Improving the Resilience of Existing Housing to Severe Wind Events (Vulnerability Modeling)

To date and Work ahead

Daniel Smith, David Henderson, Korah Parackal, John Ginger
Cyclone Testing Station, James Cook University, Townsville, QLD

Martin Wehner, Hyeuk Ryu, Mark Edwards
GeoScience Australia, Canberra, ACT
**PROJECT OUTLINE**

- **Objective** - To develop cost-effective retrofitting details for mitigating structural damage to “pre-code” housing from severe windstorms across Australia.

- These strategies are to be (a) tailored to both aid policy formulation and decision making in government and industry, and (b) provide guidelines detailing various options and benefits to homeowners and the building community for retrofitting the large percentage of at risk houses in Australian communities.

- Project to support work across other BNHZ-CRC harden-up themes (flood and earthquake) on vulnerability, and resilience
National Construction Code of Australia: Structural objectives

- Safeguard people from injury caused by structural failure,
- Safeguard people from loss of amenity caused by structural behaviour,
- Protect other property from physical damage caused by structural failure, and
- Safeguard people from injury that may be caused by failure of, or impact with, glazing.
AS/NZS1170.2  Wind load standard

BCA: Class 2 Importance level

1:500 Annual probability of exceedance

or

10% in 50 yrs prob of exceedance
CONTEMPORARY STANDARDS (e.g. Post-80)

Australian Building Standards:
- AS1170.2 / AS4055
- AS1562.1
- AS1684

Great for new construction....
...doesn’t address older homes
Estimated wind speeds

- Max gust speed estimated at 245 km/h
  (Design wind speed houses 250 km/h)

- Max gust ~90% design speed
  Cardwell, Tully Heads, South Mission Beach

- Max gust ~80% design speed
  Tully, Kurrimine Beach

Communities in these areas subjected to Cat 3 to Cat 4 wind speeds (mainland)
Post-80s housing (current construction)
Pre-80s houses
Damage Data

Post 80s (current construction)
- <3% major roof damage
- ~30% all roller doors damaged
- But many houses had water ingress

Pre 80s (older housing)
- >12% major roof damage
- ~2% damaged by large debris
- May have hidden damage

Lower levels of damage of “newer” housing similar pattern in other surveys (e.g. Cyclone Winifred, Cyclone Vance, Cyclone Larry)

Lessons have been learnt since Cyclone Tracy!
Older housing - Traditional pitched roof framing

- Ridgeboard
- Rafter
- Ceiling Joist
- Batten

STRENGTH OF CONNECTIONS
House wind resistance models

<table>
<thead>
<tr>
<th>House Groups</th>
<th>Built during</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt; 1925</td>
</tr>
<tr>
<td>2</td>
<td>1925 – 1950</td>
</tr>
<tr>
<td>3</td>
<td>1951 – 1960</td>
</tr>
<tr>
<td>4</td>
<td>1961 – 1972</td>
</tr>
<tr>
<td>5</td>
<td>1973 – 1984</td>
</tr>
<tr>
<td>6</td>
<td>&gt; 1984</td>
</tr>
</tbody>
</table>

Failure Modes for each Group

<table>
<thead>
<tr>
<th>Failure Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
</tbody>
</table>

2 damage prob curves for each Mode 1 to 5

Cpi = 0.7

Cpi = 0.2
Estimated damage comparison (for cyclonic region)

- Failure of structural connections in older housing at wind speeds less than design
Improve structural performance of older houses
Improving future for Pre-80s housing

- General information on upgrading structural performance in existing houses can be found in Standards Australia Handbook HB 132.2 and Timber Qld builder notes.
Details from HB132.2

Overbatten: Either galvanised CHS, RHS or steel angle

Timber packer between sheeting and rafter - at each location where overbatten passes across rafter (or truss)

12 mm galvanised tie rods (Grade 4.6S) (Turnbuckles with capacity of not less than the tie rod may be used to take slack out of tie rod. Do not overtighten).

Tie rod

120 x 60 x 6 (min). plate

2 of 10 mm diameter Hilti HSA or similar masonry anchors with a safe load capacity not less than 6.05kN each

Min of 60 mm of 5 mm fillet weld evenly distributed to both sides of rod.

SECTION A-A

10 x into min. masc
Cladding connection improved during reroof but...

...moved failure to next link in chain – the batten / truss joint

IS HB132 EFFECTIVE?

HB132 Over-batten
Aged nail connection up to 50% less capacity
Modelling of structural system with focus on load sharing and damage progression based on validated FEA model
Claims Analysis Region

- **Townsville**
  - Claims: 7,273
  - Non-claims: 16,605
  - Claim rate: 30%

- **Tully/Mission Beach**
  - Claims: 2,699
  - Non-claims: 1,325
  - Claim rate: 67%

- **70% \( V_{des} \) (180 km/h)**
- **85% \( V_{des} \) (210 km/h)**
- **95% \( V_{des} \) (240 km/h)**

- **55% \( V_{des} \) (135 km/h)**

---

Loss Ratio
- 0-10%
- 10-50%
- 50-100%
- >100%
Townsville Region (55% $V_{des}$)

Construction Age

<table>
<thead>
<tr>
<th>Age Range</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982-2011</td>
<td>✝</td>
</tr>
<tr>
<td>1976-1981</td>
<td>✶</td>
</tr>
<tr>
<td>1960-1975</td>
<td>✟</td>
</tr>
<tr>
<td>1925-1959</td>
<td>✡</td>
</tr>
<tr>
<td>&lt;1925</td>
<td>⚫</td>
</tr>
</tbody>
</table>
Townsville Region (55% $V_{des}$)

**Loss Ratio**
- 0-10%
- 10-50%
- 50-100%
- >100%

- Low damage levels BUT high frequency
- Minor damages independent of age
- Moderate/severe damages ‘older’ areas
Low claim ratio <0.1 Townsville region
Loss of roof in Townsville
1. **CTS Database**
   - 40 yrs of housing surveys, damage assessments, etc.

2. **NEXIS Database (GA)**
   - Valuer-general, etc.
   - Includes TAS, NSW, ACT, WA data from various sources

3. **Field Surveys (non-cylonic)**
   - Compiled by CTS and GA
   - Detailed construction information for Adelaide and Canberra

4. **Aggregated Insurance Policy Data**
   - 54,000 policies in north Queensland
   - Proportion of building ages and roof type
Canberra
>50% Tile/Veneer
1140 data pts

WA (34%)
63% Tile/Cavity
861,000 data pts

SA (65%)
53% Tile/Cavity
30% Metal/Cavity
512,000 data pts

TAS (65%)
37% Metal/Timber
15% Tile/Veneer
203,000 data pts

Wagga Wagga (52%)
47% Metal/Veneer
23% Tile/Veneer
3,700 data pts

North QLD (50-60%)
>70% Metal
CTS Data

PRE-1980 SURVEY DATA

Canberra
>50% Tile/Veneer
1140 data pts
NON-CYCLONIC HOUSING MODELS

Roof Construction
- Pitched frame (22-25°)
- Collar ties every 2nd
- Weak batten/rafter conn.
- Unsecured tiles (ridge, etc.)
- Tile/metal

Wall Construction
- Minimal roof tie-down
- Raised timber floors
- Brick cavity or veneer

Four Housing Models
- Typical 1950-1970
- Southern AU
- Tile/metal
- Brick cavity/veneer
CYCLONIC HOUSING MODEL

Roof Construction
- Pitched frame (25°)
- Mixed hip/gable
- Corrugated iron (nails)
- Collar ties every 2nd

Wall Construction
- Timber frame
- Weatherboard or FC
- Cyclone rods @ 3 m

Queenslander (typical 1925-1959)
## RESILIENCE RATING SYSTEM

<table>
<thead>
<tr>
<th>COMPONENT/SYSTEM</th>
<th>Bronze</th>
<th>Silver</th>
<th>Gold</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ROOF</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Sarking installed for entire roof (if applicable)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>· Roof cladding attachment meets CTS standards</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Roof cladding condition meets CTS standards</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ATTIC VENTILATION</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Whirly birds are high-wind rated</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>APPURTENENCES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Fencing is structurally sound</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>· Shade sails, antennas, etc. wind rated? (or removable?)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Guttering is securely attached</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SHEDS (if applicable)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Shed is cyclone rated</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td><strong>OPENINGS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Impact-protected windows with an approved system</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Doors have appropriate locking mechanisms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Roller door installed post-2012 or has aftermarket bracing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ATTACHED STRUCTURES – PORCHES/CARPORTS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Roof connected to beam to resist uplift</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Beam connected to column to resist uplift</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Column anchored to structure to resist uplift</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>OPENINGS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Meet CTS standard pressure ratings</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><strong>CONTINUOUS LOAD PATH</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Roof-to-wall connection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Wall-to-floor connection (i.e. cyclone rods)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Floor-to-foundation connection</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

May include windows and sliding glass doors for water ingress

e.g. clips for all tiles (including ridge/hip lines) and cyclone washers for metal in addition to no corrosion of metal roofing and weathering of tile pointing
How do we get homeowners to invest in mitigation?

New Roof?

New Kitchen!
UNDERSTANDING BEHAVIOR CHANGE

- Mitigation capacity?
- Prior experience with events?
- Understanding of risk?
- Financial incentive?
- The “hassle factor”
- What is my neighbor doing?
PROPOSED NEXT STEPS

1. Review validity of current GA/CTS vulnerability modelling logic
2. Expand model to include new housing types
3. Develop input data for selected house types in both existing and retrofitted conditions
4. Develop proposed retrofit details
5. Costing of retrofit works on selected house types
6. Economic analysis of retrofit effectiveness
7. Reporting and dissemination