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IMPROVING THE RESILIENCE OF EXISTING HOUSING TO SEVERE WIND EVENTS

Annual project report 2014-2015

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Photo: Cyclone Testing Station.

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EXECUTIVE SUMMARY

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.

Structural retrofitting details exist for some forms of legacy housing but the uptake 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 ideal opportunity to improve resilience of the house and community. Hence, the issues of retrofitting legacy housing, including feasibility and hindrances on take-up, etc., must be analysed.

The primary objective of this research 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 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 houses in Australian communities. Specific task items include:

- Categorize residential structures into types based on building features that influence windstorm vulnerability using Geoscience Australia and CTS survey data. From these, a suite will be selected to represent those contributing most to windstorm risk
- Involve end-users and stakeholders (i.e. homeowners, builders, regulators, insurers) to assess amendments and provide feedback on practicality and aesthetics of potential upgrading methods for a range of buildings. Cost effective strategies will be developed for key house types
- Vulnerability models will be developed for each retrofit strategy using survey data, the authors' existing vulnerability models, and the NEXIS database of Australian housing characteristics. Case studies will be used to evaluate effectiveness of proposed retrofit solutions in risk reduction. Economic assessment using the same case studies will be used to promote uptake of practical retrofit options

END USER STATEMENT

Leesa Carson, *Community Safety and Earth Monitoring Division, GEOSCIENCE AUSTRALIA, ACT*

The majority of wind risk is in the older existing housing stock. This project will provide evidence-based cost-effective solutions to improve resilience of existing housing from severe windstorms. The project is currently on track and has delivered its scheduled outputs.

Over the past year the team has been collecting and analysing information from the impacts of tropical cyclones and thunderstorms, which will provide valuable input into the development of vulnerability modelling.

The team has been proactive in communicating their research through presenting papers and posters at conferences and workshop and publicly releasing reports as well as contributing to a range of media mediums.

Engagement with key stakeholders has been positive both in informing the research and ensuring the project outputs are useful. The team has engaged with industry and Standard Committees which will assist in achieving practical outcomes.

INTRODUCTION

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. Structural retrofitting details exist for some forms of legacy (pre-1980s) housing but the uptake 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 ideal opportunity to improve resilience of the house and community. Hence, the issues of retrofitting legacy housing, including feasibility and hindrances on take-up, etc., must be analyzed. The primary objective of this project is to develop cost-effective strategies for mitigating damage to housing from severe windstorms across Australia. Strategies will be (a) tailored to 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 houses in Australian communities.

Tropical Cyclone Tracy caused significant damage to housing in December 1974, especially in the Northern suburbs of Darwin [1]. Changes to design and building standards of houses were implemented during the reconstruction. The Queensland Home Building Code (HBC) was introduced as legislation in 1982 (with realization of the need to provide adequate strength to housing). By 1984 it is reasonable to presume that houses in the cyclonic region of Queensland were being fully designed and built to its requirements.

Damage investigations of housing, conducted by the Cyclone Testing Station (CTS) over the past fifteen years have suggested that the majority of houses designed and constructed to current building regulations have performed well structurally by resisting wind loads and remaining intact. However, these reports also detail failures of contemporary construction at wind speeds below design requirements, in particular for water-ingress related issues. The poor performance of these structures resulted from design and construction failings, poor connections (i.e. batten/rafter, rafter/top plate) (Figure 1 and Figure 2), or from degradation of construction elements (i.e., corroded screws, nails and straps, and decayed or insect-attacked timber). Hence, the development of retrofit solutions for structural vulnerabilities are critical to the performance longevity of both legacy and contemporary housing.

Damage surveys invariably reveal some failures due to loss of integrity of building components from aging or durability issues (i.e., corrosion, dry rot, insect attack, etc.). The CTS conducted a detailed inspection of houses built in the 1970s and 1980s in Darwin [13]. Although the majority of surveyed houses appeared in an overall sound condition, they had potential issues like decay of timber members, corrosion at connections, missing/removed structural elements, etc. The damage survey after Cyclone Yasi showed substantial corrosion of roof elements in houses less than 10 year old [6]. This study confirmed that ongoing maintenance is also an important part of improving community resilience in severe weather.

FIGURE 1. WIND-INDUCED FAILURE OF A NEW (< 1 YEAR) METAL CLADDING ROOF ON AN OLD HOUSE AT THE RAFTER TO TOP-PLATE CONNECTION DURING CYCLONE MARCIA (2015) IN YEPPOON, AUSTRALIA - THERE APPEARED TO BE NO RETROFITTING OF THE WEKER CONNECTIONS.

FIGURE 2. WIND-INDUCED FAILURE OF A METAL CLADDING ROOF (LEFT) AT THE BATTEN TO RAFTER CONNECTION (RIGHT) DURING CYCLONE MARCIA (2015) IN YEPPOON, AUSTRALIA.

The issues of poor construction practices in renovation, degradation of materials (lack of advice for maintenance), etc. are not constrained to northern Australia. Damage investigations in Brisbane, Dubbo and Perth revealed similar issues. Figure 3 and Figure 4 show failed housing with missing roofing from not improving the batten to rafter connection when upgrading the roofing to batten connection.

Considering the prevalence of roofing failures due to inadequate upgrading techniques, current building industry literature for upgrading the wind (and water-ingress) resistance of existing Australian housing were reviewed. In parallel, a brief internet-based questionnaire was distributed to a wide range of Australian building industry constituents in order to identify specific limitations of current upgrading guidelines.

FIGURE 3. FAILED HOUSING AFTER BRISBANE THUNDERSTORMS (NOVEMBER 2014) WITH MISSING ROOFING FROM NOT IMPROVING THE BATTEN TO RAFTER CONNECTION WHEN UPGRADING THE ROOFING TO BATTEN CONNECTION (EXAMPLE 1)

FIGURE 4. FAILED HOUSING AFTER BRISBANE THUNDERSTORMS (NOVEMBER 2014) WITH MISSING ROOFING FROM NOT IMPROVING THE BATTEN TO RAFTER CONNECTION WHEN UPGRADING THE ROOFING TO BATTEN CONNECTION (EXAMPLE 2)

PROJECT BACKGROUND

WIND LOADS ON HOUSING AND STRUCTURAL PERFORMANCE

The wind field within a cyclone is well known to be highly turbulent. Dynamic fluctuating winds subject the building envelope and structure to a multitude of spatially and temporally varying loads. Generally, the structural design of housing uses peak gust wind speeds for determining the positive and negative pressure loads the structure must resist. The storm duration and temporally varying forces are important for assessing elements of the envelope and frame (i.e., roofing, battens, connections, etc.) that may be subject to low cycle fatigue.

Maintaining a sealed building envelop is critical to the wind resistance of buildings. If there is a breach on the windward face, (i.e., from broken window or failed door) (Figure 5), the internal pressure of the house can be dramatically increased. The internal loads act in concert with external pressures, increasing the load on cladding elements and the structure. Depending on the geometry of the building, the increase in internal pressure caused by this opening can double the load in certain areas, increasing the risk of failure, especially if the building has not been designed for a dominant opening.

Residential structures in cyclonic regions designed in accordance with contemporary design standard AS4055 Wind Loads for Housing [3] are required to incorporate load cases for internal pressure increases created by envelop breaches. Houses in non-cyclonic regions designed to AS4055 are not required to account for this load case, resulting in a higher probability of failure if such an opening were to occur.

The National Construction Code [18] is continually reviewed to ensure that it supports acceptable performance of new housing. However, only a small fraction of our housing stock is replaced per annum, therefore most Australians will spend the majority of their lives in houses that are already built. Further, from an emergency management, community recovery, and insurance perspective, the majority of the risk is in housing stock that already exists.

FIGURE 5. TYPICAL LOCK AND DAMAGED DOOR AFTER BEING BLOWN INWARD DURING CYCLONE YASI IN 2011.

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 [14].

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 houses. The models focus on the chain of connections from roof cladding fixings down to wall tie-downs and incorporate parameters like building envelop breach.

The Geoscience Australia NEXIS data base will be used to establish common housing classifications for various regions around Australia [17]. Vulnerability models for these types of building systems will be derived.

AS/NZS 1170.2 [2] provides information for selecting the design wind speed related to the return period. Using vulnerability curves developed by CTS, Figure 6 shows the percentage of housing damaged versus the return period for homes in a typical cyclonic region C, suburban site. These curves show the significant decrease in damage to housing that could be achieved if pre-1980s houses were upgraded to the wind resistance of contemporary post-1980s houses.

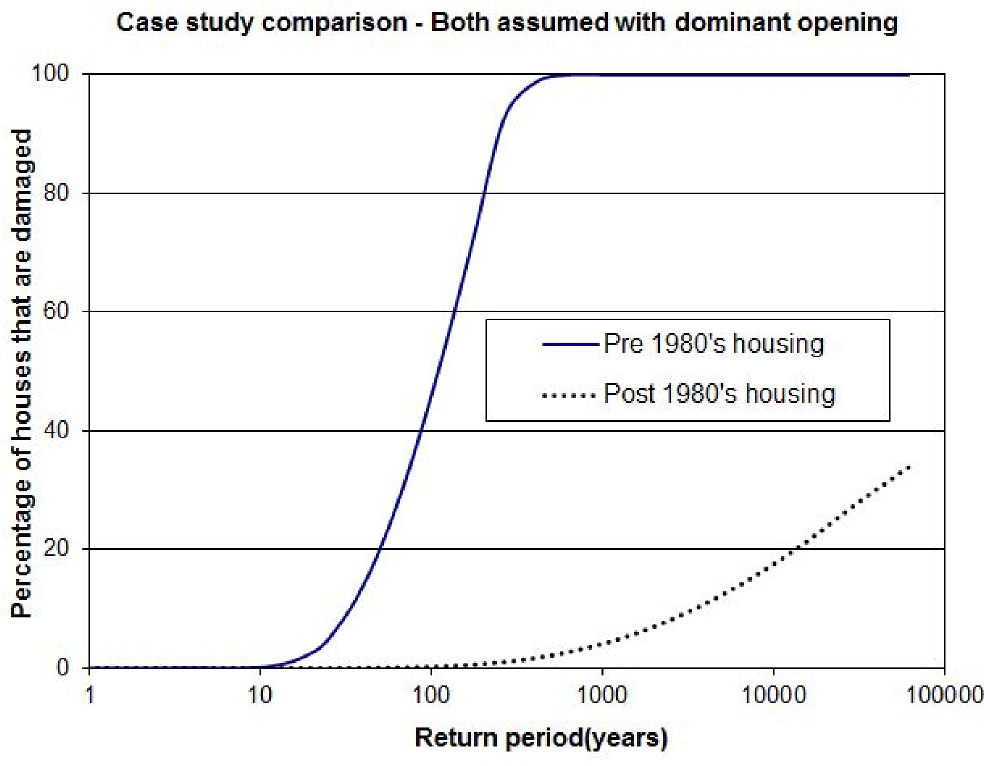

FIGURE 6. VULNERABILITY CURVES FOR PRE-1980S AND POST-1980S RESIDENTIAL STRUCTURES WITH INCREASING RETURN PERIOD [18]

POST-EVENT DAMAGE OBSERVATIONS

Following Cyclone Yasi in 2011, Boughton et al [6] showed that homes correctly designed and constructed to the Australian building standards introduced in the 1980s generally performed well under wind load actions. Damage survey results indicated that in the most highly affected areas, ~3% of post-1980s homes experienced significant roof damage, in contrast to ~15% for pre-1980s homes. Greater than 20% of the pre-1980s housing experienced significant roof loss in some areas. The relatively low incidence of roofing damage to post-1980s buildings indicates that modern building practices deliver better performance for the roofing structure in severe wind event conditions.

A damage survey following Cyclone Larry [7] showed that although wind-induced structural damage was minimal for 95% of contemporary housing, these houses experienced water ingress damage from wind-driven rain. A survey conducted by Melita [10], details building envelope failures during Cyclone Larry. Approximately 75% of post-1985 homes experienced water ingress through breaches in the building envelope (i.e. broken windows, punctured cladding, failed fascia or guttering, etc.). In many cases replacement of internal components and owner contents were required.

These observations are similar to those of other other post-event damage assessments in Australia (e.g. Cyclone Winifred [11], Cyclone Vance [12], Cyclone Ingrid [8], and Cyclone George [5]). Consistent findings include:

- 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 (i.e. screwed fixing as opposed to nailed) 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 for 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 damages were observed for structures with and without apparent exterior building 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) [18]. 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 progression to other buildings, thus failing to meet specific objectives and performance requirements of the NCC.

PROJECT ACTIVITIES

PROJECT RECRUITMENT

Daniel Smith, Post-doc Researcher

Following a lengthy recruitment process, Dr. Daniel Smith was appointed as the Post-doc with the project in August 2014. Daniel brings experience from research on cyclone-resistant construction at the University of Florida (USA). He studied the wind-resistance of roofing tile systems as part of his PhD research.

Korah Paracka l, BE (UQ)

Korah commenced his PhD in March 2015. The topic of his study is “An Analytical Technique for Determining the Redistribution of Structural Load Effects with Increasing Wind Loads”. He is studying structural response of connections to wind loads and the progressive failures in light framed structures (i.e. houses). This will enable retrofitting guidelines for Pre-80s houses to be developed, reducing their vulnerability.

FIGURE 7. KORAH PARACKAL (LEFT), DAVID HENDERSON (CENTER), AND DANIEL SMITH (RIGHT) IN COOKTOWN FOR INSTRUMENTATION DEPLOYMENT BEFORE TROPICAL CYCLONE NATHAN (2015)

TROPICAL CYCLONE & THUNDERSTORM ANALYSIS

The 2014-15 year was very active from a severe wind event perspective, with five landfalling tropical cyclones in Australia and the pacific islands and several severe thunderstorm events. These events provide unique opportunities for the project to learn more about the vulnerabilities of residential construction. A key project objective is to increase cyclone mitigation and preparedness through education. This year the project team had a very active role in informing the public about these events through technical reports, magazine articles, and more than 50 television, newspaper, and radio interview appearances. Two examples are as follows:

http://www.brisbanetimes.com.au/queensland/cyclone-marcia-damage-to-newer-homes-a-concern-20150301-13s1ei.html

http://www.townsvillebulletin.com.au/news/jcu-report-shows-marcia-less-powerful-than-thought/story-fnjfzs4b-1227243812301

Brisbane Thunderstorms

Between 2 and 6pm the on the 27th of October 2014 severe thunderstorm activity was observed in the South-East Queensland region. Two adjoining storm cells moving in a northerly direction subjected the Brisbane CBD and neighbouring suburbs to severe hail, damaging winds and localized flooding. Field surveys were conducted with BNHCRC support on the 1st and 5th of December by five CTS staff members to assess structural damage and to compare overall impacts of the storm to the media reported outlook. A full length report on the event can be found at the following link:

https://www.jcu.edu.au/cts/publications/content/technical-reports/tech-report-tr60/view

Tropical Cyclone Nathan

In March 2015 a CTS team travelled to Cooktown prior to landfall of TC Nathan to deploy the SWIRLnet anemometer network. All six anemometers satisfactorily recorded wind speed and pressure data and transferred summary files to the researchers via remote internet connection every 10 minutes. A damage assessment was conducted following the event. Damage was minimal in Cooktown considering the centre of the storm crossed the coast north of this area. The event produced strong enough winds to enable assessment of the turbulent (wind gusts) at single storey house height in and around the community. This data will be used to inform vulnerability modelling at later stages in the project. An initial summary report of the event, including preliminary SWIRLnet data, was distributed to the public and research communities within 24 hrs of landfall via contributions from the recently formulated International Wind Hazard Damage Assessment Group which consists of research personnel and students from James Cook University and the University of Florida (USA). This report can be found at the following link:

https://www.jcu.edu.au/cts/publications/content/cyclone-nathan-rapid-damage-assessment-report/view

Tropical Cyclone Marcia

Supported by the BNHCRC, the CTS spent five days in Rockhampton and Yeppoon after landfall of TC Marcia (February 20th 2015) to conduct damage assessment surveys. An initial summary report of the event (sourced from media content) was distributed to the public and research communities within 24 hrs of landfall (prior to CTS damage assessment) via the International Wind Hazard Damage Assessment Group. Direct wind speed data for the affected area were limited to one anemometer in Yeppoon and one anemometer in Rockhampton. However, indirect wind speed indication data (i.e. fallen trees, street signage failures, etc.) were also recorded and were analysed to determine wind speed estimates as a supplement to anemometer data. There was significant damage to older housing even though the wind speeds in urban areas were significantly less than design loads. To help inform public perception, recovery efforts, and engineering analysis the CTS team released a summary of wind field observations and published an article in the technical magazine for Engineers Australia following the event. An article was also published in the AIBS magazine to inform members on building failure issues. The data collected will add to the vulnerability modelling of houses for this project. All four publications on TC Marcia can be found at the following links:

https://www.jcu.edu.au/cts/publications/content/TCMarciaRapidAssessmentReport20_02_2015.pdf/view

https://www.jcu.edu.au/cts/publications/content/overview-of-cyclone-marcia-wind-speeds

https://www.jcu.edu.au/cts/publications/content/cyclone-marcia-article-in-engineers-australia/view

https://www.jcu.edu.au/cts/publications/content/weathering-the-storm/view

Tropical Cyclone Olwyn

Following landfall of TC Olwyn on the Western coast of Australia in March 2015, a CTS team travelled to Exmouth in Western Australia and the surrounding areas to conduct a damage assessment. An initial summary report of the event (sourced from media content) was distributed to the public and research communities within 24 hrs of landfall (prior to CTS damage assessment) via the International Wind Hazard Damage Assessment Group. A formal report on the investigation is soon to be released. The preliminary report can be found at the following link:

https://www.jcu.edu.au/cts/publications/content/cyclone-olwyn-rapid-damage-assessment-report/view

CONFERENCE PAPERS AND PRESENTATIONS

Australasian Fire & Emergency Services Authorities Council (AFAC, 2014)

Daniel Smith and David Henderson attended the AFAC conference in New Zealand where the project paper and a poster were presented. Meetings were held aside from the conference with all other project leaders within the cluster to discuss autonomy within the cluster, cohesiveness in reporting, end-user engagement, etc. While in New Zealand, the CTS team travelled to the BRANZ laboratory in Porirua to discuss overlapping research interests and potential collaboration on the BNHCRC project.

Australasian Wind Engineering Society Workshop (AWES, 2015)

A paper on the BNHCRC project was presented by Martin Wehner (Geoscience Australia) and included in the proceedings publication at the 17th AWES workshop in New Zealand.

International Conference on Wind Engineering (ICWE, 2015)

A paper on the BNHCRC project was accepted for oral presentation and conference proceedings publication. A paper on the wind resistance of roofing tile systems was also presented. This conference provided the opportunity to present the BNHCRC project among international leaders in wind-resistant construction. The CTS received feedback on methods and findings thus far and established additional collaboration opportunities for the vulnerability modelling aspects of the project. Specifically, the CTS gained additional expertise on techniques for computational modelling of housing stock vulnerabilities to wind from experts in this field. This information will be used by the CTS and Geoscience Australia to expand the existing VAWS software, which currently has limited utility in numerical modelling of housing vulnerabilities. The modelling results will be used in cost/benefit analysis of retrofit construction solutions developed from this project. Utilizing a methodology that is vetted by the leaders in this field ensures project findings are a reliable basis for government initiatives, insurance incentives, etc.

STAKEHOLDER ENGAGEMENT

Queensland Building and Construction Commission

The CTS hosted the Queensland Building & Construction Commission (QBCC) Board in Townsville in July 2015. The QBCCC has been auditing construction and certification of houses in North Queensland, to ascertain the level of compliance with codes and regulations. David Henderson gave a presentation on the Scope and Progress of this project noting aspects of interest to QBCC.

Queensland tropical cyclone consultative committee (QTCCC)

CTS gave a presentation to the Queensland tropical cyclone consultative committee (QTCCC) meeting in Cairns in May 2015. The committee is joint chaired by the head of the Qld BoM and QFES. Its role is to provide information and respond to issues from across the local, state and federal levels in relation to cyclone awareness, preparation, planning, response and recovery. David Henderson presented findings from the CTS work following TCs Marcia, Nathan and Olwyn along with our anemometer program. The committee found it informative as to the level of damage to older housing from inadequate roof upgrades, and were informed of this project to investigate mitigation measures.

Northern Australia Insurance Premiums Taskforce

A panel from the Northern Australia Insurance Premiums Taskforce visited the CTS on 2 June. The CTS was able to present information on damage and loss to housing in cyclonic and thunderstorm regions. Although this project is in the early stages, we were able to discuss drivers of loss, and potential mitigation measures to improve resilience of already constructed housing (as opposed to building code changes for new housing). The Taskforce was very interested in the benefits of the various proposed mitigation measures to reduce risk.

AS 2050 Committee Meetings

Daniel Smith is now on the Standards Australia BD-008 Roof Tile Committee. The committee met in February to discuss revisions to AS2050 (e.g., sarking requirements, updates to match AS 4055, consistency of wording, etc.) and AS4046.8. Daniel proposed changes to wind load testing and design considerations for tiles, which the committee agreed to discuss in further detail at a later date. These changes may significantly reduce the vulnerability of roofing tile systems in contemporary construction.

AS/NZS 1170.2 Committee Meetings

John Ginger is in the BD 6/2 committee responsible for recent revisions related in the wind loading standard AS/NZS1170.2

AS 4055 Committee Meetings

David Henderson is in the BD99 committee responsible for recent revisions related in the wind loading for housing standard. David reported to members on the issues of damage to housing and critical connections from the recent damage surveys.

BNHCRC COLLABORATIVE MEETINGS

BNHCRC RAF - Melbourne (2014 December)

Daniel Smith, David Henderson, and John Ginger (project leader) attended the meeting at RMIT in December 2014. In addition to presenting a project update and discussing overlap with other projects in the cluster, project team members discussed methods to select house types for which the project would assess the benefit of mitigation against severe wind. As a first step, the project team resolved that the building schemas for Queensland, Western Australia / South Australia and South-east Australia be examined to determine dominant housing types.

BNHCRC RAF - Sydney (2015 April)

Daniel Smith attended the meeting in April 2015 and presented a project update to the cluster and lead end user.

ADDITIONAL RESEARCH ACTIVITIES

Roofing Tile Research and Student Thesis Support

The Roofing Tile Association of Australia (RTAA) has supported research to improve the wind resistance of roofing tile systems. Removal of roofing tiles has been observed frequently during post-storm damage investigations in Australia in both new and older construction. In order to improve the wind resistance of roofing tiles and inform vulnerability modeling for this project, the wind loading mechanism on tiles must be understood. Two undergraduate engineering students at James Cook University were selected to conduct the research on roofing tiles at the CTS as their fourth year thesis project (Figure 8).

The design of roofing tile systems in Australia is governed by AS 2049 and AS 2050 in tandem with the wind load provisions of AS/NZS 1170.2 (or AS 4055). The design provisions are prescriptive, mandating the number of tiles that must be fastened based on the wind classification for the building, without consideration of variations in tile profile, attachment method, roof pitch, etc. The tile fastening designations for each wind speed category of AS 2050 are based on wind-induced roof pressures from AS/NZS 1170.2 and a porosity factor reduction (0.7-0.9) to account for pressure equalization between the upper and lower tile surfaces.

The roof pressures in AS/NZS 1170.2 are based on generic wind tunnel tests that did not incorporate wind loading effects on roofing tiles. In addition, the porosity factor reduction is based experimental testing using a scaled prismatic building model with a flat roof in a wind tunnel. This study has limited applicability to moderate-slope domestic tile roof coverings. Current experimental techniques allow examination of pitched roofing effects, near-roof surface flow, and different profiles, none of which were part of the original study. Objectives of the research are as follows:

- Measure surface pressures at high-resolution on upper and lower surfaces of several typical Australian tile systems

- Determine porosity factors and lift coefficients for tiles using measured surface pressures
- Establish direct relationship between design wind speed and expected wind load for tiles
- Determine the wind load capacity of a range of tile profiles and fixing methods via mechanical uplift testing

FIGURE 8. UNDERGRADUATE STUDENTS AT JAMES COOK UNIVERSITY CONTRIBUTE TO THE PROJECT BY CONDUCTING WIND LOAD CHARACTERIZATION TESTING FOR ROOFING TILES IN THE CTS WIND TUNNEL AS PART OF A FOURTH YEAR THESIS PROJECT

HB132 Survey

There are existing guidelines for upgrading of older houses in the form of handbooks (HB132) published by Standards Australia in 1999 [15-16]. However, the success of these handbooks has not been effective in light of recurring severe wind damage to older structures. These details and methods were reviewed to consider reasons for lack of use. To further investigate, an online survey was distributed nationally to members of Building Codes Queensland (BCQ), Housing Industry Association (HIA), Master Builders Association (MBA), Australian Institute of Building Surveyors (AIBS), BNHCRC, and AFAC. Objectives of the survey were to estimate the extent of HB132 usage and determine what other references/practices (if any) are used in retrofit construction.

The survey was distributed via email and social media to the members of each participating organization. A total of 245 survey responses were returned. Participants were not required to answer all questions. The occupations of 221 participants were certifiers (65%), regulators (24%), and builders (10%). Other occupations included engineers (5%), architects (3%), homeowners (3%), and roofing contractors (<1%). Additional responses were collected from building inspectors, designers, and surveyors.

The state/territory in which participants performed their occupation was recorded for 244 participants. The majority of responses were from Queensland (38%) and New South Wales (20%). A significant number of responses were also recorded for Victoria (14%), Western Australia (11%), and South Australia (10%). Responses from Tasmania, Australian Capital Territory, and Northern Territory were approximately 3% each.

Participants were asked to provide their formatting preference for occupational reference literature. More than 62% of participants prefer access to both hardcopy and electronic versions of reference materials, 28% prefer electronic only, and 10% prefer hardcopy only. Based on these results, an effective guide for construction retrofit techniques should be developed with strong consideration of both electronic and hardcopy distribution.

AS 1684 Residential Timber Framed Construction [4] is a four-part Australian Standard covering design criteria, building practices, tie-downs, bracing and span tables for timber framing members. It is a critical reference publication for housing design throughout Australia for new construction projects. Although the standard does not address retrofit construction practices, the survey results indicate it is used for reference during structural upgrading of existing timber framed residential structures. In order to determine the extent to which this occurs, participants were asked if AS 1684 is referenced during alteration or re-roofing of timber framed structures. Of the 240 responses recorded for this question, over 84% claimed to use AS 1684 (Figure 9). In contrast, when participants were asked whether or not they were familiar with HB132, 91% responded they were not. Therefore, nearly all of the Australian residential construction industry is utilizing a reference document that is not applicable for retrofitting and furthermore are unaware that a document for retrofitting does exist.

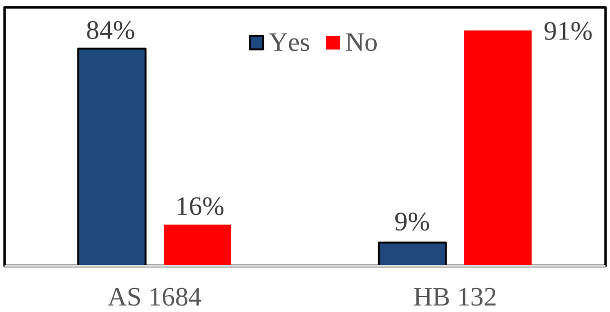

FIGURE 9. PROPORTIONS OF BUILDING INDUSTRY PERSONNEL THAT REFERENCE (“YES”) OR DO NOT REFERENCE (“NO”) AS 1684 RESIDENTIAL TIMBER FRAMED CONSTRUCTION (AUSTRALIAN STANDARD FOR NEW CONSTRUCTION) AND HB 132 STRUCTURAL UPGRADING OF OLDER HOUSES (NON-MANDATORY REFERENCE GUIDELINES FOR UPGRADING EXISTING STRUCTURES).

If participants indicated they were familiar with HB132, they were asked to comment on utility of the document. Of the 22 responding participants, 27% found HB132 “very useful”, 36% found it “somewhat useful but could be improved”, and 36% found it “not useful at all”. When asked why they found HB132 useful or not, typical responses included “details are not architecturally acceptable to clients” and “the cost of each part of HB132 is $70, as it is only an advisory document, this is a disincentive for its use”.

Participants were asked to identify what improvements could be made to HB132. A total of 19 responses were recorded. Most indicated that the cost of access to HB132 is too expensive. Furthermore, because HB132 is a handbook as opposed to a statutory document, there is reduced motivation for purchasing it. One response suggested moving the retrofit details "into AS1684 so more people know about them".

The survey results suggest that in order to enhance reference literature for structural upgrading of existing Australian housing, future development of retrofitting guidelines must consider cost, enforcement, literature format, and architectural acceptability of structural details.

Canberra and Geoscience Surveys

Over the week of November 24-28 2014, Daniel Smith and Martin Wehner (GA) surveyed ten homes in the Canberra area for building attributes. Information collected included roofing type, construction type, roof structure dimensions (i.e. rafter spacing, sizing, etc.), in addition to other characteristics deemed critical to the wind resistance of residential structures. The majority of the homes were legacy (pre-1980s), providing the opportunity to record arange of irregular building characteristics and dimensions for homes built prior to current building standards. This information will be used in conjunction with previous CTS surveys to determine representative housing types for retrofit solution case studies. A preliminary analysis of the results are provided in Table 1.

TABLE 1. PROPORTIONS OF HOUSING WITH BUILDING ATTRIBUTES FOR 125 DATA POINTS RECORDED IN CANBERRA VIA FIELD AND ONLINE SURVEYING

Age	Roof Material	Wall Material				
		Brick Veneer	Reinf'd Masonry	Cavity Double Brick	Timber or Metal Clad	Fibre Cement Clad
1996 to now	Sheet Metal	3.25	0.00	0.00	1.63	0.00
	Tile	**14.63**	0.00	0.00	0.81	0.81
1980 to 1995	Sheet Metal	3.25	0.00	0.81	1.63	0.00
	Tile and Slate	**18.70**	0.00	0.00	0.81	0.00
1960 to 1979	Sheet Metal	2.44	0.00	0.81	2.44	0.00
	Tile and Slate	**35.77**	0.00	3.25	1.63	0.00
	Fibre Cement	0.00	0.00	0.00	0.81	0.00
1914 to 1959	Sheet Metal	0.00		0.00	2.44	0.90
	Tile and Slate	0.00		2.44	0.00	0.00
	Fibre Cement	0.00		0.00	0.00	0.00

Insurance Claims Analysis

A direct relationship between observed damage modes and societal cost is needed to inform cost-benefit analysis of retrofit mitigation solutions. In a research effort supported by Suncorp Group Limited, policy data from one insurer in the North Queensland region of Australia during Cyclone Yasi (2011) were analyzed to identify correlations between claim value, typical damage modes, and construction age. This was achieved by extracting qualitative and quantitative insights from aggregated insurance policy data from one insurer at the time of the event. The aggregated data included information on policies both with and without a claim for Cyclone Yasi. A more detailed analysis that addresses detailed topographic effects (i.e. localized wind conditions, etc) at policy level will be completed as the next step. The regional analysis, including a wind map for the most severely affected area, is included in Figure 10.

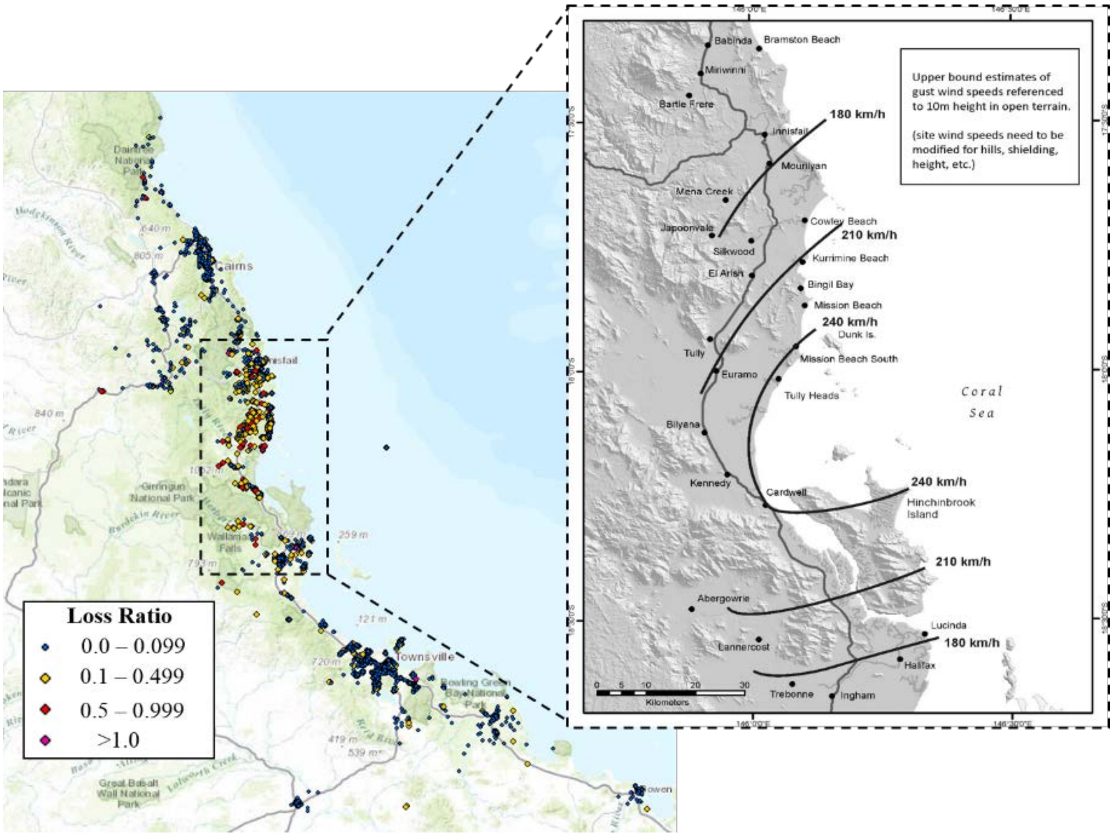

FIGURE 10. NORTH QUEENSLAND COASTAL REGION IMPACTED BY CYCLONE YASI (2011) WITH DISTRIBUTION OF CLAIMS SUBDIVIDED BY FOUR LOSS RATIO BINS (CLAIM VALUE/INSURED VALUE) AND WIND FIELD ESTIMATION [6] (SMITH ET AL. 2015 "INSURANCE LOSS DRIVERS AND MITIGATION FOR AUSTRALIAN HOUSING IN SEVERE WIND EVENTS")

To isolate a relatively high population of housing subjected to a similar wind field characteristics (i.e. velocity, direction, and duration) and rainfall intensity, preliminary analysis focused on the Townsville region. Peak 3-second gust wind speed measured at the Townsville airport weather station (10 m) was 135 km/h during Cyclone Yasi.

A conference paper was presented on this work (Smith et al 2015 - "Insurance loss drivers and mitigation for Australian housing in severe wind events") and the CTS has also had conversations with insurers for access to data from severe storm damage in non-cyclonic area to investigate loss drivers etc.

PUBLICATIONS

Smith, D.J., Masters, F. J., and Gurley, K. R., 2014 "An Historical Perspective on the Wind Resistance of Clay and Concrete Roofing Tiles" RCI Interface Vol. 32, No. 10

Smith, D.J., Henderson D.J., and Ginger, J.D. 2015 "Improving the Wind Resistance of Australian Legacy Housing". 17th Australasian Wind Engineering Society Workshop Proceedings, Wellington, New Zealand, 12-13 February, 2015

Smith, D.J., Henderson, D., and Ginger, J. 2015. "Insurance loss drivers and mitigation for Australian housing in severe wind events". 14th International Conference on Wind Engineering Proceedings, Porto Alegre, Brazil, June 21-26, 2015

Smith, D.J., Masters, F. J. 2015. "A study of wind load interaction for roofing field tiles". 14th International Conference on Wind Engineering Proceedings, Porto Alegre, Brazil, June 21-26, 2015

K. Parackal, M. Mason, D. Henderson, G. Stark, J. Ginger, L. Somerville, B. Harper, D. Smith, M. Humphreys 2015. "Investigation of Damage: Brisbane, 27 November 2014 Severe Storm Event". Cyclone Testing Station, Technical Report No. 60. ISBN 978-0-9941500-8-0

Smith, D.J., Henderson, D., Humphreys, M., Parackal, K., Mason, M., Prevatt, D.O., Roueche, D.R. 2015. "Tropical Cyclone Marcia, Queensland Australia". Cyclone Testing Station, Rapid Damage Assessment Report, February 20th

Smith, D.J., Henderson, D., Parackal, K., Mason, M., Prevatt, D.O., Roueche, D.R., Thompson, A. 2015. "Tropical Cyclone Nathan, Far North QLD, Australia". Cyclone Testing Station, Rapid Damage Assessment Report, March 20th

Smith, D.J., Boughton, G., Falck, D., Henderson, Prevatt, D.O., Roueche, D.R., 2015. "Tropical Cyclone Olwyn, WA, Australia". Cyclone Testing Station, Rapid Damage Assessment Report, March 11-14th

Henderson D.J., and Ginger, J.D. 2014 "Improving the resilience of existing housing to severe wind events". Australasian Fire and Emergency Services Authorities Council Conference Proceedings, Wellington, New Zealand, 2-5 September, 2014

Mason, M., Smith, D.J., Henderson, D.J., 2015. "Interference of surface wind speeds during Tropical Cyclone Marcia based on damage observations". Australian Meteorological and Oceanographic Society National Conference Proceedings, Brisbane, Australia, 15-17 July (to be presented)

Smith, D.J., Henderson, D., and Ginger, J. 2015. "Vulnerability models for Australian Housing Wind Resistance". Second International Conference on Performance-based and Life-cycle Structural Engineering Proceedings, Brisbane, Australia, 9-11 December, 2015 (to be presented)

Smith, D.J., Henderson, D., and Ginger, J. 2015. "Performance-based design considerations for roofing tile systems in Australia". Second International Conference on Performance-based and Life-cycle Structural Engineering Proceedings, Brisbane, Australia, 9-11 December, 2015 (to be presented)

Smith, D.J., Thompson, A.P., Prevatt, D.O., Roueche, D.B., 2015. "A vulnerability assessment tool for residential structures in extreme wind events". Second International Conference on Performance-based and Life-cycle Structural Engineering Proceedings, Brisbane, Australia, 9-11 December, 2015 (to be presented)

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REFERENCES

[1] Walker, G. (1975). Report on Cyclone Tracy – Effect on buildings – Dec 1974. Australian Dept of Housing and Construction.
[2] Standards Australia (2011), AS/NZS 1170.2:2011 Structural design actions Part 2: Wind actions, Standards Australia, Sydney NSW, Australia.
[3] Standards Australia (2011), AS 4055 Wind Loads for Housing, Standards Australia, Sydney, NSW.
[4] Standards Australia (2010), AS 1684.3:2010 Residential timber-framed construction – Cyclonic areas, Standards Australia, Sydney, NSW, Australia.
[5] Boughton, G. & Falck, D. (2007) Tropical Cyclone George: Damage to buildings in the Port Hedland area. Cyclone Testing Station. Townsville, James Cook University.
[6] Boughton G., Henderson D., Ginger J., Holmes J., Walker G., Leitch C., Somerville L., Frye U., Jayasinghe N. and Kim P., (2011) Tropical Cyclone Yasi: Structural damage to buildings, Cyclone Testing Station, James Cook University, Report TR57. http://www.jcu.edu.au/cts/research_reports/index.htm
[7] Henderson, D., Ginger, J., Leitch, C., Boughton, G. and Falck, D. (2006) Tropical Cyclone Larry – Damage to buildings in the Innisfail area. Cyclone Testing Station. Townsville, James Cook University.
[8] Henderson, D. & Leitch, C. (2005) Damage investigation of buildings at Minjilang, Cape Don and Smith Point in NT following Cyclone Ingrid. Cyclone Testing Station, Townsville, James Cook University.
[9] Henderson, D.J., Leitch, C., Frye, U., Ginger, J.D., Kim, P., Jayasinghe, N.C., (2010). Investigation of Housing and Sheds in Procerpine, Midge point, and Airlie Beach, Following Tropical Cyclone Ului. Cyclone Testing Station, James Cook University, Townsville.TR 56.
[10] Melita, B. (2007) Performance of Housing Envelope in Tropical Cyclone Larry. School of Engineering. Townsville, James Cook University.
[11] Reardon, G., Walker, G. & Jancauskas, E. D. (1986) Effects of Cyclone Winifred on Buildings. CTS. Townsville, James Cook University.
[12] Reardon, G., Henderson, D., Ginger, J., (1999). A structural assessment of the effects of Cyclone Vance on houses in Exmouth WA Cyclone Testing Station. 1999, James Cook University, Townsville.TR48.
[13] Henderson, D. & Somerville, L. (2012) TIO Housing survey (Built 1975 to 1980). TS859, Cyclone Testing Station, Townsville, James Cook University.
[14] Henderson, D. and Harper, B. (2003). Climate Change and Tropical Cyclone Impact on Coastal Communities' Vulnerability. CTS Report TS582 for Dept Emergency Services and Dept Natural Resources and Mines, Queensland Government.
http://www.longpaddock.qld.gov.au/about/publications/vulnerabilitytocyclones/stage4.html
[15] Standards Australia (1999). HB 132.1:1999 Structural upgrading of older houses, Part 1: Non-cyclonic areas, Standards Australia, Sydney, NSW
[16] Standards Australia (1999) HB 132.2:1999 Structural upgrading of older houses - Part 2: Cyclone areas, Standards Australia, Sydney, NSW
[17] Edwards, M. and Wehner, M. (2014), Improving the Resilience of Existing Housing to Severe Wind Events - Preliminary Building Schema, BNHCRC progress report, GEOSCIENCE AUSTRALIA, ACT
[18] Australia Building Codes Board (2012). National Construction Code Series: Building Code of Australia, Class 2 to Class 9 Buildings. Volume One.
[19] King, D., J. Ginger, S. Williams, A. Cottrell, Y. Gurtner, C. Leitch, D. Henderson, N. Jayasinghe, P. Kim, K. Booth, C. Ewin, K. Innes, K. Jacobs, M. Jago-Bassingthwaighte and L. Jackson (2013). Planning, building and insuring: Adaptation of built environment to climate change induced increased intensity of natural hazards. Gold Coast, National Climate Change Adaptation Research Facility.