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IMPROVING THE RESILIENCE OF EXISTING HOUSING TO SEVERE WIND EVENTS

Annual project report 2018-2019

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CYCLONE TESTING STATION

Australian Government
Geoscience Australia

Version	Release history	Date
1.0	Initial release of document	16/12//2019

Australian Government
Department of Industry, Innovation and Science

Business Cooperative Research Centres Programme

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Publisher:
Bushfire and Natural Hazards CRC

December 2019

Citation: Ginger, J, Parackal, K, Wehner, M, Ryu, H, Henderson, D, Edwards M 2019 'Improving the resilience of existing housing to severe wind events', Annual Report, Bushfire and Natural Hazards CRC, Melbourne 2019.

Cover: VAWS stakeholder workshop 2019. Photo: K Parackal

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EXECUTIVE SUMMARY

This project will provide practical structural retrofits that will make a significant improvement in the performance of Pre-80s (Legacy) houses to wind loads.

The major activity carried out in 2018-19 by the CTS-JCU and GA has been progressing the VAWS software package using wind loading and structural response and other test data:

- Two house types were selected and incorporated in the VAWS package. The structural response (i.e. damage progression) with increasing wind speed has been modelled, calibrated and validated. Costing modules have also been incorporated in VAWS.
- The VAWS model was demonstrated at a Stakeholder Workshop in Sydney on 3 June 2019. The VAWS model and outputs for a High-set house was presented at this workshop and the stakeholders were asked for feedback on VAWS and proposed guidelines for upgrading methods. Further uses for VAWS were also discussed. The feedback from the Stakeholders was positive and useful for further development of the software package.

This project has also provided advice to the Queensland Government Household Resilience Program which provides funding to help eligible home owners improve the resilience of their homes against cyclones. This program is managed by the Queensland Department of Housing & Public Works (QDHPW) and commenced in late 2018. Eligible home owners can apply to receive a Queensland Government grant of 75% of the cost of improvements (up to a maximum of $11,250 including GST. About 2000 houses have been retrofitted.

END-USER PROJECT IMPACT STATEMENT

Leesa Carson *GEOSCIENCE AUSTRALIA, ACT*

Wind damage investigations and insurance loss data analysis undertaken by the project's researchers demonstrate the disproportionate contribution of legacy or pre-code houses to housing damage loss. The impacts are also much broader than building damage. Extreme wind event damage on households and communities impact physical and mental health, necessitate the need for temporary housing and result in long-term losses in economic activity. This project is directed at a key need for an evidence base that can inform the address of this vulnerability.

The project outcomes will serve to provide an evidence base to inform the development of practical guides to improve the resilience of existing housing. It will also provide vulnerability models for assessing broader scale community risk and mitigation effectiveness for decision making. This year has seen a substantial step forward towards the project's goals with a PhD program successfully completed along with undergraduate projects at the CTS-JCU targeted at specific problems pertinent to the project. The development of the VAWS software package has continued to progress with refinements to the logic during 2018/19. The year has also seen a significant body of quantity surveying work undertaken which included damage scenario development, costing of repair, costing of building replacement and costing of the implementation a variation retrofit strategies. These key costing outputs have been integrated into VAWS to enable economic evaluation of effectiveness. I am looking forward to VAWS application now being broadening across the full range of building types in the scope.

The project has continued to publicize its work through journal papers, conference papers and presentations to a wide variety of agencies. What has been notable has been the recent stakeholder workshop in Sydney on the 3rd June 2019 with attendance from a broad range of participants. These included the insurance industry (primary, reinsurance, brokers and the catastrophic loss modelling industry), academia, private engineering consultants, government policy makers and government science agencies. Two participants travelled from NZ to participate. The formal feedback from the attendees was very positive. The workshop strongly endorsed to me the value of the VAWS development work and the research that underpins it in assessing mitigation effectiveness and provided strategic direction for future development.

PRODUCT USER TESTIMONIALS

Lindsay Walker, Director Building and Legislation Policy Division, QDHPW

The QDHPW is excited by the potential of the groundbreaking work being undertaken by JCU – CTS through the VAWS project.

Recent experience through the housing resilience project administered by QDHPW has demonstrated significant demand from owners of older pre-code housing to improve the resilience of their properties. This is particularly the case when there is clear guidance on cost effective strategies to improve building resilience. Increasing the resilience of the most vulnerable building stock has the potential to make a disproportionate impact on overall community resilience, as the majority of catastrophic failures affect these buildings.

Further development of VAWS to assess the risk of wind related damage, including water penetration, to a wider range of building types, has the potential to identify those buildings most at risk of failure and the most cost effective strategies to improve the resilience of these buildings.

QDHPW expect that the downstream benefits of the VAWS project will include:

- Better understanding of the risk of wind damage posed to a wider range of existing buildings
- Better understanding of how to improve the resilience of the most vulnerable aspects of existing building stock
- Better and more accurate pricing of insurance products, particularly after work is undertaken to improve the resilience of a building.
- Potential codification to guide retrofitting of existing buildings to increase resilience to wind related damage.

INTRODUCTION

Post windstorm damage investigations carried out by the Cyclone Testing Station (CTS) have shown that Pre-80s houses across Australia are vulnerable to wind damage. The damage is caused by design and construction failings, poor connections (i.e. batten/rafter, rafter/top plate). These studies also show that wind driven rainwater ingress related damage at wind speeds below design are common across all (including Post-80s contemporary) house types.

This project will provide practical structural retrofit solutions for improving the performance of these houses. Considering the prevalence of roofing failures due to unsatisfactory upgrading techniques used the project aims to widely disseminate guidelines on the benefits of good retrofitting measures. Additional benefits to home-owners (i.e. reduction in insurance premiums) will also be highlighted to encourage take-up of these upgrading provisions. The VAWS software package forms an integral part of developing these cost effective retrofit solutions.

BACKGROUND AND RESEARCH APPROACH

Damage surveys carried out following Cyclone Larry, Cyclone Yasi and many others by the CTS have shown that homes designed and constructed to the Australian building standards introduced in the 1980s generally performed well. Around 20% of the pre-1980s housing in some areas experienced significant roof loss. The relatively low incidence of roofing damage to post-1980s houses indicates that modern building codes and practices produce houses with better structural performance in severe windstorms. However, contemporary houses can experience water ingress damage from wind-driven rain.

- In general, contemporary construction performance for single family residential housing was adequate under wind loading.
- Significant structural damage to legacy (pre-1980s) housing was typically associated with loss of roof cladding and/or roof structure. There were many examples of legacy housing with relatively new roof cladding installed to contemporary standards but lacking upgrades to batten/rafter or rafter/top-plate connections, resulting in loss of roof cladding with battens attached.
- Corrosion or degradation of connections and framing elements initiated failures.
- Where wind-induced structural failures were observed in contemporary housing, they were often associated with either poor construction practice or design faults.
- Breaches in the building envelope (i.e. failed doors and windows, debris impact, etc.) exacerbated failure potential from increased internal pressures.
- Extensive water ingress damage was observed in many houses with or without apparent exterior damage.

These observations suggest the majority of contemporary houses remained structurally sound, protecting occupants and therefore meeting the life safety objective of Australia's National Construction Code (NCC). However, contemporary homes did experience water ingress (resulting in loss of amenity) and component failures (i.e. doors, soffits, guttering, etc.) with the potential for damage to surrounding buildings, thus failing to meet specific objectives and performance requirements of the NCC.

WIND LOADING CODES AND HOUSEING VULNERABILITY

The fluctuating winds subject the building envelope and structure to spatially and temporally varying loads. The structural design of houses utilise AS4055 and AS/NZ1170.2 and other related standards such as AS1684 to derive the wind loads and to design the structural components and connections. HB132 provides some details for retrofitting of existing houses.

Maintaining a sealed building envelope is also important to the wind resistance of buildings. If there is a breach on the windward face, (i.e., from broken window or failed door), the internal pressure can be dramatically increased. These internal pressures act in combination with external pressures, increasing the net load on cladding elements and the structure. The increase in internal pressure caused by

this opening can double the load in certain areas, increasing the risk of roof failure, especially if the building has not been designed for such a scenario.

Houses in cyclonic regions designed in accordance with contemporary design standard AS4055 incorporate higher loads from internal pressure increase caused by a breached envelope. Houses in non-cyclonic regions designed to AS4055 are not required to account for this load case, thus making them more vulnerable to damage, if such an opening were to occur.

New houses are a varying proportion of the overall housing stock depending on the location in Australia, and most people will spend their lives in houses that are already built. In addition, from an emergency management, community recovery, and insurance perspective, the majority of the risk is in housing stock that already exists.

The complexity of housing structures does not lend them to simple design and analysis due to various load paths from multiple elements and connections with many building elements providing load sharing and in some cases redundancy. Different types of housing construction will have varying degrees of resistance to wind loads. From a review of building regulations, interviews, housing inspections, and load testing, the CTS classified housing stock in the North Queensland region into six basic classifications.

For each of these classifications, 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 each of these house types. The models focus on the chain of connections from roof cladding fixings down to wall tie-downs and account for situations such as a breached building envelope.

Figure 1 is an example of the vulnerability analysis used by CTS that shows the percentage of houses (of a specific type) that are damaged versus the gust wind speed, in a cyclonic region C, suburban site. These wind speeds can be related to the design wind speed and the return period using AS/NZS 1170.2. These vulnerability curves show the significant decrease in damage to housing that could be achieved if pre-1980s houses were upgraded with opening protection and improved connections.

Data available from GA's National Exposure Information System (NEXIS), desktop surveys and the CTS database is used to establish common housing classifications for various regions around Australia. This project has defined a suite of House types for all parts of Australia and use this analysis method to produce vulnerability models for these types of houses. This technique is being codified in the software package: VAWS being developed. This process has progressed significantly in 2018/19 with the VAWS package being validated for assessing structural damage for two types of houses.

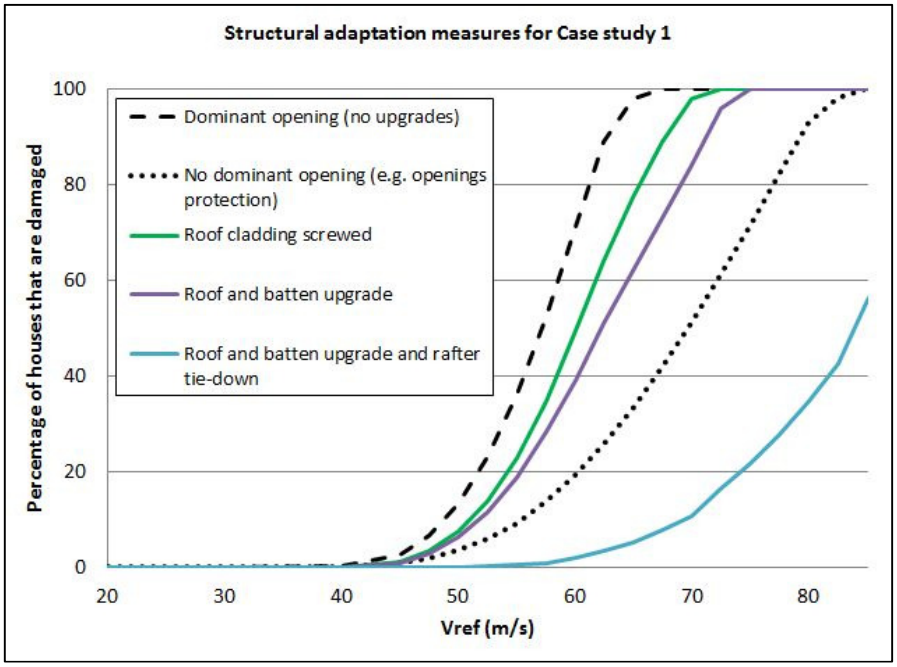

FIGURE 1. ESTIMATED DAMAGE FROM WIND LOADS TO HOUSES WITH DIFFERENT STRUCTURAL ADAPTATION MEASURES FOR HOUSE MODEL

KEY MILESTONES

Several important Milestones were achieved in 2018-19 as listed in Table . These Milestones have enabled the project to progress satisfactorily and to develop products that will be utilized by the Building and Insurance Industries.

The VAWS software package has been calibrated and validated for vulnerable house types and was successfully demonstrated by the team at a Stakeholder Meeting in Sydney, on 3 June. Input data for other selected legacy houses will be added and the package finalized in the next year. VAWS will be used in the development of cost-effective structural retrofit options for these house types. Proposed guidelines will be presented at the next Stakeholder meeting with the intention of producing a finalized set at the end of the project.

TABLE 1 MILESTONES FOR FINANCIAL YEAR 2018/19

Milestone	Description	Due Date
1.4.1	Technical report on vulnerability assessment of selected house types for which repair and replacement cost information exists (using VAWS) for Stakeholder use and feedback	30/03/2019
1.3.2	Evaluating community benefits of retrofitting (beyond mitigating damage) for incorporating into cost benefit analysis. Includes assessment of wind driven rain (WDR) water ingress damage and potential mitigation strategies.	31/03/2019
2.3.1	Finalising designs from stakeholder feedback (but prior to cost benefit analysis)	31/03/2019
2.3.2	Tender and execute QS contract	31/03/2019
2.3.3	Costings of retrofitting details	31/03/2019
2.3.4	Quarterly Report	31/03/2019
2.1.1	Design details of retrofitting measures for different house types. Analysis of drivers of WDR for various storm types (relevance to whole of country)	30/06/2019
2.2.1	Stakeholder workshop for determining preferred retrofitting and mitigation strategies based on practical implementation (i.e. ease of construction on real house/community)	30/06/2019
2.4.1	Revise VAWS input datasets based on results of QS contract	30/06/2019
2.4.2	Rerun vulnerability analyses for selected house types and retrofitting details	30/06/2019
2.4.3	Economic analysis (cost benefit analysis) for mitigation options. Assessment of retrofitting measures for WDR water ingress	30/06/2019

UTILISATION AND IMPACT

SUMMARY

The project has had two important Utilizations and Impacts.

1. **The Queensland Government Household Resilience Program (HRP)**
2. **Vulnerability and Adaption to Wind Simulation (VAWS)**

In addition the CTS has also been developing guidelines titled: Cyclone Resilient Homes" dealing with the risks of Cyclones and Storm Tide for the Queensland Reconstruction Authority (QRA). These guidelines are scheduled to be released in 2019/20.

THE QUEENSLAND GOVERNMENT HOUSEHOLD RESILIENCE PROGRAM

The Queensland Government Household Resilience Program (HRP) provides funding to help eligible home owners improve the resilience of their homes against cyclones. This program developed with advice from the Cyclone Testing Station is managed by the Queensland Department of Housing & Public Works (QDPWH) and commenced in late 2018.

Eligible home owners can apply to receive a Queensland Government grant of 75% of the cost of improvements (up to a maximum of $11,250 including GST).

Eligibility criteria require that the homeowner:

- Live in a recognized cyclone risk area (in the area from Bundaberg to the Queensland/Northern Territory border within 50km of the coast)
- Own or be the mortgagor of a house built before 1984
- Live in the home (primary place of residence)
- Meet certain income eligibility requirements.

Approved applicants are required to make a minimum 25% co-contribution towards the approved program works undertaken and may be able to arrange a loan to fund all or part of this co-contribution.

Improvements covered under the program, include:

- roof replacement including upgrade to roof tie-down
- roof structure tie-down upgrades using an external over-batten system
- replacement of garage doors and frames
- window protection including cyclone shutters or screens
- tie downs of external structures (e.g. sheds)
- replacement of external hollow core doors with solid core external grade doors

Extent of Use, Utilisation & Impact

At the end of March 2019 The Department of Housing and Public Works has indicated that approximately 1800 applications have been received to date of which about 800 valued at $8.5M have been approved. The total works value of this is $13.2M. These works have resulted in reductions in insurance premiums averaging from about 4% to 15%. Summary statistics provided in reports from the Department of Housing and Public Works, an extract is shown in Figure 2.

Utilisation and Impact Evidence

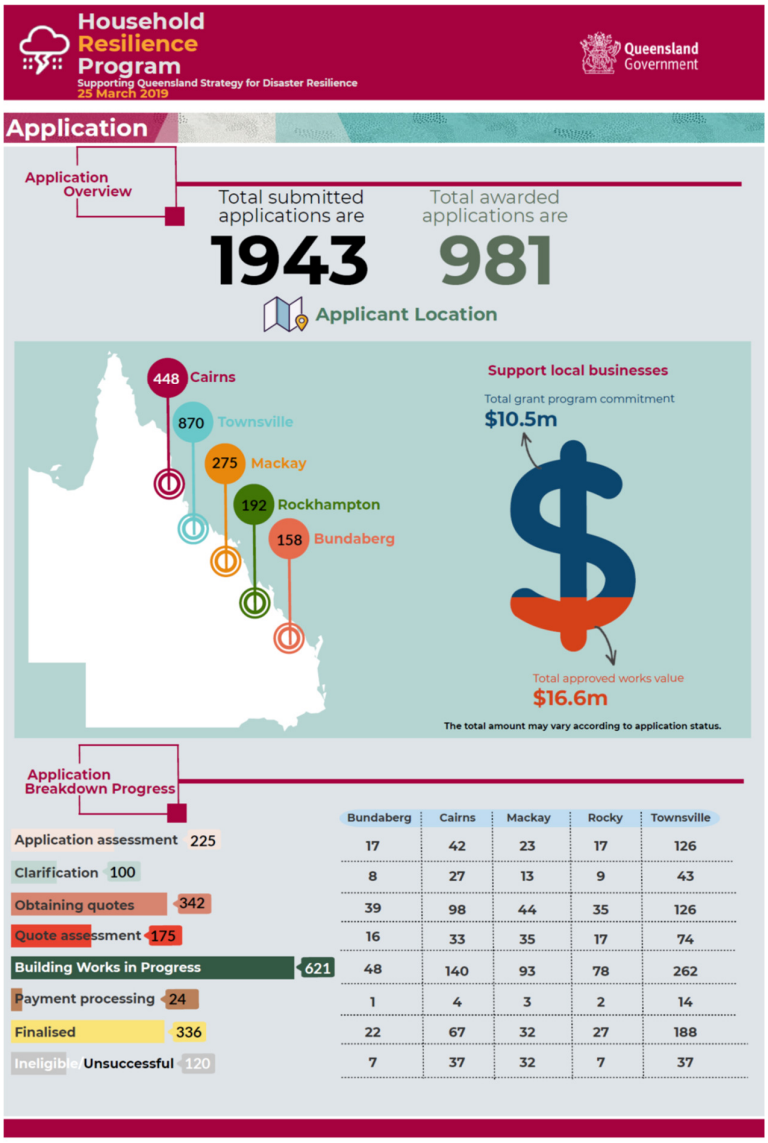

FIGURE 2. SUMMARY STATISTICS OF THE QLD HOUSING RESILIENCE PROGRAM IN MARCH 2019. SOURCE: QLD GOVERNMENT DEPT OF HOUSING AND PUBLIC WORKS.

VULNERABILITY AND ADAPTION TO WIND SIMULATION (VAWS)

Modelling the vulnerability of houses in windstorms is important for insurance pricing, policy-making, and emergency management. Models for Australian house types have been developed since the 1970s, and have ranged from empirical insurance to reliability based structural engineering models, which provide estimates of damage for a range of wind speeds of interest. However, outputs from these models also frequently misinterpreted as the basis of these models including underlying assumptions aren't adequately understood by the user. The Vulnerability and Adaption to Wind Simulation (VAWS), which uses probability based reliability analysis and structural engineering for the loading and response coupled with an extensive test database and field damage assessments to calculate the damage experienced by selected Australian house types.

VAWS consist of probabilistic modules for the 1. Wind hazard – external and internal pressures generated by the atmospheric wind and 2. Structural response – related to the structural system and capacities of the components and connections and load effects. VAWS consists of the main modules (i.e. the house type and structural system, external and internal pressure distribution, structural response, initiation and progression of damage, and other effects such as windborne debris impact and water ingress and cost of repair). VAWS has had its preliminary outputs validated for two vulnerable house types.

VAWS is able to accommodate a range of house types for which the structural system and their strengths and the external pressure distribution for wind exposure from directions around the compass are known. The critical structural components are probabilistically assigned their strengths and the wind loads are applied for winds approaching from a specified direction. Failure is initiated when the load exceeds the capacity of a critical component or connection as the wind loads are increased with increasing wind speed. When components fail, loads are redistributed through the structural system. The cost of repair is calculated for the given level of damage and the damage index = repair cost/ original cost is calculated at each wind speed increment.

Extent of Use, Utilisation & Impact

An Invitation as detailed below was sent out for a Workshop on "Improving the Resilience of Existing Housing to Severe Wind Events" held on 3rd June 2019 at IAG, Tower Two, Darling Park, 201 Sussex Street, Sydney 2000

The Cyclone Testing Station at James Cook University and Geoscience Australia are collaborating on a Bushfires and Natural Hazards CRC project titled: Improving the Resilience of Existing Housing to Severe Wind Events.

A key part of the project is to develop a software package that provides a measure of the vulnerability of several Australian house types to inform the cost benefit of carrying out practical structural retrofits.

The software package, known as Vulnerability and Wind Simulation (VAWS), is currently under development and is now at the stage where we solicit stakeholder feedback and advice on applicability, usability and capability (including modelling techniques and outputs).

We invite representatives of your organization to attendance and participation at a Workshop that will demonstrate VAWS and its capabilities. This 1/2-day Workshop will introduce the project and the software tool. The aims of the Workshop are to gain an understanding of the needs of potential users (including your organization) and as a quality assurance process. The short presentations will be intended to promote discussion amongst the workshop attendees.

Utilisation and Impact Evidence

FIGURE 3 DISCUSSIONS AT THE VAWS STAKEHOLDER WORKSHOP

Attendees at the VAWS (Vulnerability and Wind Simulation) Software Stakeholder Workshop, Sydney 3rd June 2019:

Name	Organisation
Adam Carrigan	Willis RE
Alex Edwards	Arup
Angelo Guerrera	Stramit
Antoinette Barba	Munich RE
Bruce Harper	Systems Engineering Australia
Chana Jayasinghe	Imparta engineers
Cora Xu	Roofing Tile Association of Australia
Desiree Beckharry	BNHCRC
Elizabeth McIntyre	Roofing Tile Association of Australia
Geoff Boughton	Cyclone Testing Station
Graeme Wood	Arup
Hamish Banks	Arup
Hao Qin	University of Newcastle
Jacob Evans	Risk Frontiers
John Bates	BNHCRC
John Holmes	JDH Consulting
Joshua Kusumo	Roofing Tile Association of Australia
Karen Messer	Northern Consulting
Lam Pham	Swinburne University
Kevin Holt	NSW Planning and Environment
Leighton Cochran	Mel Consultants
Mark Leplastrier	IAG Insurance
Michael Barkhausen	Willis RE
Michael Drayton	RMS
Robert Reeb	Munich RE
Ryan Crompton	Risk Frontiers
Stephen Durnford	NSW Planning and Environment
Stuart Moore	NIWA
Subo Gowripalam	Stramit

Workshop attendees were given questionnaires at the end of the session in order to provide general feedback on the workshop itself and to allow individuals to provide recommendations that were not discussed during the session. Answers to the four questions in the feedback form are presented below.

Stakeholder Feedback
Improving the Resilience of Existing Housing to Severe Wind Events Workshop

1. **Was the workshop useful to you/your organisation? Would VAWS be useful for the kind of work your organisation does?**
   - Yes it helped to review the current state of the project; to get a better understanding of VAWS
   - Interesting and helpful. In doubt, it is slightly too detailed and technical
   - Yes it is useful. It would need more validation before use
   - Yes. This was valuable to participate in. It has the potential to provide useful inputs to our risk –scenario modelling activities.

- The workshop was very informative. VAWS may not be useful to a wind engineer
- Yes. Not yet but definitely in the future if tiles are incorporated.
- Yes, however the current scope of VAWS testing (wind tunnel study) does not cover non-tile applications. Until then ARTA's stakeholder involvement would be observation based.
- Yes, it could be useful for risk assessments
- No
- Marginal to our firm. But could aid client's efforts
- Yes, with product development
- Absolutely: Resilience is core to CTS work

2. **Which part of VAWS or the workshop did you find most useful?**
   - After lunch discussions, and brainstorming
   - Discussion of building stock and structures
   - Presentations by Martin and Korah, though the earlier presentations are needed for context
   - Discussions around the assumptions and underlying logic in the tool was most useful. Particularly, learning what not to expect from the tool in term of how it can be used was insightful.
   - The failure scenarios built into VAWS
   - Progressive failure and pressure distribution analysis
   - Heat map analysis – Load redistribution to the superstructure of the roof frame/rafters/battens.
   - Technical Discussion
   - All
   - Damage curves for Australian building stock
   - The detail of how VAWS works
   - Interactive session

3. **What did you think could be improved or changed?**
   - There needs to be a more user friendly version of VAWS. A 3 bullet explanation of what VAWS can do for you
   - Tool Simplification. Better graphics
   - Perhaps the management/editing of all the CSV files could be brought inside the tool with the appropriate metadata included. Would reduce some barriers and lower the knowledge level needed to understand/run the tool.
   - Some other building types, especially 2-torey houses. Should building damage by falling trees be incorporated? (More critical for non-cyclonic winds in Vic, NSW, ACT)
   - Capillary effect + tiles. User friendliness.
   - 10 Generic housing models – Provide more applicable studies which can be interpreted for end users according to region/design/geometry/component.
   - Graphics and interface improvements
   - Incorporate insurance claim data for the damage index. Increase COV values
   - Input user interface with better graphical output
   - More calibration with reality to check assumptions

- The water ingress module, the debris impact model (understanding the effects of impact). Make output more visual with internal walls visible. Make it more accessible to government official and building owners

4. **Other Comments? – E.g. would your organisation be interested in collaborating on VAWS?**
   - It might be interesting to develop the tool beyond housing. An obvious example could be school buildings.
   - JDG had already collaborated on earlier developments e.g. the debris model.
   - May be avenue to collaborating via development and contribution of housing design common to other areas beyond the default 10 cases and on VAWS output types that could be used or other downstream risk modelling tools.
   - Would be interested in seeing tiles study in the future
   - Yes our organisation would be able to assist in providing roof tile inputs/finding in relation to wind pressures (internal/external).
   - Lack of change of wind directions in storm (Cyclone or thunderstorm). Expand to overseas –This would be of interest to Arup. Shielding from neighbouring buildings and impact on Cfigs from adjacent buildings not covered.
   - For experience with technology transfer like this to external common use suggest that the non-profit organisation called Applied Technology Council be explored
   - CTS does, is, and should remain Building owners (even of large buildings) have no idea that resilience is probabilistic. It is important that this gets out into the general community.

NEXT STEPS

Upcoming Milestones in 2019/20:

The next financial year will continue the development of the VAWS vulnerability model and economic analyses. Selected retrofitting options will be assessed for their economic cost benefit in further detail.

A second stakeholder meeting will be held, this time with the focus on the retrofitting schemes rather than the vulnerability modelling techniques. This meeting will be used promote retrofitting systems and their cost benefit.

Key outputs for financial year 2019/20 will include a journal paper on the cost-benefit analysis of retrofitting. Draft reports used in development of this research will be reviewed by stakeholders. Additionally, an alpha version of the web based guidelines for retrofitting houses based on the retrofitting details developed and the cost benefit analysis will be completed. A list of the upcoming milestones for next financial year are presented in Table 2

TABLE 2. MILESTONES FOR FINANCIAL YEAR 2019/20

Milestone	*Description*	*Due Date*
3.1.1	*Draft report on proposed retrofitting methods and incentive schemes for stakeholder comments (not public release)*	*30/09/2019*
3.1.2	*Stakeholder workshop on retrofitting measures cost benefit outcomes (U2.6.3)*	*30/09/2019*
3.1.3	*Poster for BNHCRC Conference*	*30/09/2019*
3.1.4	*Quarterly Report*	*30/09/2019*
3.3.1	*Journal paper on vulnerability assessment incorporating cost benefit analysis (CM 2.5.24)*	*31/03/2020*
3.3.2	*Quarterly Report*	*31/03/2020*
3.4.1	*Alpha version – Content for web based Guidelines for retrofitting and improving home resilience to severe storms*	*30/06/2020*
3.4.2	*Quarterly Report, Annual Report, Self-Assessment Matrix, Adjust utilisation Road Map if needed*	*30/06/2020*

PUBLICATIONS LIST

Journal Articles

Stewart, Mark G., Ginger, John D., Henderson, David J., Ryan, Paraic C. *Fragility and climate impact assessment of contemporary housing roof sheeting failure due to extreme wind*. Engineering Structures, 171. pp. 464-475, 2018.

Parackal, Korah I., Ginger, John D. and Henderson, David J., *Wind Load Fluctuations on Roof Batten to Rafter/Truss Connections*, Journal of Wind Engineering & Industrial Aerodynamics, 175, pp. 193-201 2018.

Humphreys M.T., Ginger J.D., and Henderson D.J., *Internal Pressures in a Full-Scale Test Enclosure with windward wall opening,* Journal of Wind Engineering & Industrial Aerodynamics, 189, pp. 118-124 2019.

Conference Papers

Henderson, D., Ginger J. and Smith D*., Large damage bills to buildings from cyclones can be reduced by small actions*, AFAC-BNHCRC, Perth, 2018

Humphreys M.T., Ginger J.D., and Henderson D.J., (2018) *Effect of Opening Size And Wind Speed On Internal Pressures In Full-Scale Buildings.* 25th Australasian Conference on Mechanics of Structures and Materials Brisbane, Australia.

Bodhinayake G., Ginger J., and Henderson D., (2018) *Net cladding pressures on industrial building roofs.* 25th Australasian Conference on Mechanics of Structures and Materials Brisbane, Australia.

Posters/Presentations

Henderson D. (2019) 12th Australasian Natural Hazards Management Conference in Canberra - David Henderson was an invited panelist for session on risk and resilience http://www.bnhcrc.com.au/events/2019-anhmc "The objective of this conference is to understand how we can reduce the impacts of catastrophic disasters by using an extreme, cascading weather scenario to see the contribution of current research, existing knowledge and future experiences of extreme weather and other emergencies."

Parackal, K. (2018), Progressive Failures of Roofs Under Wind Loads, Poster presented at the 2018 Bushfire and Natural Hazards CRC & AFAC conference, Perth.

Parackal, K. (2019), Engineering Houses to Resist Cyclones, Public Lecture at the Museum of Tropical Queensland, Townsville.

Parackal, K. (2019), Wind Loading and AS/NZS 1770.2, Presentation at the Australian Institute of Building Surveyors (AIBS) Regional Conference, Brisbane.

Humphreys, M, Engineering and Physical Sciences JCU Postgraduate Symposium, 15 minute presentation about PhD projects, 2 Nov 2018.

Humphreys, M, JCU 3MT, (3 minute presentation) about PhD projects, 16 August 2018.

Ginger J (2019), "Improving the Resilience of Existing Housing to Severe Wind Events" Seminar presented at USQ Toowoomba on 5 October 2018

Ginger J (2019) "VAWS modelling and outputs" Seminar presented at USQ Toowoomba on 6 June 2019

Theses:

Parackal, K. (2018), The Structural Response and Progressive Failure of Batten to Rafter Connections under Wind Loads, PhD Thesis, College of Science and Engineering, James Cook University, Australia.

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