Information Sheet 8:

Condensation control in energy efficient Australian residential buildings

This information sheet examines the permeance control strategy and alternative temperature control strategy for Australian residential buildings, and their impacts on energy efficiency, durability and occupant health.

Introduction

Buildings must be designed and constructed to manage condensation risk.

They need to avoid getting damp, and if they do accumulate condensation, they need to be able to dry to the exterior or interior to avoid prolonged periods of dampness.

A 2016 report by the Australian Building Codes Board (ABCB) estimated that 40 per cent of new and existing residential buildings using fiberglass (FG) batt cavity insulation – or no insulation at all – across all climate zones were affected by interstitial condensation of water vapour.[1]

This can adversely impact both the energy efficiency and durability of the building, as well as the health of its occupants.[2]

There is a common misconception that building elements need to *breathe* to allow airborne moisture to pass through building elements such as walls to control condensation.

However, this *permeance control strategy* for walls with air and moisture permeable insulation, such as FG batt cavity insulation, is just one approach to managing condensation – not necessarily the optimal approach.

This information sheet references residential timber frame wall construction in Australia to explore both the permeance control strategy (breathable walls) and alternative temperature control strategy (impermeable walls).

While it provides a basic summary of the condensation control methodologies used in light-frame wall assemblies, a more definitive review can be found in the *Assessment of Water Vapour Control Methods for Modern Insulated Light-Frame Wall Assemblies* developed by the Applied Building Technology Group.[3]

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Permeance control strategy for fiberglass (FG) batt cavity insulation

The National Construction Code (NCC) advocates a permeance control strategy for condensation in residential buildings using FG batt cavity insulation. The condensation deemed-to-satisfy (DTS) provisions in the NCC 2019 Volume 2 require a vapour permeable pliable building membrane to be installed in climate zones 6 to 8 or a vapour barrier pliable building membrane in climate zones 1 to 5, because FG insulation batts are both air and moisture vapour permeable.

So, in principle, a brick veneer house in Melbourne (climate zone 6) during the heating months will have warm moist internal air pass through the FG batts and vapour permeable pliable building membrane (vapour permeable wall wrap) into the drainage cavity.

If a vapour barrier wall wrap was installed instead of the water permeable wall wrap, the relative humidity (RH) within the fibrous insulation could exceed 80 per cent, with potential for condensation, mould growth and timber decay.[4]

To assist drying to the exterior, the NCC 2019 DTS provisions also include an airtight drywall solution to prevent uncontrolled air leakage of warm moist air from the interior into the wall cavity. This is because the volume of convective moisture caused by air leakage can be over 100 times larger than water vapour diffusion (breathability) through a wall.[2]

However it has been found in practice that up to 30 per cent of convective moisture passing through FG batt insulation[5] will condense within the insulation or on timber studs if it involves a tortuous path through the insulation,[6] which could overwhelm the drying potential of the permeance control strategy.

Finally, during the cooling months in Melbourne, warm moist exterior air can pass through the vapour permeable wall wrap into the building wall cavity. If the wall cavity – including the FG batts – does become damp due to incidental water intrusion, it can, in principle, dry to the interior.

Limitations of a permeance control strategy

There are, however, possible problems with the implementation of a permeance control strategy that can cause unexpected consequences.[3]

First, brick veneer can act as a reservoir of moisture which, when heated by the sun in a cold climate, can cause a reversal of the normal vapour drive through the vapour permeable wall wrap into the wall cavity and the FG batt insulation.[1,3,7,8]

Second, in a climate which has both heating and cooling months (mixed climate) like Brisbane (climate zone 2), reversal of the vapour drive in the heating months can lead to condensation in the wall cavity and FG batts and on the vapour barrier wall wrap.

Third, the permeance control strategy does not address the issue of thermal bridging due to the timber frame.

Finally, there is a significant knowledge gap in the design and construction industry regarding permeance control strategies.[1] This may result in poor and incorrect installation that can cause convective looping in the stud space or cold spots that could increase the risk of moisture condensation.

While the permeance control strategy works by controlling the movement of water vapour, there is another approach to controlling condensation which uses polymer-based insulation and the continuous insulation concept.[3,9]

Temperature control strategy for polyisocyanurate (PIR) insulated sheathing

Continuous insulation is defined by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) as "insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings."[10]

For example, polymer-based materials such as foil faced PIR insulation board can be installed to the exterior of a timber frame (see Figure 1) as insulating sheathing. This insulating sheathing negates the need for a separate thermal break to reduce thermal bridging and replaces the need for a separate air or water-resistive barrier.

As a result, there are less materials on site, less waste, faster installation and fewer installation issues to meet airtightness and thermal bridging standards.

Adopting continuous insulation using external foil faced PIR board meets the description of the perfect wall by the Building Science Corporation in that it "has the rainwater control layer, the air control layer, the vapour control layer and the thermal control layer on the exterior of the building structure."[11]

In the case of a brick veneer house in Melbourne during the heating months, the insulating sheathing raises the cavity temperature above the dew point of the warm moist air leaking past the drywall, which inhibits condensation forming in the wall cavity or on the internal foil face of the sheathing. This is why a semi-impermeable interior finish[12] such as gypsum board coated with water-based paint is always used with impermeable foil faced PIR board to allow drying of the wall to the interior.[9]

Finally, the external foil facing on the insulating sheathing also prevents the brick veneer acting as a reservoir of moisture[7] and during the cooling months in Melbourne blocks any warm moist exterior air entering the wall cavity. For these reasons, this temperature control strategy is considered by many researchers to be the best choice for controlling exfiltration of warm moist air in cold climates.[7,13]

The following steady state interstitial condensation risk analysis for a low occupancy brick veneer residential building in a cold or temperate climate zone compares a construction with 90mm timber studs and R-2.5HD FG batts between the studs (Table 1) with a construction using 70mm timber studs and R-0.95 (20mm) continuous foil faced PIR board insulation external to the frame (Table 2).

Using insulated sheathing provides a total effective wall R-value 30 per cent higher than that achieved using FG batt cavity insulation at an equivalent wall thickness (see Table 1 in AMBA Information Sheet 7).

Given that condensation caused by air leakage is 100 times greater than that caused by vapour diffusion, and that thermal bridges provide a cold surface for potential condensation, using insulating sheathing rather than a combination of wall wrap and cavity insulation (Table 2) also provides greater confidence controlling interstitial condensation.

Although this methodology only accounts for vapour diffusion and does not incorporate the effect of thermal bridging or air leakage it is "suitable for comparing different constructions and assessing the effects of modification."[14]

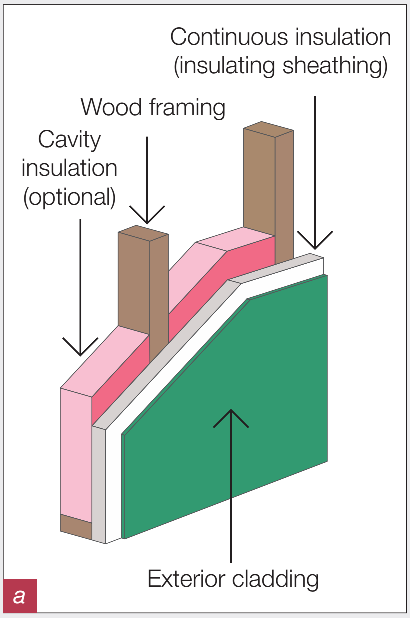

***Figure 1:** a) Schematic illustration of the continuous insulation concept for a timber frame wall, b) PIR board insulation with foil facers (photo courtesy of Pirmax Pty Ltd).*

Building Element	Vapour Resistance (MNs/g)	Temperature (°C)		Vapour Pressure (kPa)		Condensation
		Interface	Dewpoint	Calculated	Saturated	
Outdoor air	0.00	6.0	5.3	0.89	0.94	No
Brickwork (110mm)	5.50	6.2	9.9	1.22	0.95	Yes
Cavity (50mm)	0.00	7.5	9.9	1.22	1.03	Yes
Vapour Permeable Membrane*	0.13	8.5	10.0	1.23	1.11	Yes
FG batts (R-2.5 HD) (90mm)	0.45	8.5	10.4	1.26	1.11	Yes
Plasterboard (10mm)	0.45	18.9	10.7	1.29	2.18	No
Indoor air	0.00	19.3	10.7	1.29	2.23	No
		20.0	10.7	1.29	2.34	No
Total	**6.53**					
*as mandated in the NCC 2019 for climate zone 6 (e.g. Melbourne)						

Table 1: *Steady state interstitial condensation risk analysis according to ISO 13788:2012. Calculations by Anderson Energy Efficiency[15] for a traditional brick veneer with 90mm timber studs and R-2.5HD FG batts between the studs.*

Building Element	Vapour Resistance (MNs/g)	Temperature (°C)		Vapour Pressure (kPa)		Condensation
		Interface	Dewpoint	Calculated	Saturated	
Outdoor air	0.00	6.0	5.2	0.89	0.94	No
Brickwork (2.75kg)	5.50	6.2	5.6	0.91	0.95	No
Cavity (50mm)	0.00	7.2	5.6	0.91	1.02	No
Foil Faced PIR Board (20mm)	100.00	11.0	10.7	1.28	1.31	No
Cavity (70mm)	0.00	15.8	10.7	1.28	1.79	No
Plasterboard (10mm)	0.45	19.4	10.7	1.29	2.25	No
Indoor air	0.00	19.4	10.7	1.29	2.25	No
		20.0	10.7	1.29	2.34	No
Total	**105.95**					

Table 2: *Steady State Interstitial Condensation Risk Analysis ISO 13788:2012. Calculations by Anderson Energy Efficiency[15] for a brick veneer with 70mm timber studs and R-0.95 (20mm) continuous foil faced PIR board insulation external to the frame.*

Similarly, in hot humid climates the external foil face of the insulating sheathing – which is air and vapour impermeable – limits water vapour (convective moisture and water vapour diffusion) entering from the exterior, which reduces the risk of interstitial condensation on the cool interior side of a wall during summer when air conditioners are being operated.

Given that outward leakage of warm humid air in a cold climate is more critical than inward leakage of warm humid air in a warm humid climate,[16] insulating sheathing alone can be very effective at eliminating potential condensation in a warm humid climate, while in very cold climates it can be augmented with cavity insulation such as FG batts or polyurethane spray foam (SPF).

In mixed climates like Brisbane, the use of insulating sheathing (temperature control strategy) is superior to the permeance control strategy because during the heating months the temperature of the inner surface of the insulating sheathing is above the dew point of the warm moist internal air, and during the cooling season the insulating sheathing acts as a vapour barrier to prevent penetration of warm-moist external air.

Continuous insulation in Europe and North America

The availability of polymer-based insulation materials such as PIR insulation board and closed cell polyurethane spray foam (ccSPF) was and remains critical to the wide adoption of continuous insulation across Europe and North America – providing further evidence of the efficacy of this concept to control condensation.

These materials are durable, resistant to moisture ingress, have a low thermal conductivity, are unaffected by air infiltration and are not easily compressed (see AMBA Information Sheet 6 for a more detailed comparison of polymer-based insulation with other insulants).

The continuous wall insulation concept has been used in the USA since the 1970s and "provides a superior means of addressing thermal bridging and moisture control concerns in comparison to vapour permeable cavity insulation approaches that attempt to meet high R-value criteria."[7]

Although ccSPF is not examined at length in this document, it is commonly used in North America as continuous insulation on the mass wall systems of commercial buildings, while open cell spray foam (ocSPF) is commonly used between the studs of framed residential buildings.

PIR insulation board has also been used as continuous insulation in low slope roofs in the USA since the 1940s[7] and has a 70 per cent market share of the non-residential roof market.

Conclusion

Both breathable and impermeable walls can control condensation, but they work differently. Breathable walls are designed to allow water vapour to escape through the wall, while impermeable walls prevent condensation by keeping the wall cavity interior warm.[17]

No matter which condensation control strategy is chosen, both are predicated on effective control of air leakage by an air-barrier,[18] and rainwater penetration by a water-resistive barrier.

Air transported moisture (convective moisture) is a far greater contributor to condensation than vapour diffusion (breathability). This is why controlling air leakage through the building envelope is critical to control moisture vapour movement, condensation and mould.

Continuous insulation is robust, applicable to any climate and readily installed. It simplifies the task of making the building envelope airtight, negates thermal bridging due to wall framing and controls interstitial condensation due to water vapour diffusion using the temperature control strategy.

It also improves the thermal performance of the building and will close the gap between the 'as designed' and 'as built' energy efficiency performance of homes under the NatHERS rating system.

When applied to a wall exterior as insulating sheathing, it increases the efficacy of FG batt insulation in the stud cavities and removes the need for separate thermal breaks, air-barriers and water-resistive barrier.[19]

While this document examines continuous insulation for a timber framed wall cladding system, it is equally applicable to metal frames, brick veneer or mass wall systems, roofs and foundations.

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