer condensation' in reports from Denmark[1,2]. It has also been reported as a problem in the Middle East particularly within the walls and ceilings of air conditioned buildings[3].

One problem with summer condensation is that the water is deposited on materials with low absorption from which it can run and perhaps wet up timber elements such as flooring, joists and battens. Deterioration of wetted timber or insulation material is unlikely to be visible until it has reached an advanced stage.

Because the distance between the back of the masonry and the vapour check is small (usually 50 mm), even a low rate of evaporation from the masonry quickly creates a high vapour pressure.

The evaporation rate from a wall depends on its temperature and its internal moisture distribution. A typical evaporation rate from the surface of damp brickwork at 20°C and 60% relative humidity is about 25 g/m^2h. This loss represents only about 0.01% change in moisture content by volume. The relative humidity within the space enclosed between a wall and its vapour check increases quickly as water evaporates from the wall, and so the rate of evaporation will drop. With a warm damp wall enclosing a cooler room there is therefore normally enough water present in the wall to increase the vapour pressure at its back and to create a pressure difference across the insulation. Permeable insulants allow water vapour to move towards the vapour check, which in unheated rooms in summer can be at temperatures below the dewpoint, resulting in the deposition of condensation on the back of the vapour check. The rate of water vapour transfer and condensate deposition is governed mainly by the temperature differential between the wall and the vapour check, the resistance of the insulation to vapour transfer and the distance between the inside masonry surface and the vapour check.

Temperature conditions leading to summer condensation could be created by internal cooling due to air conditioning, sudden meteorological changes or, more likely in the UK, by solar radiation on the surface of the wall. The aspect and colour of the wall surface affect the external surface temperature. The problems reported occurred in early summer on south facing walls, although in April and May the total radiation on walls facing east through south to west is similar; peak radiations are lower on south compared with east and west.

2 Experimental

2.1. Test rig

The simple construction described below was used to demonstrate the formation of summer condensation under natural conditions and to determine the occasions when condensation occurred.

50×50 mm dry timber battens were fixed on a strip of sealant to the inside of a solid SSW facing wall of an unheated building at East Kilbride. The 100 mm thick solid

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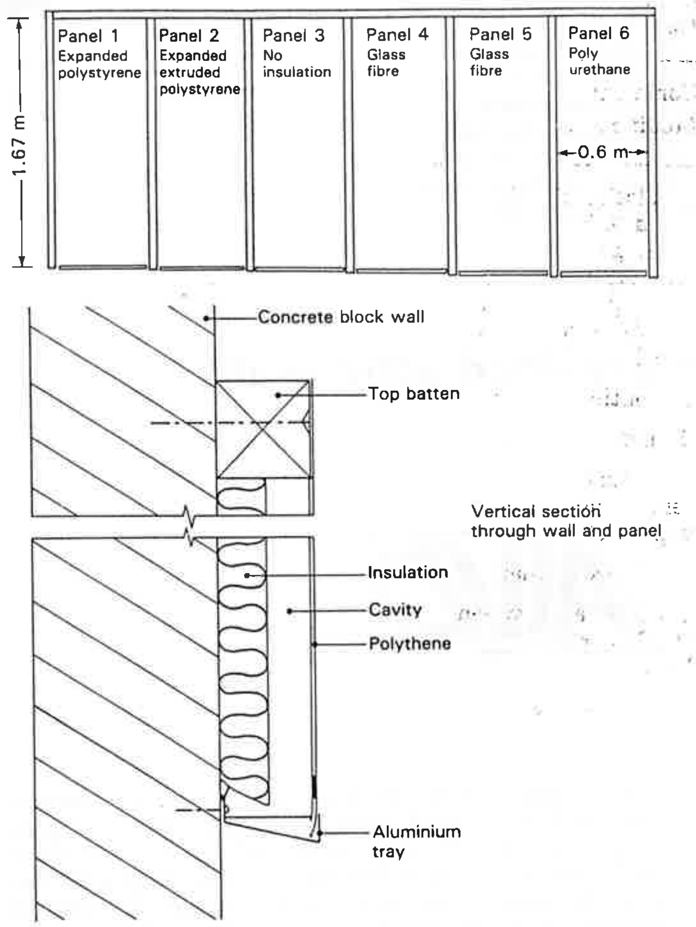


Fig. 1. Insulated panels on concrete block wall.

concrete block wall had been built a year before and the battens divided the inner wall surface into panels each 1.6 m high and 600 mm wide, that is, each panel covering 1 m^2 of wall (Fig. 1). Between the battens 25 mm thick dry insulation was placed in contact with the wall and the battens were then covered with a layer of 500 gauge polythene sheeting. This gave a notional cavity of 25 mm between the insulation and polythene. A sloping aluminium channel was fixed at the bottom of each panel to catch any condensate. The insulants were chosen to give a range of vapour permeabilities (Table 1).

Table 1. Insulants and vapour check used in tests

Material	Abbreviation	Thickness (mm)	Density (kg/m^3)	Vapour resistance (GNs/kg)
Expanded Polystyrene	EPS	25	15	4.9
Extruded Expanded Polystyrene	EEP	25	33	15.6
Cavity (Air)	CAV	50	—	0.3
Glass fibre Mat	GFM	40†	10	0.5
Polyurethane Foam	PUF	25	43	8.7
Polythene vapour check	VC	0.065	—	250

†Nominal 25 mm but expanded to 40 mm.

Moisture content of the block wall at the start of the tests was 6.4% by volume which is higher than the 5% taken for external masonry in U value calculations.

During the summer some alterations were made to the arrangement of the construction to extend the information gathered. These panels are identified by the suffix A on their labels.

2.2 Observations and instrumentation

The polythene was examined on weekdays for signs of condensation and a sketch made of the distribution of the condensate on the polythene within each panel. The temperature and relative humidity of the air between the wall and the polythene in two of the panels were recorded at 20 minute intervals. Thermistors connected to recorders were mounted on the outside and inside surfaces of the wall and on the polythene at the locations shown in Fig. 2.

2.3 Results

Condensation was noted on the back of the polythene of Panels 2, 4, 5 and 6 within 3 hours of fixing the polythene to the battens. Deposition in Panels 4 and 5 was over most of the area of the polythene but in Panel 2 the condensation was associated with the joint in the insulation board and in Panel 6 with the gap between the insulation board and the top batten.

Over a three-week period from 20 May 1985 condensation formed on the 20, 28 and 29 May. An increase in condensation was also noticed over the weekends 31 May–3 June. These periods of condensation deposition were typified by solar radiation on the wall coupled with cool internal temperatures. Measurements of dewpoint temperature and relative humidity in the cavity between the insulant and polythene of Panel 4 showed that during periods of condensation the polythene temperature fell to within 1 °C of the calculated dewpoint temperature of the enclosed air and on two of the occasions (28 and 29 May) fell below the dewpoint temperature (Fig. 3). The thermistors and especially the humidity sensors are not sufficiently accurate or responsive to indicate all the occasions when the polythene surface temperature falls below the dewpoint. The condensation was probably deposited over a period of 2–8 hours in the afternoon and evening.

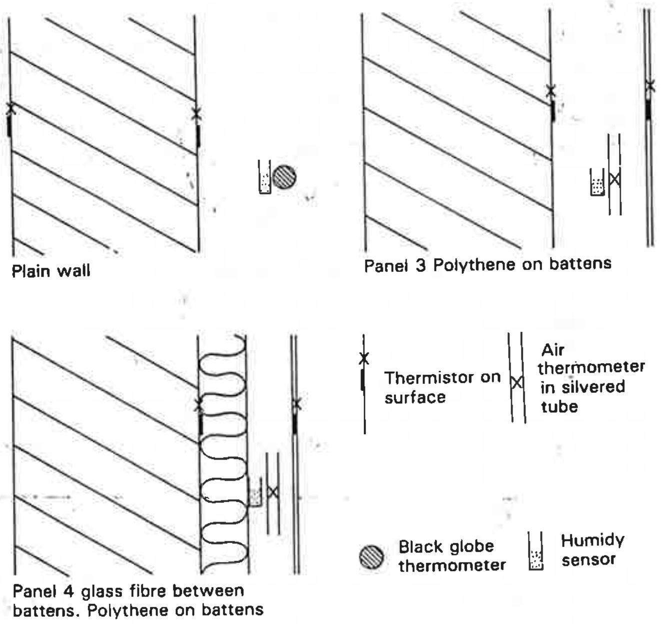


Fig. 2. Location of temperature and humidity sensors.

Table 2. Summer condensation panel materials and modifications from 20 May to 8 October 1985.

Panel No.	Period		Materials		Comments and Modifications
	From	To	Wall	Inside	
1	20 May	31 May	25 mm EPS/25 mm CAV/VC		Insulation tightly fitted to battens
1A	31 May	8 Oct	25 mm EPS/25 mm CAV/VC		2 mm gap between EPS top and batten
2	20 May	8 Oct	25 mm EEP/25 mm CAV/VC		1 mm gap between boards across centre of panel
3	20 May	8 Oct	50 mm CAV/VC		Unventilated cavity
4	20 May	19 July	40 mm GFM/10 mm CAV/VC		'Standard' panel
4A	19 July	8 Oct	40 mm GFM/10 mm CAV/VC/	9.5 mm Pb	⅓ of plasterboard removable to inspect vapour check
5	20 May	8 Oct	40 mm GFM/10 mm CAV/VC		'Standard' Panel
6	20 May	19 Aug	25 mm PUF/25 mm CAV/VC		1.5 mm gap between PUF board and top batten
6A	19 Aug	8 Oct	50 mm CAV*/40 mm GFM/ 10 mm CAV/VC		Cavity ventilated to outside; 100 mm battens

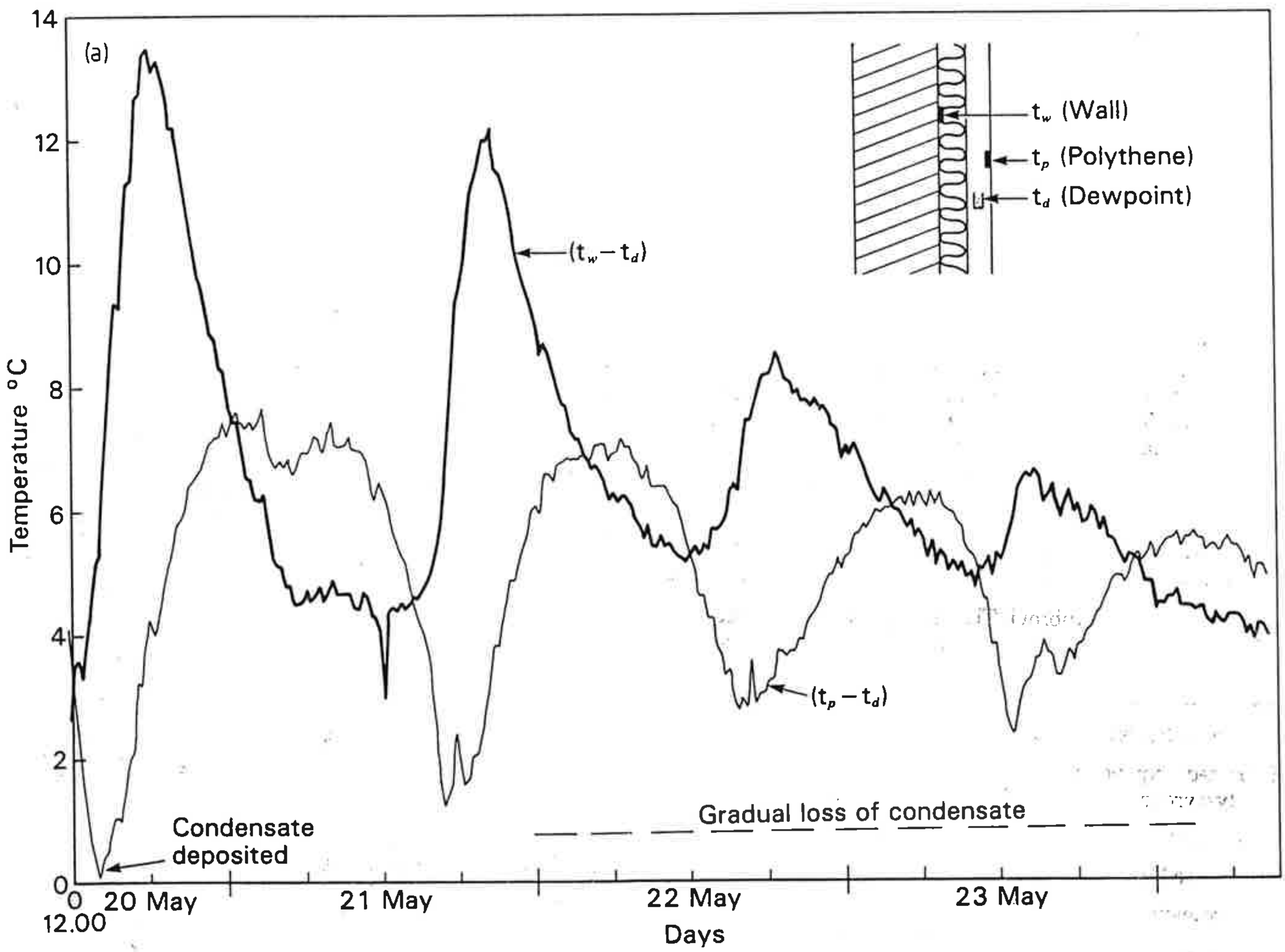
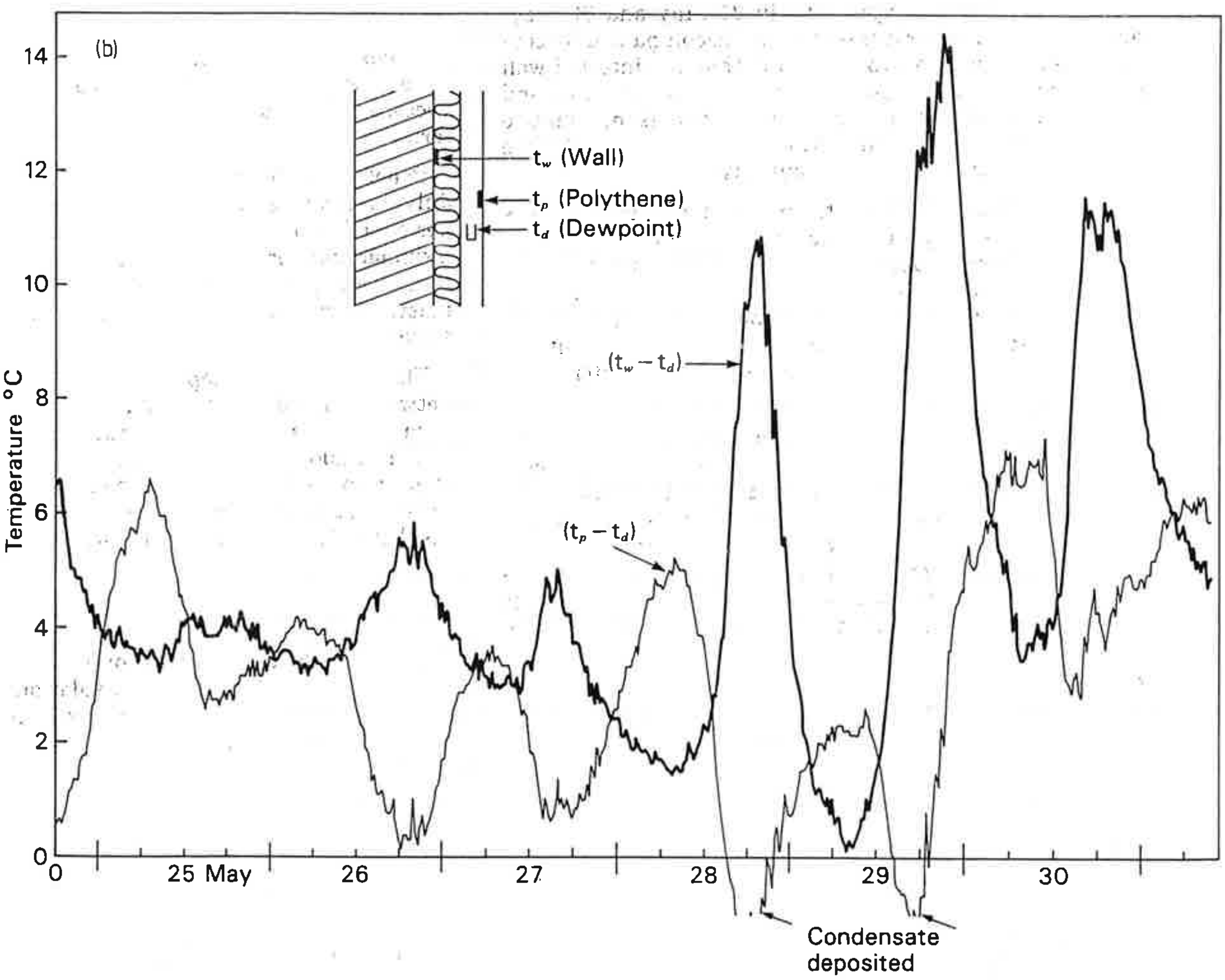
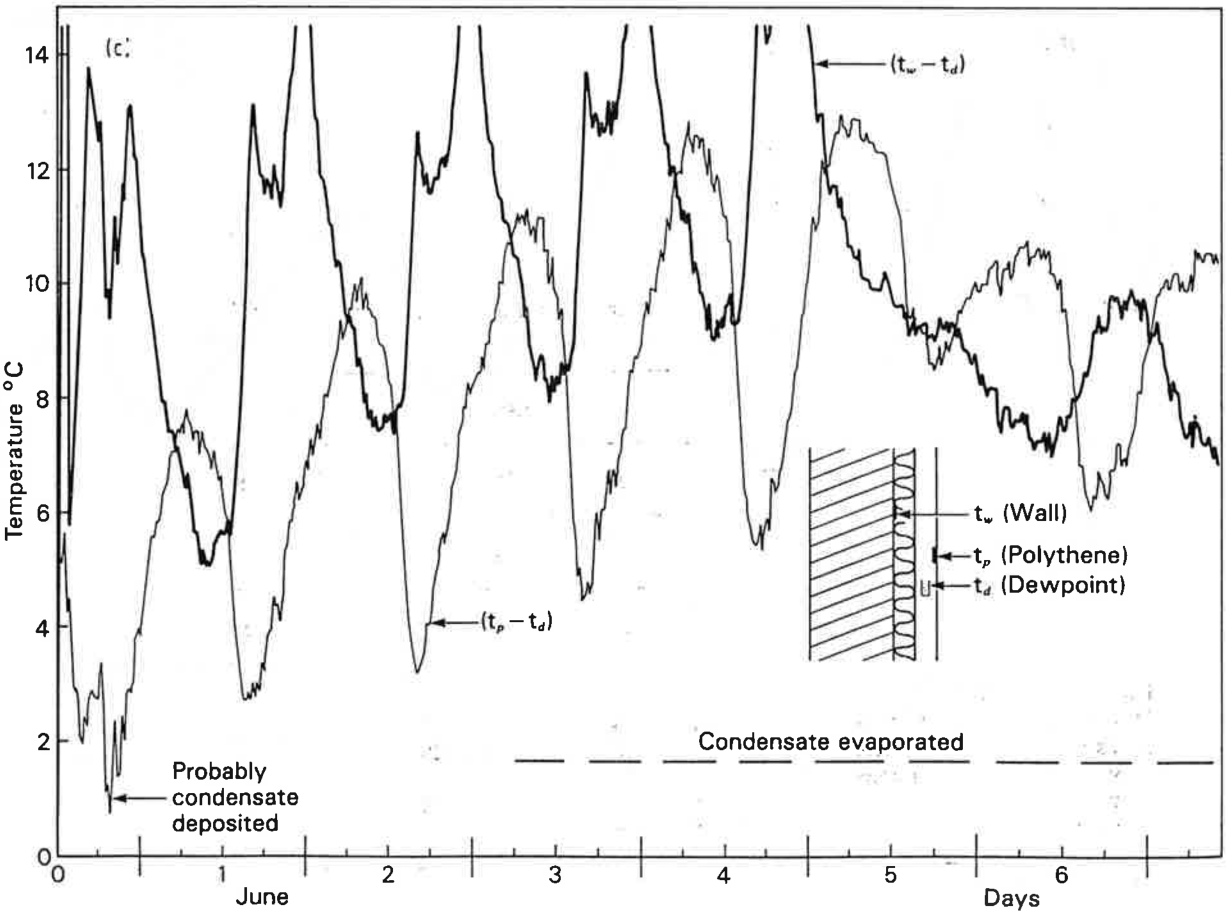


Fig. 3. Difference between surface and dewpoint temperatures for wall and vapour check during (a) first, (b) second and (c) third weeks of test.


(b)
t_w (Wall)
t_p (Polythene)
t_d (Dewpoint)
$(t_w - t_d)$
$(t_p - t_d)$
Temperature °C
0
2
4
6
8
10
12
14
0
25 May
26
27
28
29
30
Condensate deposited


(c)
$(t_w - t_d)$
$(t_p - t_d)$
t_w (Wall)
t_p (Polythene)
t_d (Dewpoint)
Temperature °C
Condensate evaporated
Probably condensate deposited
0
2
4
6
8
10
12
14
0
1
June
2
3
4
5
6
Days

There were several days, notably 21 May and 30 May, when high wall temperatures were not accompanied by condensation. A possible explanation is that the internal wall surface had dried out during the previous hot days and there was insufficient water at the internal masonry surface to give high relative humidities at temperatures which were slightly lower than on the previous day.

Condensation remained on the polythene for several days after it had been deposited. Re-evaporation of the condensate was only noticeable when the polythene temperature was 3 K or more above the dewpoint temperature and the internal masonry temperature fell below that of the polythene for some of the period. Under these conditions evaporation of water from the polythene and transfer to the masonry is feasible.

No measurable condensate collected in the trays at the bottom of the panels, but on 30 May the polythene removed from Panel 5 had about 30 cm^3 of water on the back surface. Other measurements indicate that the greatest amount of water which can condense on vertical polythene sheets without run-off is about 80 g/m^2. Freshly deposited condensation gives a misty appearance at 0.2 to 30 g/m^2 of water and droplets indicate 15 to 80 g/m^2 of water on the polythene. After some drying has occurred discrete drops separated by several millimetres may remain and in these instances there is less water than indicated above.

Observations continued throughout the summer until the first week in October when the test was stopped due to impending heating of the buildings. Over the period of the test from May to October condensation was deposited and then evaporated in a series of cycles interspersed with periods of no condensation or little evaporation (Table 3).

2.4 Accuracy of insulation fitting

Condensation formed on all the panels except Panel 1 during the first nine days, indicating that the EPS insulation tightly fitted against the battens was capable of preventing water vapour migration. The other two board insulants with higher vapour resistances than the EPS, but fitted with slight gaps between the boards and frame or between boards, allowed water vapour to transfer from the wall to the vapour check. A small gap introduced between the EPS and the batten in Panel 1 was enough to cause condensation at regular intervals over the remainder of the test period. Nevertheless, the standard of fitting in these panels was higher than that normally to be expected on site.

2.5 Insulants

Condensation in Panel 3, but on fewer days than in the panels with insulation, demonstrating that it is not necessary for insulation to be present for condensation to form.

Panels 4 and 5 were of the same construction up to the 19 July, and gave a similar pattern of condensation over this period indicating that different areas of the wall behaved in a similar manner. Even after Panel 4 had been covered with plasterboard, the results were similar and it is likely that plasterboard will have little effect on this type of condensation.

The pattern of deposition and evaporation differed between the insulants. Fibreglass has a higher vapour permeability, resulting in condensation on more days, but this also allowed the condensate to evaporate more freely than the other insulants. Condensation on the vapour check over board insulants began to form near the gaps in the insulants, then gradually spread over a larger area.

2.6 Ventilation

During the last six weeks of the test when the cavity between the wall and the insulation in Panel 6A was ventilated to the outside there was a marked reduction in the amount of condensation in this panel compared with Panel 5 which was similar apart from the ventilation. Condensation was recorded in the ventilated panel on only two days, and this had evaporated by the next day. Over the same period Panel 5 had 26 days with condensation including 7 when the condensation increased.

3 Moisture contents in materials after the test

3.1 Timber

The linings were dismantled on 8 October 1985 and the moisture content of the timber was determined by weighing and drying at 103°C. Pairs of samples about 50×50×50 mm were cut out and split into three pieces either in the plane of the wall or at right angles to it. Moisture content variations could therefore be determined for the timber from the wall to the room side of the building and from the panel side to the edge of the frame.

None of the top batten moisture contents showed a marked variation from the wall side to the room side. There

Table 3. Condensation on the back of a vapour check during the summer of 1985 at East Kilbride.

	Insulant								
	EPS	EPS	EEP	CAV	GFM	GFM	GFM	PUF	GFM
	Panel No.								
	1	1A	2	3	4	4A	5	6	6A
Days inspected	9	87	95	95	38	56	95	63	33
Days with condensation %	0	71	44	24	63	77	77	66	7
Days with no condensation %	100	29	56	76	37	23	23	34	94
Days condensation increased %	0	16	16	12	11	21	25	23	6
Days condensation decreased %	0	22	22	16	37	45	40	32	6
Days condensation same % †	0	38	18	5	21	20	16	19	0

† Excludes days with no condensation.

Table 4. **Timber moisture content at the end of the tests.**

Location	Timber moisture content (% by mass)									
	Top battens				Vertical battens					
	Panel no.				Panel 1/2			Panel 4/5		
	1	2	4	5	Top	Mid	Bottom	Top	Mid	Bottom
Wall side	25	20	21	20	21	24	17	22	21	17
Centre	25	20	23	21	22	26	18	22	21	18
Room side	24	19	24	22	22	27	18	21	22	18
Panel side	32	22	24	23						
Centre	24	21	23	21						
Edge	20	18	22	19						

was, however, some variation depending on which panel was enclosed, the highest moisture contents being found in the batten above Panel 1. A higher moisture content was obtained for the timber enclosed within the panel compared with the exposed top. In Panel 1, these high moisture contents reached 32%.

The results from the vertical battens again showed no marked change from the wall side to the room side of the batten, but there were generally low moisture contents near the bottom of the battens and higher moisture contents further up. The batten between Panels 1 and 2 gave a high moisture content near a joint in the insulation of Panel 2 where condensation tended to be deposited.

3.2 Insulation

The moisture content of the insulation was determined at the end of the test on strips cut from the top, middle and bottom of the panels. Moisture contents were very low with a maximum of 85 g/m^2 in the glass fibre and 63 g/m^2 in the polyurethane equivalent to only 0.02 and 0.025% by volume. There was a general trend of higher moisture contents at the top of the panels compared with the bottom of the panels. These low moisture contents do not significantly affect the thermal transmission properties of the insulants.

3.3 Masonry

Drilled samples taken in three stages from the inside to the outside of the masonry wall gave moisture contents of 5.4, 7.0 and 7.5% by volume, an average of 6.6, which was slightly higher than the 6.4 at the start of the experiment in May.

4 Conclusions

The demonstration panels showed that condensation on the back of a vapour check can occur under natural weather conditions. Condensation deposition was mainly influenced by solar heating of the wall surface coupled with a cooler internal room temperature. Insulation permeability, gaps in the insulation and the masonry temperature over the preceding few days also affected the pattern of condensation deposition. It was found that summer condensation could occur from the end of May to at least early October and over this period condensation increased on between 16 and 25% of the days when the panels were inspected. However the 1985 summer was particularly wet and this may have influenced both the number of occasions when condensation was deposited and the amount of condensate.

Deposition of condensation may occur for a few hours during a day but re-evaporation can take several days. With highly permeable insulants such as mineral fibre quilts or mats, the condensation is likely to be deposited over most of the area of the vapour check as an even layer. Lower permeability insulants such as expanded polystyrene when fitted very accurately can prevent formation of condensation on the vapour check. Joints or gaps as small as 1 mm in the insulation will allow water vapour to migrate from the wall and be deposited on the vapour check.

A cavity between the insulation and the wall ventilated to the outside can reduce the number of occasions when condensation is deposited and also increase the rate of removal of condensate.

At the end of the tests, the moisture content of the timber battens was highest in those parts of the battens facing the insulated panels; some of the battens were wet enough to be at the risk threshold for rot to develop.

The experimental work has shown that the moisture content of the timber battens can rise due to this effect, but on this evidence alone it is difficult to say whether there is a substantial risk of decay in practice. However, until the situation is resolved more clearly it would appear to be a sensible precaution to use preservative pre-treated battens for this purpose.

The investigation only included one wall type and one orientation. Further information is needed about the effect of wall materials, wall thicknesses and orientation on this type of condensation. An extension of the tests during the summer of 1986 included these variables.

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