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Energy Efficiency and Resilience in Residential Buildings

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Abstract

Climate change provides challenges for building designers who want to future proof buildings against future weather events. The selection of resilient building materials which can provide thermal efficiency and also endure in weather events such as temperature extremes, bushfire and floods in not straightforward, as different building materials can suit different performance scenarios. The use of insulated panels continues to expand in most classes of buildings in Australia, and their use in residential construction is increasing. Insulated panels offer many advantages including speed of build, high levels of resilience, high thermal performance and structural rigidity. Kingspan Insulated Panels has worked with local area builders in New South Wales Australia to develop two prototype residential houses that capture many of the benefits of insulated panels, and particularly the high product thermal performance available for use in roof and wall designs. The use of high thermal performance building envelopes offers increased design flexibility, and provides a pathway for better managing temperature extremes, when used in conjunction with other heating, cooling or ventilation strategies.

Keywords: insulated panel; climate change; thermal performance; resilience

Introduction

The Australian Business Roundtable for Disaster Resilience and Safer Communities [1] found in 2013 that "the financial and emotional burden of natural disasters in Australia has been great and the costs of extreme weather events continue to rise", as indicated in Figure 1.

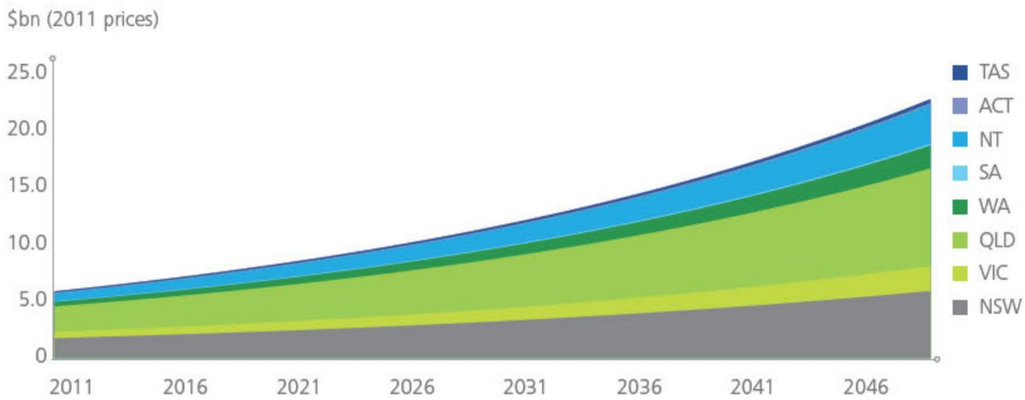

Figure 1. Forecast of total economic and natural disasters in Australia by state 2011-2015 (Deloitte Access Economics [1])

Climate change, natural disasters and other extreme weather events present life-threatening challenges for members of the community, with poor and disadvantaged groups being hardest hit (Hughes and McMichael [2]). The social and economic costs in terms of occupant health, productivity, increased energy costs, loss of livelihood and rise in disease represent just a few of the unfavourable outcomes.

Life threatening events can include temperature extremes, bushfires, drought, storms and cyclones, for which the frequency, severity and geographical patterns could well change in the future. Almost 50% of the Australian coastline is in a designated cyclone affected belt. The reach of cyclones and storm events is expected to grow in time. The levels of risk exposure for buildings built today based on current building design standards can change both in level of risk and event intensity going forward.

Under a scenario of unmitigated climate change, where greenhouse gas emissions increase unconstrained by any preventative measures, the number of temperature related deaths (predominantly from increased temperatures) is predicted to reach around 17,200 deaths by 2100 (Bambrick et al. [3]), as indicated in Figure 2.

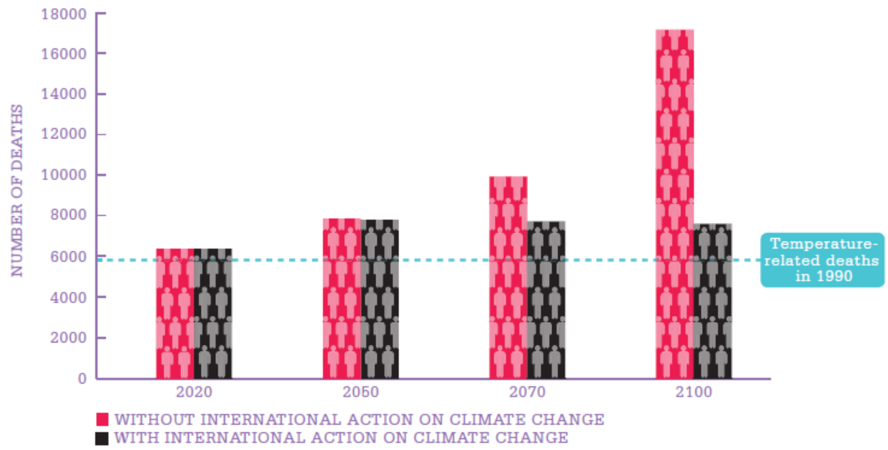

Figure 2. Projected temperature-related deaths in Australia with and without action on climate change (Bambrick et al [3])

Building regulatory Requirements and Future Proofing Buildings

The design of buildings to improve thermal efficiency has been in Australia for many years now, with prescriptive requirements in state building codes to improve the level of thermal comfort by prescribing mandatory insulation levels, along with a range of other measures designed to increase the energy efficiency of buildings. These measures and insulation levels represent today's minimum requirements and will in all probability change going forward in time as energy costs rise. Therefore they may not recessarily meet future requirements going forward. They are based on a cost benefit analysis, which does not take into account the impact of extreme weather events, or changes to climate patterns in the future. Protection against extreme weather temperature fluctuations should be an important consideration in providing for levels of occupant comfort and health longevity.

Ideally today's new buildings need to manage a range of performance functions to provide future proofing against changing weather patterns. These include higher levels of insulation than required by the local building codes, building designs that are thermally efficient and operationally cost effective, and products that are resilient or resistant to degradation over time from extreme weather events.

Roofs	***Total R-Value (Up-Down) m^{2}K/W***
Flat roof, skillion roof and cathedral ceiling – ceiling lining under rafter	0.36-0.48
Flat roof, skillion roof and cathedral ceiling – exposed rafters	0.38-0.44
Pitched roof with flat ceiling – tiled roof	0.23-0.74 (vent.); 0.41-0.56 (unvent.)
Pitched roof with flat ceiling – metal roof	0.21-0.72 (vent.); 0.39-0.54 (unvent.)
Walls	***Total R-Value m2K/W***
Weatherboard	0.48
Fibre cement shhet	0.42
Clay masonry veneer	0.56
Concrete blockwork masonry	0.54
Cavity clay masonry	0.69
Externally insulated clay masonry	0.53
Externally insulated concrete masonry	0.46
Autoclaved aerated concrete masonry	2.42

Table 1. Typical roof and wall construction details from the National Construction Code for Residential Housing [4]

Typical forms of roof and wall construction, as listed in the National Construction Code (NCC) [4] are given in Table 1. The minimum required total R value for roofs is in excess of R=4.0, and for walls is R=2.8, with exceptions. Only the autoclaved aerated concrete masonry wall system shows any significant level of thermal insulation. Additional insulation is required in all cases to meet minimum NCC requirements. There is ample evidence in the literature (see for example Saman et al [5] and Belusko et al [6]) of poor thermally performing systems, which can be attributed to any number of reasons including poor installation or gaps in continuity of insulation, shrinkage or compaction / compression issues and protection against moisture. Although designs may be compliant in many cases the actual delivered thermal performance can be below the minimum value given in the NCC.

The key issue is that all these systems are essentially composite in nature and rely on many components working together to perform to the minimum requirements of the National Construction Code. Future proofing against rising energy costs and adverse weather conditions is not normally considered in most building designs. This when combined with poor performance of some buildings, can mean that these buildings are likely to fall well short of future performance expectations.

The Use of Insulated Panels in Residential Construction

Building design which makes use of building materials that offer a range of performance in different types of weather events can help solve some of the product selection issues. Insulated panels is one such material. A typical insulated panel is shown in Figure 3, which comprises two metal faces with an internal 'sandwich' of high performance material. The two metal faces are thermally isolated from each other by a core material which (usually) has a high thermal resistance. Insulated panels offer advantages over traditional building materials in a number of areas, such as

- Light-weight and easy to handle
- All-in-one product with declared levels of performance - does not rely on a many different products assembled together to achieve many different levels of performance
- Offer a rigid form of construction due to the two metal faces
- High thermal performance per unit of thickness (ie high R-value in a thin panel)
- Fast to assemble
- Resilient – able to be reused and / or recover from extreme weather events
- Good spanning capability, especially for roofs
- Aesthically pleasing and often come with pre-painted plain and metallic finishes, secret fixing (ie no visible screws) and a variety of surface finish profiles

It is recognised that not all insulated panels are the same, and can vary in levels of performance even though some may look similar from the outside. Insulated panels never-the-less offer attractive benefits to suit residential building construction.

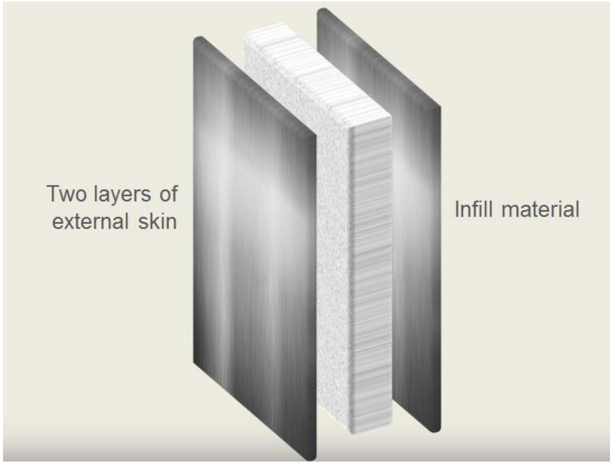

Figure 3. A typical insulated panel comprising two tough external faces, usually metal, and a high performance internal insulant core.

Their use has been growing in applications since early beginnings in Australia as a “cool-room” panel product. They are now widely used on roofs and walls, in commercial, industrial and retail applications, and frequently in high importance (in terms of life safety and emergency) buildings such as cyclone and bushfire shelters, hospitals and assembly halls. Today they have a firm foothold in domestic construction and can replace or integrate with many classical cladding and built-up roof system designs.

There are a number of different insulated panel core types on the market, including mineral fibre, expanded polystyrene, polyurethane and polyisocyanurate. Each product is different in terms of thermal performance, and will perform differently in bushfire, flood and other extreme weather event situations. The polyisocyanurate (PIR) cored products have a ‘closed-cell’ structure which aids in achieving high thermal performance. A 50mm thick Kingspan PIR panel will offer R=2.65 m^2K/W of thermal resistance at a surface density of around 10kg/m^2. These types of ptoducts offer high thermal performance without impacting on the thickness of the wall or roof system unduly, and provide an opportunity to have higher than the minimum NCC R-value in building designs.

Gererally typical methods of construction can be restrictive in terms of the level of thermal performance that can be “built-in” to buildings. For example it is difficult to get high R-value performance into some roof and wall designs, especially when the space is limited. A combination of insulation at ceiling level and roof level is required in some residential designs to achieve required thermal performance.

Future Proofing and Flexibility / Resilience in Design

Kingspan Insulated Panels manufactures PIR insulated panels that have higher R-value per unit thickness when compared to most other products used in residential insulation. Kingspan has worked with local area builders in New South wales Australia to complement two custom house designs that take advantage of the high thermal performance inherent in the Kingspan PIR systems. The insulated panels in these houses combine creatively with other traditional building materials to provide both attractive and resilient building designs, as shown in Figures 4 and 5. Depending on the geographical location and aspect, the panel thicknesses can be selected to provide location specific optimum thermally efficient designs. This provides a starting point to achieve better control of the internal temperature space. The costs of heating and cooling can be greatly reduced by having a better performing thermal envelope.

Building construction requires the use of many components, which when assembled provide a finished desired performance. The selection of products that are better performing for roofs and walls enhances the overall total performance of the building, and provides an opportunity for greater flexibility in design to allow natural roof and wall lighting systems to be used. There are translucent roof and wall products available today that can integrate with proprietary insulated panel systems. These are often multi-cellular in composition, and as a result provide better R-values than were available in products many years ago.

Future proofing also extends beyond not just energy efficiency. It can embrace many factors including those based on climatic extremes, improving indoor air quality and eliminating sick building syndrome. The roof and wall panels used in these buildings provide resilient performance in a number of areas, with an ability to endure storms and bushfires in particular. These insulated panels have industry leading high thermal performance, offer insurance industry fire certification performance, are water resistant, Global Grentag and EPD Australasia environmentally accredited, and have been assessed against the WELL building standard for areas including indoor air quality. Additionally the insulated panel products have been tested to local meet building codes for wind / strom performance, and designs details are available to meet the building requirements for cyclone rated areas nationally. They also provide fire performance and can be used in bushfire areas. The Kingspan insulated panels can typically be used without interior plasterboard lining to reduce construction costs and enhance design flexibility, as is typically done in a number of retail and commercial type building constructions.

Conclusions

A key component of future proofing buildings is the ability to provide a high thermal performance building envelope as a starting point towards reducing the overall energy consumption of the building. Combined with other modes of heating and cooling and with natural air flow cross-ventilation it is possible to achieve greater control of the internal environment, reduce energy efficiency and peak energy loading, as demonstrated for example in Saman et al [5] for residential housing. Kingspan have demonstrated the effectiveness of this approach with a number of non-residential classes of buildings in different geographical locations around Australia, and are working to extend this philosophy to residential buildings. This concept is not new, but the use of higher thermally performing insulated panels such as polyisocyanurate offers ways to achieve this more easily in compact simple buildings designs which offer other benefits as well. These other benefits are linked to the resilient nature of the insulated panels to resist and survive storms, floods, cyclones and bushfire events. With products like this available, building designers have a greater choice of materials for use in helping future proof buildings against natural hazards.

Figure 4a. Kingspan protytype house 1, with a shaded verandah which makes use of overhanging insulated roof panels. The front and side uses recycled hardwood to provide feature walling.

Figure 4b. Kingspan prototype house 1, showing the seamless integration of recycled materials and insulated panels, where the high thermal performance insulated panels are located on the rear wall (and the roof) to limit internal temperature rise on hot days.

Figure 5a. Kingspan prototype house 2, showing the integration of an 'industrial' panel look into a pleasing architectural design, offering high levels of thermal performance.

Figure 5b. Kingspan prototype house 2, showing good design versatility in the use of insulated panels. The high thermal performance envelope permits the opportunity for greater glassed areas, which is a feature of insulated panels typically used in retail shopping centre design to enhance design flexibility.

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