AUSTRALIAN MODERN BUILDING ALLIANCE

Safe and sustainable construction with polymers

Information Sheet 6:

Comparison of polyurethane insulation with other insulants

This information sheet compares polyurethane insulation with other common polymer-based and traditional fibrous insulants, and details their fire safety merits as part of a safe, sustainable built environment.

AMBA Information Sheet 5 explored choice and impact of insulation when designing low-energy buildings.[1]

Because a building's operating energy represents 90 to 95 per cent of its total life cycle energy usage,[2] it is more important to control a building's operating costs and energy, rather than focus solely on its embodied energy (the energy used to produce its materials).

Insulation plays an important role minimising a building's operating energy over its lifetime.

Maximally effective insulation should have:

- low thermal conductivity (or a high R-value) to reduce the life cycle cost and environmental impact by reducing the amount of building materials needed
- high strength to weight ratio to reduce the weight of building materials used in the supporting structure
- the durability to last the entire life of the building (in excess of 50 years); be unaffected by air or moisture penetration and not compress, settle or sag over time, and
- (preferably) the capacity to be chemically recycled or re-used at the end of a building's life.

***Figure 1:** a) PIR board insulation with foil facers (photo courtesy of Pirmax Pty Ltd), b) Installation of polyurethane spray foam to a wall (photo courtesy of Huntsman International LLC), c) Installation of ccSPF to a concrete block wall (photo courtesy of Huntsman Polyurethanes).*

Classification and benefits of insulation

There are broadly two types of insulation: traditional fibrous insulation, such as glass wool or stone wool, and polymer-based insulation (Figure 1), such as foil faced polyisocyanurate (PIR) board and polyurethane spray foam.

The differences between polyurethane-based insulation such as foil faced PIR board, open celled polyurethane spray foam (ocSPF) and closed cell polyurethane spray foam (ccSPF), and traditional fibrous insulation are shown in Table 1.

For a more detailed overview of the properties of polyurethane insulation see AMBA Reference Paper 1 – Physical properties of polyurethane insulation.[3]

Both foil faced PIR board and ccSPF have the lowest thermal conductivity (and thus the highest R-value).

This means they allow thinner walls (Figure 2) at a common insulation value, thereby maximising internal space or decreasing the size of the building footprint.

When taped at the joints or sealed with one component foam,[4] foil faced PIR board insulation, and ccSPF can also act as an air barrier, vapour barrier and weather (water) resistive barrier – eliminating the need for separate air or water-resistive house wraps.

For example, under EN 12865:2001 ccSPF is water resistant for driving rain up to the maximum test pressure of 1800 Pa – the equivalent of wind blowing at 197 kilometres per hour.[5]

Insulant	Fiberglass batts	ocSPF	ccSPF	PIR board (foil faced)
Thermal conductivity (W/m.K) @ 23°C (AS/NZS 4859.1: 2018)	0.038 HD 0.052 LD	0.038	0.022	0.021
R-value @ 25 mm (m^2K/W)	0.65	0.66	1.14	1.19
Emissivity (EN 15976)	Not applicable			E0.03
Density (kg/m^3): Wall grade	16-24	8	35	36-38 (core)
Compressive strength (kPa) AS2498.3	Not applicable	<5	>150	>125
Closed cell content (%)	Not applicable	<10%	>90%	>90%
Air barrier (air permeance ≤ 0.2 L/s.m^2 @ 75 Pa according to ASTM E 2178)	✘	✔	✔	✔
Water vapour retarder (as classified in the USA according to ASTM E96)	✘	✔	✔	✔
Continuous insulation	✘	✔	✔	✔
Water resistive barrier	✘	✘	✔	✔
Structural strengths (racking strength) a timber frame wall	✘	✘	✔	✔
Durability (does not settle or sag and is not easily compressed)	✘	✔	✔	✔
Small Scale Fire Tests				
AS/NZS 1530.3 (Ignitability, Flame spread, Heat Release & Smoke release)	0,0,0,0-1	0,0,0,6	16,0,1,5	0,0,0,1
Large Scale Fire Tests				
EN 1365-1: Timber Frame Wall	✔	Not tested		✔
General Characteristics in Fire				
Thermoset (does not melt on exposure to heat)	Not applicable	✔	✔	✔
Chars and forms a protective barrier when exposed to fire	Not applicable	✘	✘	✔
Thermal conductivity of fiberglass batts varies by density. R-2.5 HD (high density) batts have a thermal conductivity of 0.036 W/mK but R-2.5 LD (low density) batts are only 0.052 W/mK.				
Water resistive barriers are classified in USA as equal to or better than No 15 asphalt felt. The Applied Building Technology Group considers ICC-ES AC71, the test for foam sheathing, to have the highest test criteria for wall assembly water resistance of any product category.[6]				

Table 1: *Typical Properties of foil faced PIR board insulation and polyurethane spray foam compared with traditional fibrous insulation.*

Both PIR board and ccSPF are also highly durable. Unlike fibrous insulation, they are resistant to moisture ingress, unaffected by air infiltration, are not easily compressed and do not settle or sag over time.

This is one reason that both the Department for Environment, Food and Rural Affairs (UK)[7] and the Federal Emergency Management Agency (USA)[8] recommend the use of polyurethane insulation in flood prone areas, rather than conventional fibrous insulation.

Research by the National Research Council of Canada found that small gaps in fiberglass batts installed in a wall can reduce the nominal R-value of the batts by up to 32 per cent.[9]

In addition, research conducted by Bradford Insulation showed that a timber frame wall insulated with fiberglass batts between the studs had an air leakage rate of 3.4 L/s/m² @ 50 Pa (Figure 3).[10]

***Figure 2:** Insulation thickness at equivalent R-value.*

Thermal conductivity (λ) is the heat flow in watts (W) through a 1m² surface and 1m thick flat layer of a material when the temperature difference between the two surfaces in the direction of heat flow amounts to 1 Kelvin (K). The unit of measurement is W/(m·K).

Thermal resistance (R) is the thermal insulation effect of a constructional layer. It is obtained by dividing the thickness (d) by the design thermal conductivity value of a building component: $R = d/\lambda$ (in accordance with EN ISO 6946). The unit of thermal resistance (R) is (m²·K)/W. In building components comprising several layers, the thermal resistances of the individual layers are added together.

Thermal transmittance (U) is the heat flow in watts (W) through 1m² of a building component when the temperature difference between the surfaces in the direction of heat flow is 1K. $U = 1/R$ for a given construction and the unit of measurement is W/(m²·K).

Note: The XPS value reflects the transition from HFC blowing agents as in Europe.

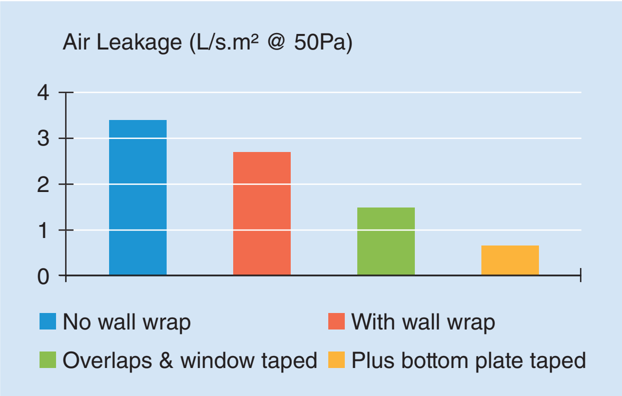

***Figure 3:** Air infiltration through a timber framed wall with fiberglass batt insulation between the studs.*

While installing an air-barrier wall wrap (Figure 3) around this fibrous insulation can reduce air leakage by 20 per cent, it must be overlapped and taped, together with taping of the windows and bottom plate, to be truly effective.[11]

Although research by the CSIRO in 2013 found that NatHERS 5 star rated houses were excessively leaky,[12] improving a building's air tightness can reduce a building's energy usage by up to 72 per cent.[13]

Substituting fibrous insulation with polyurethane insulation has been demonstrated to provide energy savings up to 22 per cent due to reduced air leakage alone.[14]

Comparison of common polymer-based insulation products

Insulating sheathing minimises thermal bridging and removes the need for a separate air or water-resistive barrier – optimising the energy efficiency of a building element in the process.

The most commonly used insulating sheathing materials in the USA are polyisocyanurate (PIR), expanded polystyrene (EPS) and extruded polystyrene (XPS)[15] (see Table 2 for a summary of their key properties).

Again, PIR board has the lowest thermal conductivity (and thus the highest R-value).

While the thermal conductivity of PIR[3] and XPS[16] is constant at the densities used for external walls, the thermal conductivity of EPS is highly dependent on the density of the wall[17] and needs to be chosen carefully to minimise the thermal conductivity (Table 3).

In addition, a vapour barrier (such as foil) facing is recommended on EPS to maintain its R-value in situations of a continuous vapour drive because there is a linear relationship between R-value and moisture content, with around 2.5 per cent loss of R-value with each 1 per cent increase in water content.[17]

PIR board insulation plays an important role in energy efficient buildings including their use on soffits and as part of insulated rainscreen facade systems in commercial buildings.

Unlike EPS and XPS, PIR insulation is a thermoset, which means it does not melt when exposed to heat.

Because of this, PIR insulation boards, used as part of an insulated rainscreen facade system with a **non-combustible rainscreen**, can achieve an EW classification in the large-scale fire test AS 5113:2016 Fire Propagation Testing and Certification of External Walls of Buildings.

PIR board can also achieve a Group 2 rating under the large-scale fire test AS/NZS 5637.1:2015 for soffits.

Property	PIR (foil)	EPS	EPS (foil)	XPS
Core density (kg/m³)	36-38	13.5 (SL Grade)		32-36
Compressive strength (kPa) AS 2498.3	>125	70	70	≥250
Thermal conductivity (W/m·K) @ 23°C (AS/NZS 4859.1: 2018)	0.021	0.047	0.047	0.028*
R-value at 25mm (m²·K/W)	1.19	0.53	0.53	0.89
Emissivity (foil face) EN 15976	E0.03	None	E0.03	None
Water Vapour Permeance (ng/Pa.s.m²) (ASTM E96) @ 25mm	1.72	300	1.72	66 @ 25mm 33 @ 50mm
USA Water vapour classification @ 25mm	Vapour Barrier	Semi-permeable	Vapour Barrier	Semi-permeable
Small Scale Fire Tests				
AS/NZS 1530.3 (Ignitability, Flame spread, Heat Release & Smoke release)	0,0,0,1 (ca softwood at 16,9,7,3)	12,0,3,5	0,0,0,1	9,0,1,4
Large Scale Fire Tests				
AS 5113: 2016 classification	✔ EW	✘	✘	✘
AS 5637.1:2015 classification	✔ Group 2	✘	✘	✘
General Characteristics in Fire				
Thermoset	✔	✘	✘	✘
Chars and forms a protective barrier when exposed to fire	✔	✘	✘	✘
Note: *Some XPS may still contain high global warming potential HFC blowing agents.				

***Table 2:** Typical properties of insulated sheathing materials.*

EPS Grade	SL	S	M	H	VH
Colour Coding (AS 1366.3)		Brown		Green	
Density (kg/m³)	13.5	16	19	24	28
Thermal conductivity (W/m.K) @ 23°C[17]	0.047	0.0394	0.0380	0.0366	0.0350
R-value (m²K/W) @ 50 mm	1.23	1.27	1.32	1.37	1.43
Note: M grade is commonly used in EIFS (exterior insulation and finish systems).					

***Table 3:** Thermal conductivity of EPS.*

Fire safety credentials and performance

Most building products carry some fire risk. AMBA supports the National Construction Code's focus on performance-based solutions and large-scale fire testing because the fire performance of a building element cannot be predicted purely based on small-scale fire tests of individual components or products.

The interaction of all components and the compliant installation of these systems in accordance with all local and national codes and standards is what defines the overall safety of the building.

Large-scale tests undertaken by Exova Warrington Fire (UK)[18] showed that there was a slight improvement in the fire resistance performance of a timber frame wall incorporating PIR board compared to fiberglass insulation when tested to EN 1365-1 – despite the difference in the small-scale reaction to fire test EN 13501 (Euroclass).

PIR board is a thermoset polymer; it does not melt and drip when exposed to the heat of a fire, it chars to form a protective barrier similar to timber (thereby preventing further spread) and self-extinguishes when the fire is removed.

Regardless of its origin and exact composition, all smoke is toxic and poses a serious threat to the health of building occupants and fire fighters.

Large scale fire tests undertaken by Exova Warrington Fire Gent (Belgium)[19] using a furnished room scenario under ISO 9705 showed that there was no significant difference in the flashover time, heat release rate or CO and CO_2 concentrations when PIR board or mineral wool insulation were used in the wall assembly.

Further, the contribution to human toxicity from the insulation materials, which largely occurred after flashover, was insignificant (HCN for the PIR board and acrolein for the mineral wool) compared to the contribution from the room furnishings.

The European Commission has also investigated the issue of smoke toxicity[20] and concluded that regulating construction products on the basis of smoke toxicity would be unproductive.

Instead, the emphasis should be on the prevention, early detection (such as fire alarms) and early suppression (such as sprinklers) as critical first steps in The 7 Layers of Fire Safety in Buildings presented by the Modern Building Alliance.[21]

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More information:
www.australianmodernbuildingalliance.org.au

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