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# ANALYSIS OF DAMAGE SURVEYS OF HOUSES AND PRELIMINARY INPUT TO VAWS

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## **ABSTRACT**

Significant financial loss in terms of cost of rebuilding or repair and loss of function of property (e.g. commercial activity, rental, relocation of residents, etc.), has been documented following recent severe tropical cyclones impacting the Australian coastal communities. These damage investigations estimate that the wind speeds in these events were less than the Australian building standard's design level wind speed for the regions impacted. Analysis of insurance claims data highlights issues with wind driven rain water damage. Additionally, investigations of the damaged buildings along with analysis of claims data reveals a high proportion of the losses are associated with contemporary construction as opposed to pre-current code buildings.

Education and awareness of consequences of such failures (e.g. damage to property and risk to life) is required in all steps of the building process (regulation, design, construction, certification and maintenance) and by all parties (designer, builder, certifier, and owner).



## **EXECUTIVE SUMMARY**

Damage investigations carried out following recent severe tropical cyclones impacting the Australian coastal communities have shown significant financial loss in terms of cost of rebuilding or repair and loss of function of property (e.g. commercial activity, rental, relocation of residents, etc.). Analysis of insurance claims data highlights issues with wind driven rain water damage. Additionally, investigations of the damaged buildings along with analysis of claims data reveals losses are associated with contemporary construction in addition to legacy housing.

This information is used for validating the VAWS software package.



## INTRODUCTION

Findings from damage investigations following severe weather events provide critical information for understanding building performance. CTS damage investigations following cyclones such as Tropical Cyclone (TC) Yasi [1], TC Olwyn [2] and TC Debbie [3], have clearly shown a significant improvement in structural performance of housing built after the introduction of the engineered provisions introduced in the early 1980s. The damage investigations did however highlight a few issues with current construction such as loss of soffits and poor performance of roof tiles and roller doors which led to some damage.

Notwithstanding improved structural performance of buildings, the CTS damage investigations of housing construction have shown that wind driven rain water ingress causes significant damage in residential construction [4]. The CTS damage surveys found that that in some cases wind-driven rain passed through the building envelope at openings such as windows and doors (even if closed), around flashings, through linings or where the envelope has been damaged.

## BACKGROUND - DESIGN WIND SPEEDS IN AUSTRALIA

The Australian and New Zealand Standard for structural design wind actions, AS/NZS 1170.2:2012 [5], divides Australia into several regions, as shown in Figure 1. Wind loads used in the design of structures (e.g. houses, shops, large storage sheds, 4 to 5 storey apartments, etc) are generated from thunderstorms, gales and tropical cyclones, depending on the building's location. AS/NZS 1170.2 excludes tornados from its scope of wind actions.

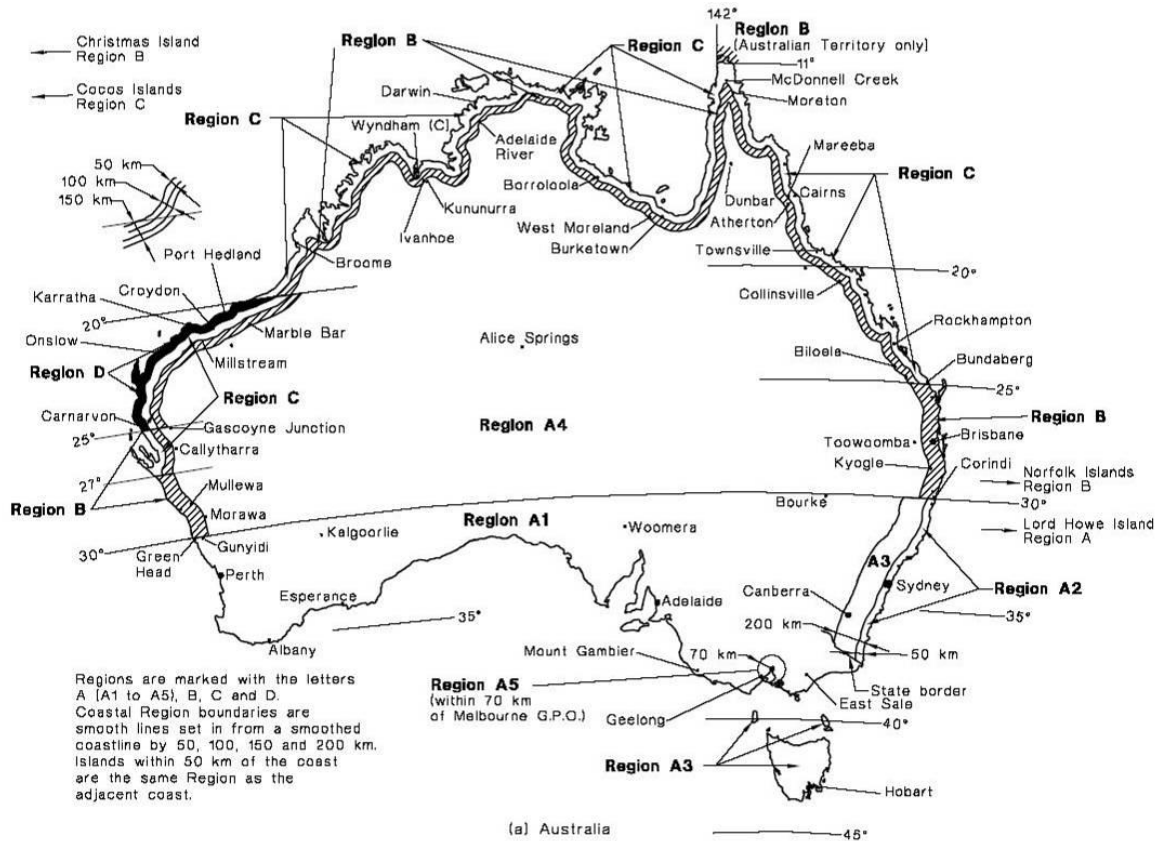


Figure 1. Wind regions of Australia [5]

### Non-cyclonic wind region (A)

The design wind speeds have been derived from a statistical analysis of recorded wind speeds from weather stations. Different methods of extreme value analysis were employed in deriving the wind speed probability distribution and the probability of exceedance. The probability of exceedance is the percentage chance that the nominated wind speed will be surpassed in any one year [6]. The design wind speeds are a function of both the large frontal gales and the much smaller footprint of thunderstorm winds.



## Cyclonic wind region (C and D) and intermediate region (B)

The design wind speeds for longer return periods (ultimate limit state design) result from land falling tropical cyclones. Due to the sparsity of the historical record for these infrequent occurrences of severe and extreme cyclone crossings, the design wind speeds were developed using computer based statistical simulations to provide artificial data sets. The method is highly dependent on the assumptions used for the probability distributions for all the parameters used in modelling these simulated events. Table 1 lists the wind speeds and central pressures associated with cyclones categories.

Table 1: Bureau of Meteorology Cyclone Categories

Cyclone Category	Gust Wind Speed at 10 m height in flat open terrain ( $V_R$ )			Central Pressure
	km/h	knots	m/s	hPa
1	<125	<68	<35	990
2	125-170	68-92	35-47	970-985
3	170-225	92-122	47-63	950-965
4	225-280	122-155	63-78	930-945
5	>280	>151	>78	<925

## Australia's National Construction Code (NCC)

The National Construction Code of Australia's [7] objectives, with respect to wind loads, are;

- Safeguard people from injury caused by structural failure,
- Safeguard people from loss of amenity caused by structural behavior,
- Protect other property from physical damage caused by structural failure, and
- Safeguard people from injury that may be caused by failure of, or impact with, glazing.

The Australian Building Codes Board sets the societal risk for the ultimate limit state strength of a structure. The level of risk is evaluated depending on the location and type of structure. For example, a hospital has a higher level of importance (Level 3) than an isolated farm shed (Level 1). The ultimate limit state design level for housing (Importance level 2) is a minimum annual probability of exceedance of 1:500.

The wind speed at ultimate limit state is the design level that the structure is meant to withstand and still protect its occupants. Table 2 shows that for a residential building in Region C, the 1:500 probability of exceedance wind speed is 69 m/s (0.2 second gust at 10 m height in open terrain). As shown from Table 1, this regional gust wind speed ( $V_R$ ) of 69 m/s is in the range of gust wind speeds for a Category 4 cyclone.



Structures designed according to Australian building standards load combinations should have a negligible probability of failure (i.e. < 0.001 or as a percentage, < 0.1 %) at ultimate limit state loads. Therefore failures of structural elements would not be expected to occur at the ultimate limit state design load.

Table 2. Regional design wind speed ( $V_R$ )

Wind Region	$V_R$ (1:500)
A	45 m/s
B	57 m/s
C	69 m/s
D	87 m/s

The building site design wind speed takes the regional design speed and modifies for several factors that can either increase or decrease the local wind speed (i.e. building height, terrain, topography, shielding from other structures, suburban terrain, etc). Therefore a building in an exposed location (e.g. on top of a hill), that is designed without proper consideration for the increase in wind speed, is at an increased risk of failure.

## RESEARCH APPROACH - DAMAGE FROM SEVERE STORMS

Following the devastation caused by Cyclones Althea and Tracy, the Cyclone Testing Station (CTS) at JCU was founded nearly 40 years ago with the realization that a dedicated focus was needed to determine the impacts on buildings and examine the effects of dynamic wind loads on construction and materials and assist in promoting better building and design practices in the community. Although the CTS has laboratory equipment for applying simulated wind and rain loads to everything from screws to complete houses, investigating the good and bad performance of buildings following severe weather is the ultimate means of evaluating our codes and standards, and their implementation along with product performance and installation.

### Tropical Cyclone Marcia [4]

Tropical cyclone Marcia impacted on the Yeppoon and Rockhampton communities as a weakening Category 3 to a Category 1 system in March 2015. Estimates of wind speeds were approximately 50% of the regional design speed for Rockhampton.

There were a number of examples of substantial damage inflicted to new medium rise commercial buildings and industrial sheds, as shown in Figure 2. Examples of observed damage were roller doors, flashings, fascia, the soffits, and failed roof top mechanical plant blown from the buildings. Wind driven rain water ingress damage was greatly exacerbated by the damage to these buildings' envelopes. From the observed damage, all exposed elements such as fascia, flashings, ceilings, vents, etc. and their fixings to the structure should be engineered to withstand design forces to prevent these premature failures and progressive damage from breaches in the building's envelope.



Figure 2. Damage to roof cladding and roof top attachments

The engineering profession is in a position to manage these risks by ensuring the engineering design of these “secondary” elements does not slip through the gaps between the responsibilities of multi-disciplinary design teams. For example, air-conditioning plant needs to be appropriately fixed, and substantial flashings require wind engineering design if they are to fulfil their waterproofing tasks in edge zones where the wind pressures are highest. Vent covers need to

have demonstrated compliance for wind loads. Likewise, fascia and soffits are part of the envelope of the building and once compromised lead to changes in internal pressure in the building with potentially damaging consequences to ceilings, walls and roofs.

### Tropical Cyclone Olwyn [2]

Tropical Cyclone Olwyn made landfall near Exmouth, Western Australia (Wind Region D) in March, 2015. The estimated peak gusts in Exmouth were around 185 km/h. The wind pressures were estimated to be 45 % of the ultimate design wind pressure for Region D.

Although the wind speeds were around the level at which buildings should remain serviceable, there was significant damage to houses and buildings from wind-driven rain entering through flashings, windows and doors. Water damaged plasterboard ceiling and wall linings, carpets, and timber floors, as shown in Figure 3. Many people reported they had tried to deal with the volumes of water entering their house during the cyclone and had put themselves at risk of serious injury while working in front of windward windows or doors.

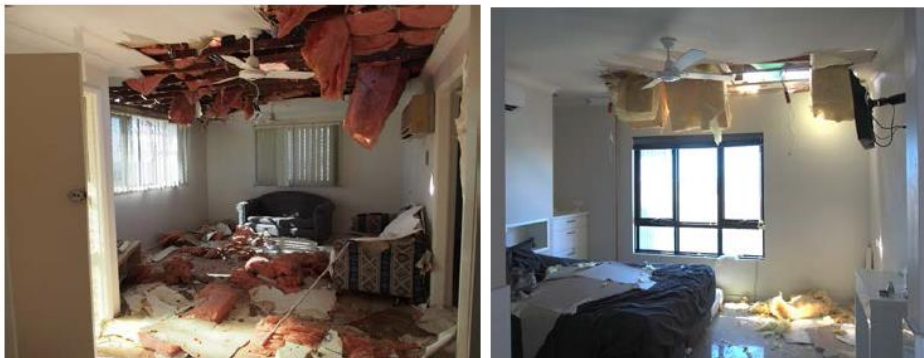


Figure 3. Ceiling damage from water ingress

### Tropical Cyclone Debbie [3]

Tropical Cyclone Debbie was classified by the Bureau of Meteorology as a Category 4 cyclone and crossed the Queensland coast north east of Airlie Beach around 28 March 2017.

Estimates of the wind field indicate that the buildings on the mainland experienced wind speeds lower than their relevant design wind speed. However, tie-down connections between roof structure and walls that had been inappropriately detailed failed on some recently constructed buildings. Connections between verandah beams and posts on some buildings with larger verandahs also failed. This study confirmed the findings of previous damage investigations concerning the vulnerability of: windows with inadequate fixings, window and door furniture; poorly fixed flashings, gutters and soffit linings; lightweight sheds; and fences. There was also significant damage from wind-driven rain entering through windows and doors or under flashings even though there was no structural damage to the building.

## Wind driven rain water ingress

Analysis of insurance claims data has shown that water ingress is a major contributor to losses in residential construction in recent events [8]. Approximately 80% of claims analyzed from TC Yasi mentioned water ingress with approximately 70% of those claims having no breach of the building envelope. That is, the wind driven rain was entering via “undamaged” windows, doors, flashings, etc. This is not surprising given that the test pressure for the Australian water resistance test requirements for windows and doors is roughly a tenth of the wind load strength design pressure, thereby making it less than the wind load serviceability pressure. A cross section of a typical window frame is shown in Figure 4. The pressure difference from exterior windward wall to interior (i.e. positive pressure to negative pressure) results in a mechanism for water being drawn into house. The pressure difference quickly exceeds the static pressure capacity (head) of the window sill.

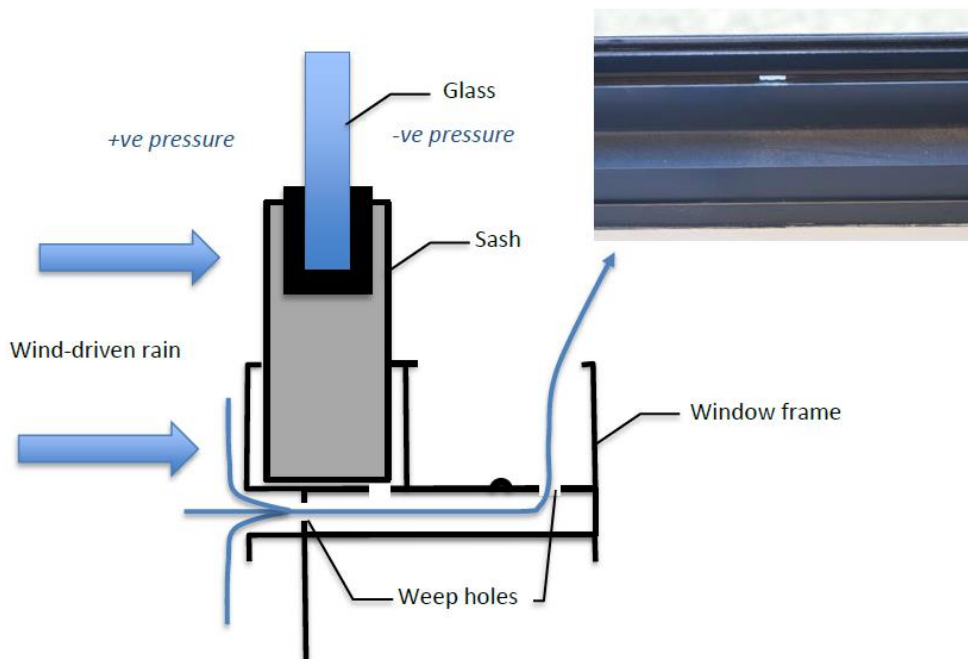


Figure 4. Cross section of window frame showing water ingress mechanism [2]

Mitigation of losses can occur through employing a combination of (a) reducing water ingress by complying with a higher serviceability test pressure, (b) using water resistant internal linings and (c) occupant education that wind driven rain will enter the residence. However the cost of products designed to more stringent test pressures may be prohibitive. The CTS is trialing several retrofit methods for reducing wind driven rain entry through typical windows and doors (Figure 5).



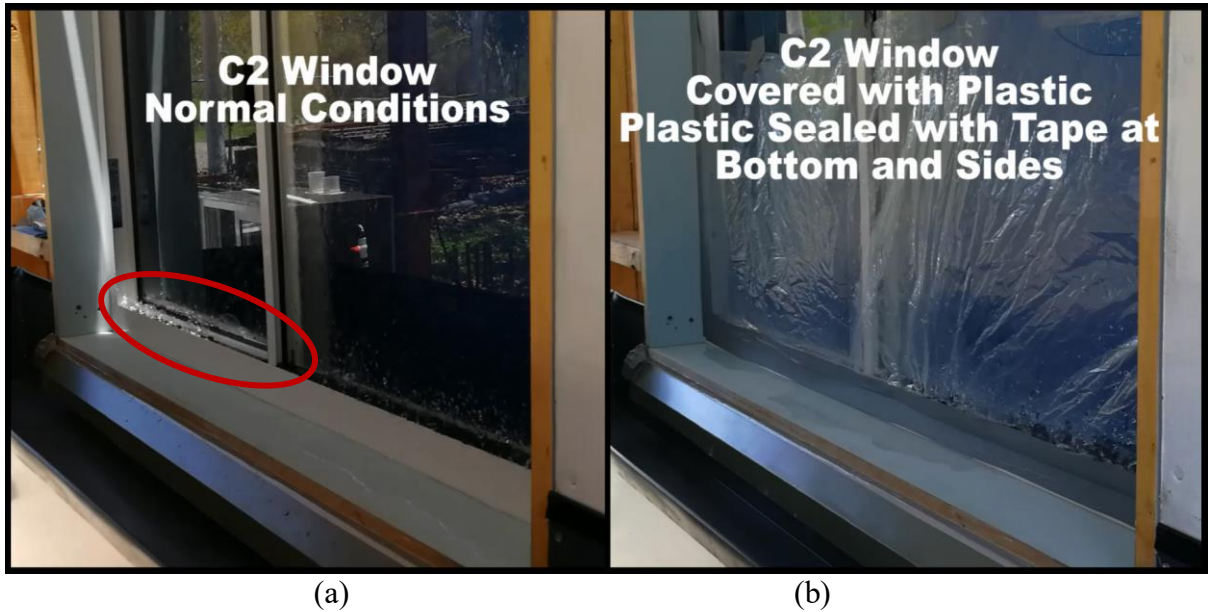


Figure 5. Wind driven rain test chamber at CTS; (a) water bubbling over sills during dynamic pressure trace; (b) simple retrofit retaining water from entering house.

## OUTCOMES

Damage investigations have shown that Australian building regulations in terms of the structural objectives generally appear to be appropriate with respect to wind loading. However, issues such as poor construction practice and/or design results in significant damage to properties. Lack of ongoing maintenance is also a factor.

Water ingress from wind driven rain has been identified as a key factor in insurance claims for contemporary houses. As structural issues have been identified and acted upon, the damage from wind driven rain ingress and the damage to ancillary components are a major factor on losses for events with wind speeds less than design level.

Recent damage investigations carried out by the CTS following cyclones that have impacted Australia have shown that older (Pre-80s) houses are susceptible to structural damage. Structural retrofit measures can be used to reduce the vulnerability of these houses to wind damage. Data from these damage investigations are being used to validate the VAWS software package being developed in this project.



## REFERENCES

- [1] Boughton, G. N., D. J. Henderson, J. D. Ginger, J. D. Holmes, G. R. Walker, C. Leitch, L. R. Somerville, U. Frye, N. C. Jayasinghe and P. Kim., *Tropical Cyclone Yasi Structural Damage to Buildings*, Cyclone Testing Station, James Cook University, Townsville. TR 57.
- [2] Boughton, G.N, Falck, D.J., and Henderson, D.J., *Tropical Cyclone Olwyn – Damage to buildings in Exmouth, Western Australia*, TR61, Cyclone Testing Station, James Cook University, Townsville. 2015
- [3] Boughton, G.N., Falck, D.J., Henderson, D.J., Smith, D.J., Parackal, K., Kloetzke, Mason, R. Krupar III, M. Humphreys, S. Navaratnam, G. Bodhinayake, S. Ingham, and J.D. Ginger, *Tropical Cyclone Debbie; Damage to buildings in the Whitsunday Region*, TR63, Cyclone Testing Station, James Cook University, Townsville. 2017
- [4] D. J. Henderson, D. J. Smith, and J. D. Ginger, *Strata Title and wind storms*, Strata and Community title in Australia Conference, Gold Coast, 2015.
- [5] Standards Australia, AS/NZS1170.2:2012 Structural design actions Part 2: Wind actions. AS/NZS1170.2:2012. Sydney NSW, Australia, Standards Australia, 2012
- [6] Holmes, J. D. *Wind loading of structures*, Spon Press, London. 2001.
- [7] NCC. *National Construction Code*. Australian Building Codes Board. Australia, 2016.
- [8] D.J., Henderson, *Pilot study: Examination of strata building risks from cyclonic weather by utilizing policy claims data*. Townsville, Cyclone Testing Station, JCU. 2018.