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IMPROVING THE RESILIENCE OF EXISTING HOUSING TO SEVERE WIND EVENTS

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ABSTRACT

Damage investigations carried out by the Cyclone Testing Station (CTS) following severe wind storms have typically shown that Australian houses built prior to the mid-1980s do not offer the same level of performance and protection during windstorms as houses constructed to contemporary building standards. Given that these older houses will represent the bulk of the housing stock for many decades, practical structural upgrading solutions based on the latest research will make a significant improvement to housing performance and to the economic and social well-being of the community.

Some structural retrofitting details exist for some forms of older housing but the take up of these details is limited. There is also evidence that retrofitting details are not being included into houses requiring major repairs following severe storm events, thus missing the opportunity to improve resilience of the house and the community. Hence the issues of retrofitting of older housing including feasibility, and hindrances on take-up etc. must be analysed.

This paper describes a Bushfire and Natural Hazards CRC project whose primary objective o is to develop cost-effective strategies for mitigating damage to housing from severe windstorms across Australia. These evidence based strategies will be (a) tailored to both aid policy formulation and decision making in government and industry, and (b) provide guidelines detailing various options and benefits to homeowners and the building community for retrofitting typical at risk older houses in Australian communities.

INTRODUCTION

Extreme damage to housing resulted from the impact of Tropical Cyclone Tracy in December 1974, especially in the Northern suburbs of Darwin (Walker, 1975). Changes to design and building standards of houses were implemented for the reconstruction.

The Queensland Home Building Code (HBC) was introduced as legislation in 1982 with the realisation of the need to provide adequate strength in housing. By 1984 it is reasonable to consider that houses in the cyclone region of Queensland were being fully designed and built to its requirements.

Damage investigations, conducted by the Cyclone Testing Station (CTS) in NT, QLD and WA, of housing from cyclones over the past fifteen years have shown that the majority of houses designed and constructed to current building regulations have performed well structurally by resisting the wind loads and remaining intact (Reardon et al, 1999; Henderson and Leitch, 2005; Henderson et al, 2006; 2010; Boughton et al 2011). However, these reports also detail failures of contemporary construction at wind speeds below design requirements. The poor performance of these structures resulted from design and construction failings or from degradation of elements such as corroded screws, nails and straps and decayed or insect attacked timber.

This paper describes work on a recently commenced Bushfire and Natural Hazards CRC project and provides an initial review with a focus on cyclonic regions, although the overall project encompasses housing types across the country. The proposed work will;

- Categorise houses into types based on the building features that influence windstorm vulnerability, using survey data collected by Geoscience Australia and CTS-JCU. From these, a suite will be selected representing those contributing most to windstorm risk.

- Involve end-users and stakeholders to assess amendments and provide feedback on practicality and aesthetics of potential upgrading methods for a range of buildings. Strategies will be developed and costed for key house types.
- Develop vulnerability functions for each retrofit strategy, using survey data, author's vulnerability models and NEXIS. Case studies will be used to evaluate effectiveness in risk reduction. Economic assessment using the same case studies will be used to promote uptake of practical retrofit options.

Figure 1. Removal of roof cladding and battens from wind ward face

Figure 2. Part of the roof cladding with battens still attached flipped on to the leeward side

WIND LOADS ON HOUSE AND STRUCTURAL PERFORMANCE

The wind field within a cyclone is a highly turbulent environment. The dynamic fluctuating winds that impact on the house subjects the building envelope (exterior skin) and structure to a multitude of spatially and temporally varying forces. Generally, the design of the house structure uses the peak gust wind speed in determining the large positive and negative pressures pushing and pulling on the house. The wind duration and temporally varying forces are important in assessing elements of the house envelope and frame, such as roofing, battens, and connections that may suffer degradation from load cycle fatigue.

Figure 3 gives a representation of the pressures acting on a house. The high suction pressures at the leading edge of the roof can be seen. If there is a breach in the building envelope on this windward face, such as from broken window or failed door (Figure 4), the interior of the house is suddenly pressurised. These internal loads act in concert with the external pressures greatly Increasing the load on the house cladding elements and structure. Depending on the geometry of the building, the increase in internal pressure caused by this opening can double the load on the structure, thereby increasing the risk of failure especially if the building has not been designed for a dominant opening.

As an aside, houses in cyclonic regions designed in accordance with contemporary design standard AS4055 Wind Loads for housing have the design assumption that a dominant opening can occur. Houses in non-cyclonic regions designed to AS4055 are not required to have the dominant opening pressure case accounted for in their design, resulting in a higher probability of failure if such an opening was to occur.

The National Construction Code (2014) is continually reviewed to ensure that it supports acceptable performance of new housing. However, as only a small fraction of our housing stock is replaced per annum, most Australians will spend the majority of their lives in houses that are already built. Further, from an emergency management, community recovery and an insurance perspective; the majority of the risk is in the housing stock that already exists.

Figure 3. Simple representation of wind pressures acting on building

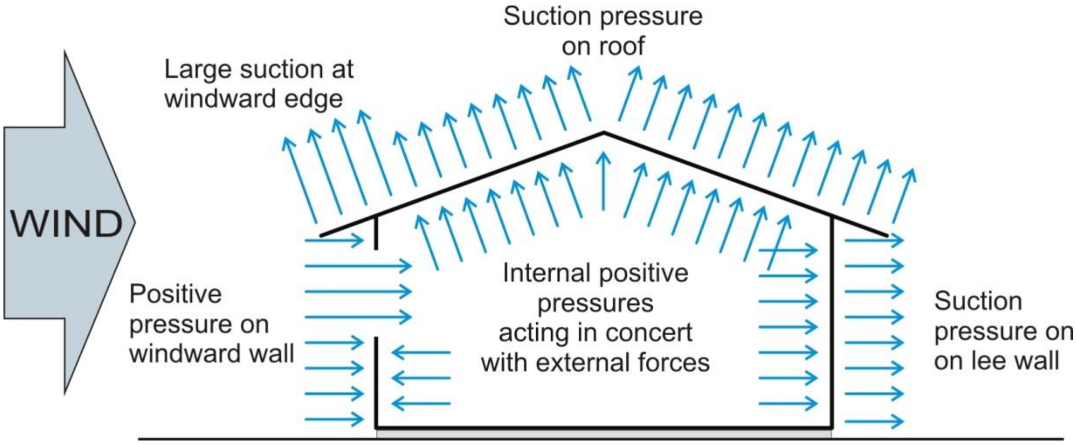


Figure 4. Standard lock and damaged door after being blown inwards during Cyclone Yasi

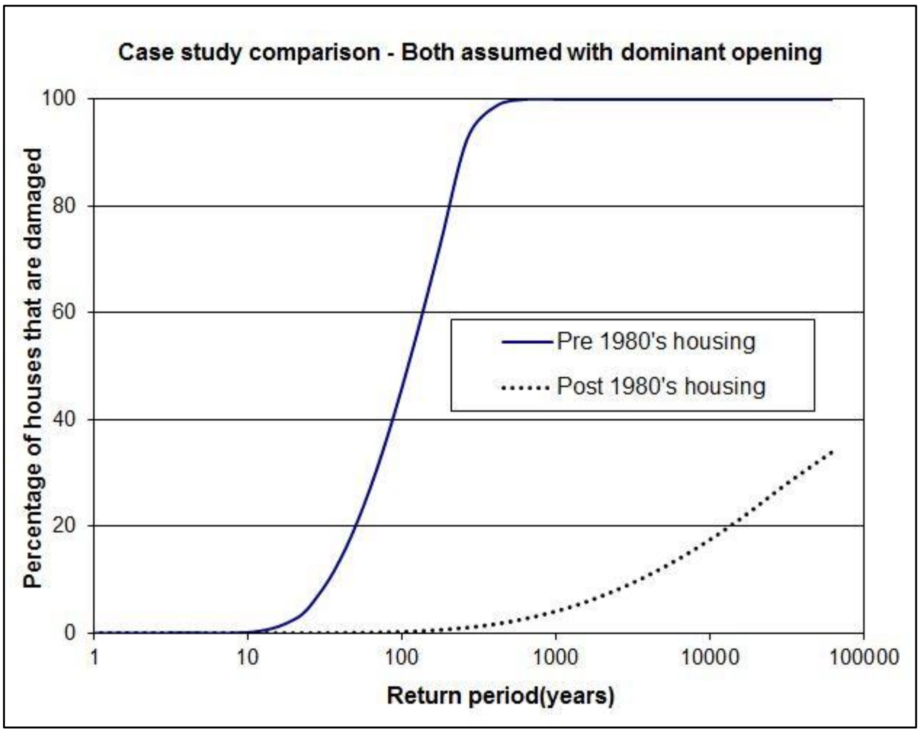
Houses are complex structures and do not lend themselves to simple design and analysis due to various load paths from mutliple elements and connections with many building elements providing load sharing and in some cases redundancy. Different types of house construction will have varying degrees of resilience to wind loads. From a review of building regulations, interviews, house inspections and load testing, the CTS classified the housing stock in the North Queensland region into six basic types (Henderson and Harper, 2003). These types are shown in Table 1.

For these six types the CTS developed preliminary housing wind resistance models to give an estimate of the likely failure mode and failure load for a representative proportion of houses. The CTS housing wind resistance models focus on the chain of connections from the roof cladding fixings down to the wall tie-down and incorporate parameters such as a chance of a dominant opening occurring.

The Geoscience Australia NEXIS data base is to be used to generate common housing forms for various regions around the country. Initial groupings for non-cyclonic regions are given in Table 2 (Edwards and Wehner, 2014). Vulnerability models for these types of building systems is to be derived.

AS/NZS 1170.2 provides information for selecting the design wind speed related to the return period. Using vulnerability curves developed by CTS, Figure 5 shows the percentage of housing damaged against the return period for a typical cyclonic region C, suburban site. These curves show the significant decrease in damage to housing that could be achieved if the older Pre-1980s houses were to be upgraded to be as strong as the contemporary Post-1980s houses.

Figure 5. Vulnerability curves for Pre 1980s and Post-1980s houses with increasing return period (King et al, 2013)



NOT JUST CONSTRUCTION AGE

Damage surveys invariably reveal some failures due to loss of integrity of building components due to aging or durability issues such as corrosion, dry rot or insect attack. The CTS conducted a detailed inspection of over 20 houses built in the 70s and 80s in the tropics. Although the majority of the surveyed houses appeared in an overall sound condition, the majority (all but two) had potential issues such as decay of a timber member, corrosion at a connection, missing/removed structural element, etc. This study highlighted that retrofitting for improved wind resistance is only a part of the process. Ongoing maintenance is an important part of improving our communities resilience in severe weather. In fact, the damage survey after Cyclone Yasi showed substantial corrosion of roof elements in houses less than 10 year old.

EXISTING UPGRADE PROVISIONS

There are existing guidelines for the upgrading of older houses in the form of handbooks (HB132) published by Standards Australia in 1999. However, the uptake of the prescribed details in the handbooks has not been effective in the light of recurring severe wind damage to older structures. These details and methods will be reviewed to consider reasons for lack of use. It is proposed that this project will access state of the art knowledge to improve the literature detailing general upgrading of structural connections in houses and other similar buildings. Where appropriate, it will also include targeted structural upgrade details for more specific types of housing. This study will provide an opportunity to assess what amendments might be warranted to current literature. The study will also consider the effectiveness of the current literature in supporting upgrading of older houses and consider whether other mechanisms may be needed to support implementation. The involvement of stakeholders including organizations such as professional builders associations, insurers, ABCB and BCQ will be sought for input.

If initial findings from surveys and engagement with stakeholders show that the biggest impediment to upgrading is that the existing HB132 details are all too expensive, excessive and in home owners eyes not aesthetic, then subsequent research should focus on development of new details. However, if the results showed that the details are acceptable, but that there is no incentive to apply them or there is lack of understanding of reasons for upgrading and maintenance, then research should focus on development of information to inform mitigation decisions including dedicated web based strategies to inform and educate home owners, designers and builders.

A major part of this is vulnerability studies combined with cost benefit analysis. This work will include analysis from wind tunnel model studies and load tests, and construction and load testing of “upgraded” representative sections of house for both proof-testing and using resulting video material for education and guides.

OBJECTIVES

- The uptake of retrofitting and maintenance of house structure will increase community resilience and reduce the needs of response and recovery following severe wind events.
- Promotion of retrofit investment by the home owner is needed.
- Incentives to encourage this action through insurance and government initiatives can be based on the economic modelling from this project.

Table 1. Generalised examples of housing constructions types (King et al, 2013)

Built During	Example of geometry and features	Generalised features
< 1920s		Hip roof, reduced rafter spans, central core, exposed studs, on stumps (low and high)
1920 – 1950s		Hip and gable, VJ lining, reduced rafter spans, on stumps (low and high)
1960s – 1970s		Gable low pitch, vermin proof flooring (studs not mortice and tennon into bearers), panel cladding, on stumps
> early 1980s		Reinforced masonry block, hip and gable, large truss spans, medium roof pitch, slab on ground

Table 2. Example of preliminary schema for house classification in non-cyclonic regions (Edwards and Wehner 2014)

Jurisdiction and Wind Region	Age	AS 4055 Classification	Roof Material	Wall Material				
				Brick Veneer	Reinf'd Masonry	Cavity Double Brick	Timber or Metal Clad	Fibre Cement Clad
Queensland Region B	1996 to Present	N2	Sheet Metal					
			Tile					
		N3	Sheet Metal					
			Tile					
		N4	Sheet Metal					
			Tile					
		N5	Sheet Metal					
			Tile					
	1980 to 1995	N/A	Sheet Metal					
			Tile and Slate					
All Other States, Territories Age Groups and Wind Regions	1996 to Present	N1	Sheet Metal					
			Tile					
		N2	Sheet Metal					
			Tile					
		N3	Sheet Metal					
			Tile					
		N4	Sheet Metal					
			Tile					
	1980 to 1995	N/A	Sheet Metal					
			Tile and Slate					
	1960 to 1979	N/A	Sheet Metal					
			Tile and Slate					
			Fibre Cement					
	1914 to 1959	N/A	Sheet Metal					
			Tile and Slate					
			Fibre Cement					
	1891 to 1913	N/A	Sheet Metal					
			Tile and Slate					

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