AWES2020
20th Australasian Wind Engineering Society Workshop
8 – 9 April, 2021

Assessing the Vulnerability of Modern Homes to Tropical Cyclones and the Suitability of Current Building Codes in Australia

Daniel Smith[1*], David Henderson[2*]
[1]*daniel.smith8@jcu.edu.au,* [2]*david.henderson@jcu.edu.au*
[*]*Cyclone Testing Station, James Cook University, Douglas, QLD, 4814 Australia*

ABSTRACT

In early 2020 the Insurance Council of Australia (ICA) Climate Change Action Committee (CCAC) commissioned the Cyclone Testing Station (CTS) and Risk Frontiers (RF) to undertake a study to investigate the vulnerability of modern homes (post-2000 only) to tropical cyclones and flood and the suitability of current building codes in Australia. The study approach for cyclones included: 1) review of specific natural hazard weather events that resulted in material insurance loss; 2) quantification of loss by investigating insurance policies and developing loss curves, and; 3) development of recommendations on the sufficiency of building codes to ensure resilience against current and future climate events. The public report on the project is due for release in April. Draft findings included that for the majority of homes, cyclone wind speeds were less than design-level, yet 1 in 5 policies filed a claim. The study indicates that current building codes do provide life safety, but do not prevent economic losses. The majority of claims were related to non-structural failures, frequently including water ingress despite an undamaged building envelope.

1. Introduction

Damage investigations following tropical cyclones over subsequent decades have shown that there is a positive step change in performance for life safety robustness of housing built after the code changes (post-1980) across the tropical cyclone regions of Australia. However, achieving life safety does not necessarily result in protection of property or minimised economic loss in natural disasters. Investigations of damage to buildings following severe weather events show continuing problems with the performance of contemporary engineered buildings, particularly with respect to water ingress. This study included a detailed review of insurance claims to further identify drivers of loss in modern housing.

A series of wind field models were developed by RF for TC Yasi (2011), TC Marcia (2015) and TC Debbie for use in the study. The models were calibrated and adjusted using wind speed observations that included BoM Automatic Weather Stations, the CTS Surface Weather Instrumentation Relay network (SWIRLnet) and CTS analysis of damaged road signs from the events. The adjusted wind field models were used in claims analyses to develop relationships between wind speed and expected loss (building and contents). In addition, specific damage modes were investigated using text mining algorithms to query claims descriptions. Finally, a subset of the claims were reviewed in detail (e.g., assessors reports, photos of damages, etc.) to provide examples of failures and loss drivers (i.e. durability, poor flashing install and/or design, etc.). The draft findings of this study were compiled in a comprehensive report (Smith et al., 2020) to the ICA for their review. Selected sections of the analysis and draft findings are included in this paper.

2. Wind Field Model

Risk Frontiers' tropical cyclone wind model (Loridan, 2017) was calibrated and validated against a series of observational data for TC Debbie (2017), Marcia (2015) and Yasi (2011). Observations included nine Bureau of Meteorology (BoM) Automatic Weather Stations (AWS), six CTS Surface and Weather Instrumentation Relay network (SWIRLnet) mobile anemometers (see Boughton et al 2017 for description) and wind speed estimates at 18 sites derived from CTS analysis of road sign damage (Ginger et al., 2007). SWIRLnet weather stations are owned and operated by CTS with anemometers that record and store data on wind speed (10 Hz, 3.2 m height), wind direction, temperature, relative humidity and pressure. The RF model validation included an exposure weighting routine that prioritised observations near urban areas (i.e., more insured properties). BoM track data (latitude, longitude, radius of maximum winds and maximum wind speed) were linearly interpolated to 30-minute time steps. Over the three TC events, the modelled event maxima wind gusts had a mean positive bias of 0.7 m/s and a Root Mean Squared Error (RMSE) of 2.7 m/s. This represents an error margin of approximately 7% compared to observed event maxima. The RF wind model was iterated 100 times for each tropical cyclone at half-hourly intervals and results were interpolated to a 0.01-deg (~ 1-km) equidistant grid and output as open terrain 3-sec gust values (m/s).

2.1 Regional correction factors

In some regions, additional adjustments were made to the wind field model outputs to better align the peak winds with observational data collected during the events (e.g., BoM Automatic weather stations or CTS SWIRLnet towers). For example, Figure 1 compares model values with observational data (m/s, standardised 3-sec gust @ 10 m) collected in Bowen for TC Debbie. TC Debbie approached landfall to the south of Bowen, generating peak winds in Bowen that came from the W/SW direction. The modelled wind field is consistent with Bowen airport (BoM AWS) and South Bowen (CTS SWIRLnet). In North Bowen near Queens Beach, the model differs from the CTS SWIRLnet observations at that location by ~11%. The more complex upwind topography (i.e. near Horseshoe Bay, Rose Bay, etc.) may have been a factor, which is difficult to fully account for in the wind field model. Therefore, model outputs were manually adjusted by 11% in the North Bowen area to better align with the observations. Similar adjustments were made as needed based on the available standardised observational data (i.e., AWS, SWIRLnet or road sign analysis) for all three tropical cyclone events. This exercise highlighted the importance of collecting high-quality distributed observations in urban areas during TCs (e.g., using SWIRLnet) and combining those observations with model outputs to improve the overall accuracy of wind field estimations (i.e. both are needed to generate realistic outputs in terms of wind footprints).

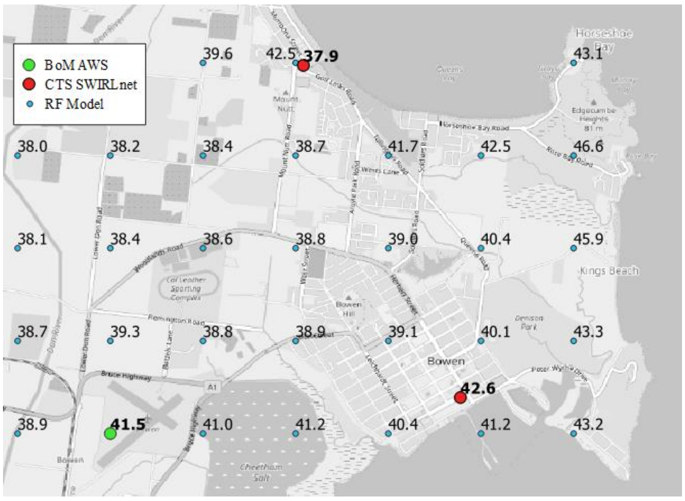

Figure 1. Wind field model outputs versus Bureau of Meteorology and CTS SWIRLnet observations (m/s, standardized 3-sec gust @ 10 m) for TC Debbie in the Bowen region

2.2 Site-level correction factors (as per AS/NZS 1170.2)
Houses have varying degrees of exposure to wind forces, with those dwellings located in a suburban environment gaining shelter from surrounding structures as distinct from those exposed houses near the sea or in open terrain. Topographical features such as hills can concentrate or divert wind flow. In addition to the regional corrections discussed above, publicly available datasets provided by Geoscience Australia for Topography (Mt), terrain (Mzcat) and shielding (Ms) factors as per AS/NZS 1170.2 were used by Risk Frontiers to adjust the regional standardized wind model output (10 m, flat, open terrain) to account for the local site characteristics at each property.

3. Claims Analysis

Claims data were provided by five different insurers for each of the three tropical cyclones. In total, ~39,000 post-2000 homes were included in the analysis, ~7,000 of which had filed either a building or contents claim. The tropical cyclone study area, extended generally along the north Queensland coastline from Bundaberg to Cairns. Claims data provided by insurers extended well outside of this region (e.g., extra-tropical Cyclone Debbie impacts extended into NSW), however analyses were restricted to only those points within the maximum wind swath (defined as 6x the radius of maximum winds) of each of the three tropical cyclone events. This restriction was needed to simplify the analysis, however it is important to acknowledge that the results presented herein are a lower bound to the true extent of loss, which extends over a much broader footprint.

3.1 Analysis of bulk cyclone claims data

Figure 2 shows the proportion of claims vs non-claims versus wind speed. In addition, the total loss (shown in red) for each 10 m/s wind speed increment. The figure shows that the majority of homes experienced wind speeds of < 40 m/s. Despite all three considered events being Category 4 (peak winds >60 m/s) or higher, this is expected since the peak winds of a tropical cyclone occur near the centre of the track and the majority of homes are subjected to lower (but still damaging) winds that extend much farther from the eyewall. That being said, note the relatively high amounts of loss ($) produced for higher wind speeds, despite a much smaller frequency of properties.

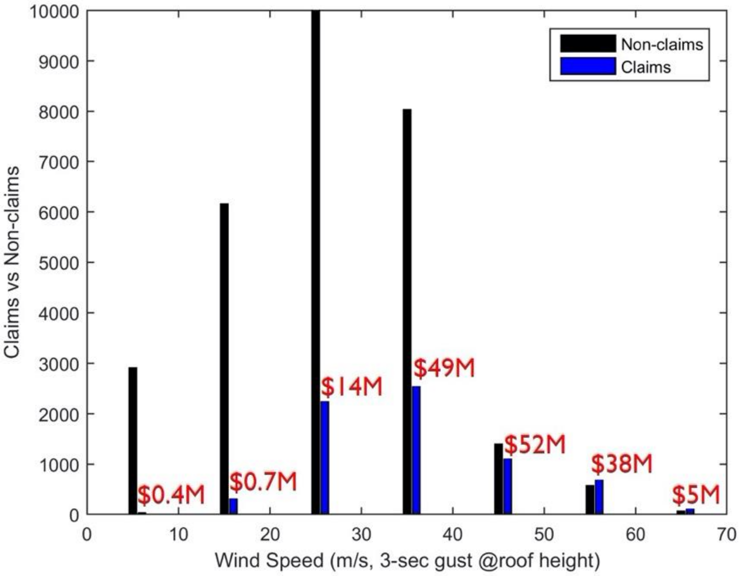

Figure 2. Number of claims and non-claims vs wind speed for all insurers and all tropical cyclones with estimate of total losses (millions, in red) for each wind speed bin

In some regions, claims data were compared with Rapid Damage Assessment (RDA) datasets. RDA's are surveys carried out by trained emergency services personnel in the immediate aftermath of disaster events. The surveys assess the condition of buildings in damaged areas so that emergency assistance can be efficiently managed and dispatched. The surveys are generally carried out on foot (by helicopter in remote areas) via handheld electronic devices. The primary objective of damage assessment during the surveys is identifying life safety and recovery issues and most surveys are conducted on foot from the street and therefore less visible damages are likely to be underreported (e.g. water ingress). Smith et al (2017) discuss analysis of these data for two previous Queensland weather events in more detail. The RDA data represent the broader community "view" of damages following severe events. Figure 3 shows the RDA data collected in Proserpine following Tropical Cyclone Debbie. The survey of this region was comprehensive, with nearly all areas of visible damage assessed. The three areas circled in green denote locations with very little identifiable damage from the exterior. Figure 3 also shows the claims for post-2000 houses (all insurers) in Proserpine. Note that areas circled in green have a significant number of insured losses, highlighting that the true extent of losses following TC events extends well beyond what can be see visibly by the broader community.

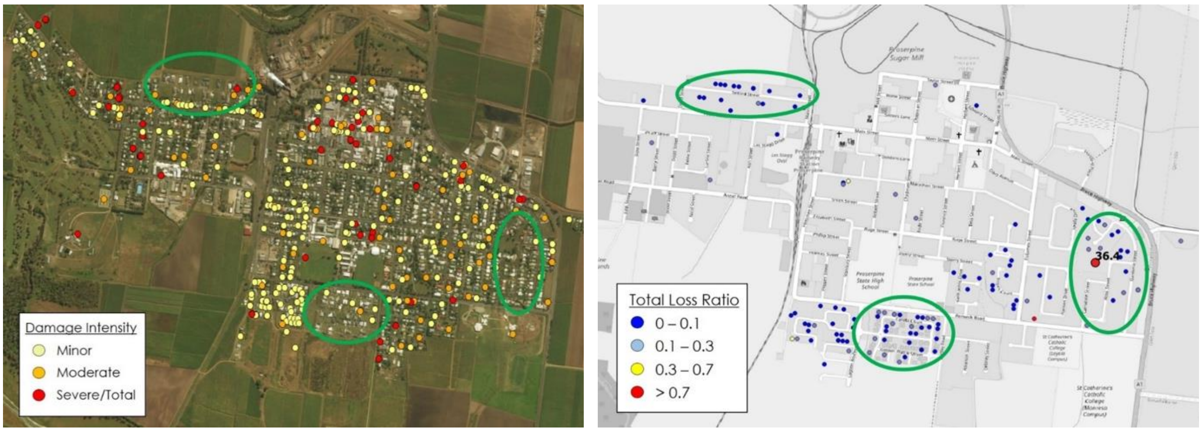

Figure 3. (Left) RDA data collected by QFES and NSW SES in Proserpine following TC Debbie. (Right) Total loss ratio (building + contents) in Proserpine for all insurers following TC Debbie. Note: areas within green ellipses show claims for modern housing where RDA data do not suggest damage from the exterior.

3.2 Analysis of claims summary text data

This analysis focuses on the short claim descriptions recorded by claims agents that is appended to the bulk claims data. The CTS text analysis program was used to make inferences about whether a given claim was associated with typical damage modes (e.g. wind, water ingress, power failure, tree fall, etc.) observed during previous damage investigations. The analysis method uses a series of rules that are used to query the claim descriptions and assign applicable damage types. For example, if a description included the words "roof" and "lifted", it would be flagged as wind damage. Similarly if a description included the words "rain" and "came through", it would be flagged as water ingress. The program aims to codify the engineering judgement that would be used by an expert reviewing each claim description individually. To calibrate the rule sets and check accuracy, text mining results were compared with a manual review of claims from TC Marcia. Nearly 6000 claims descriptions were examined by CTS engineers and flagged with the applicable damage modes. The program was then iteratively updated to improve accuracy relative to the manual results. It is important to note that the accuracy of the program is entirely dependent on the quality and detail provided in the claims description, which varies for each given insurer and event. Figure 4 shows the percentage of claims within each wind speed bin that were tagged with each damage mode for all insurers and all tropical cyclone events in this study.

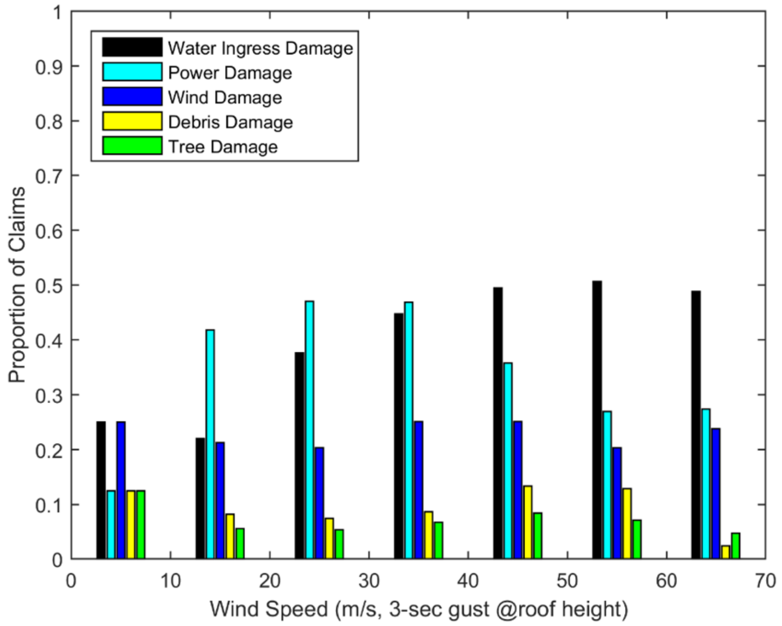

Figure 4. Proportion of various (not mutually exclusive) damage modes based on text mining for all claims within each 10 m/s wind speed bins for all insurers and all three tropical cyclones

The data indicate that 20% of post-2000 homes affected by a TC will have some form of water ingress (WI) damage (40-50% at higher wind speeds). Anecdotally, these numbers are consistent with CTS damage investigations (e.g., Boughton et al, 2017), however this analysis offers a much more concrete perspective than previously available since WI damage is often difficult to detect from outside the building during damage surveys, and therefore is primarily documented via discussions between insurers and insureds.

3.3 Summary of results

For the tropical cyclone (TC) analysis, impact wind speeds across study areas were less than the minimum wind load design level (i.e. implies little or no damage should occur for modern homes). Yet a high number of claims occurred with an overall claim rate of ~20%. The majority of TC claims were non-structural, e.g. interior linings, water ingress, debris damage, ancillary items (e.g. fences, sheds, etc.), but there were cases of structural failures from wind loads. The high volume of claims results in substantial direct costs (i.e. paid claims) and indirect costs associated with processing each claim. Damage initiation begins around 20 m/s and increases with wind speed. Loss ratios as high as 1.0 are seen for wind speeds as low as 40 m/s. Water ingress (loss of amenity, sometimes uninhabitable) was a key driver of loss at all wind speeds and was common for homes with zero or minimal envelope damage. Other key findings from the claims analysis include:

- Based on the analysis of properties with estimated design wind AS4055 classes of C1, C2 and C3, it appears the rated components of the building (windows, garage doors, cladding) are, for the majority, scaling with the design level. This is encouraging, as it reinforces how effective the building code can be when the appropriate performance criteria are used and correctly applied and constructed for a given building.
- Inconsistencies in descriptors of house from insurers data (e.g. policy description for wall construction is brick veneer but is constructed from masonry block, etc.) add significant uncertainty to the loss modelling. A nationally consistent asset register may assist in improving data quality.

4. Discussion and Recommendations

In general, the analysis herein reinforces that the performance of contemporary homes is a significant improvement from those constructed prior to modern building code changes, particularly with respect to providing life safety. However, the analysis also clearly indicates that modern buildings are still vulnerable to TC events and that the expected losses from these events will be high. The draft findings from the project indicate that unless significant updates to the building code are made (e.g., with respect to water ingress design criteria, durability, etc.), the impact (and losses) from these events in Australian communities will remain high and in fact may increase with a changing climate. It is recommended that key stakeholders (code bodies, government, and industry) develop a robust dialogue and action plan regarding the role of building codes in preventing societal damage and losses from severe natural hazard events both now and into the future. A key consideration is whether these losses are acceptable and what the implications are for the cost of insurance and for community recovery. Other draft recommendations based on this study include the following:

- Improved design standards/criteria with focus on the building’s functionality post-event. E.g.:
    - Examination of low wind pressure requirements in AS2047 in evaluating windows and doors for wind driven rain
    - Revisions to HB39 for increased sealing requirements and flashing lengths for complex roofs (e.g. valley gutters) and design and fixing requirements for flashings in AS1562.1
    - Economic assessment of increasing water tightness of building envelope versus criteria for water resilient building products (e.g. ceilings) should water get through the building envelope
- Education for designers on correct application of site classification criteria in AS4055 and AS/NZS1170.2
- Public awareness campaigns promoting regular maintenance regimes on important features (roof condition, effective flashing, pointing of roof tiles, restraint of aerials, etc.)

References

Boughton, G.N., Falck, D.J., Henderson, D.J., Smith, D.J., Parackal, K., Kloetzke, T., Mason, M., Krupar, R.J., Humphreys, M.T., Navaratnam, S., Bodhinayake, G., Ingham, S., Ginger, J.D., 2017. Technical Report No. 63: Tropical Cyclone Debbie damage to buildings in the Whitsunday Region. Cyclone Testing Station, James Cook University Townsville, Australia.

Ginger, J.D., Henderson, D.J., Leitch, C.J., Boughton, G.N., 2007. Tropical Cyclone Larry: Estimation of Wind Field and Assessment of Building Damage. Australian Journal of Structural Engineering 7, 209-224.

Loridan, T., Crompton, R., and Dubossarky, E., 2017. A Machine Learning Approach to Modeling Tropical Cyclone Wind Field Uncertainty. AMS, DOI: 10.1175/MWR-D-16-0429.1.

Smith, D.J., Henderson, D.J., Obrien, J., Evans, J., Mortlock, T., Springall, R., Crompton, R., 2020. Residential Vulnerability Assessment: Assessment of the vulnerability of modern homes to tropical cyclones and flood and the suitability of current building codes in Australia. Report No. TS1202, Cyclone Testing Station, James Cook University.

Smith, D.J., Krupar, RJ., Henderson, DJ., Mason MS. (2017) Analysis of rapid damage assessment data following severe windstorm events, Australian Journal of Emergency Management 32 (4)

Standards Australia, (2011), "Structural design actions. Part 2 Wind actions", Australian/New Zealand Standard, AS/NZS 1170.2:2011.