Improving the Resilience of Existing Housing to Severe Wind Events

AFAC / 2019

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Improving the Resilience of Existing Housing to Severe Wind Events

• Post windstorm Damage investigations following have shown that Australian houses built prior to the mid 1980s do not offer the same level of performance as houses constructed to contemporary building standards.

• The primary objective of this project is to develop cost-effective strategies for mitigating damage to housing from severe windstorms across Australia. These 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.
Pre-80s Houses

Post-80s Houses
Brisbane Thunderstorm 2008
Overall project method

1. Characterise housing stock into a limited number of generic house types
2. Develop retrofitting details together with installation costs and changes in capacity
3. Quantitatively estimate vulnerability both prior to retrofit and afterwards
4. Assess the cost-benefit of installing the retrofit through reductions in future loss afforded by the increased resilience

To achieve step 3 the project requires a way to quantitatively estimate vulnerability of houses to severe wind. To this end we have developed a software package (VAWS) as empirical models cannot account for the change in vulnerability afforded by retrofit.
The VAWS Software

- Set up individual house and wind simulation
- Apply wind pressures to building envelope
- Calculate loads at connections and check for failure
- Redistribute loads to other connections
- Run debris simulation and check for internal pressurisation
- Calculate water ingress and damage index
- Increase wind speed to next increment
- Set up new model

Vulnerability Curve (n = 100)
House Types to Study the Effectiveness of Retrofit

- 10 generic house types of simple geometry based on surveys from different parts of Australia, interviews and exposure databases

<table>
<thead>
<tr>
<th>Generic house type</th>
<th>Vintage</th>
<th>Wall construction</th>
<th>Roof material</th>
<th>Roof shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Legacy</td>
<td>Fibro (high set)</td>
<td>Metal sheeting</td>
<td>Gable, low pitch</td>
</tr>
<tr>
<td>2</td>
<td>Modern</td>
<td>Reinforced block</td>
<td>Metal sheeting</td>
<td>Gable, medium pitch</td>
</tr>
<tr>
<td>3</td>
<td>Legacy</td>
<td>Double brick</td>
<td>Metal sheeting</td>
<td>Gable, medium pitch</td>
</tr>
<tr>
<td>4</td>
<td>Legacy</td>
<td>Double brick</td>
<td>Tile</td>
<td>Gable, medium pitch</td>
</tr>
<tr>
<td>5</td>
<td>Legacy</td>
<td>Double brick</td>
<td>Metal sheeting</td>
<td>Hip, medium pitch</td>
</tr>
<tr>
<td>6</td>
<td>Legacy</td>
<td>Double brick</td>
<td>Tile</td>
<td>Hip, medium pitch</td>
</tr>
<tr>
<td>7</td>
<td>Legacy</td>
<td>Brick veneer</td>
<td>Metal sheeting</td>
<td>Gable, medium pitch</td>
</tr>
<tr>
<td>8</td>
<td>Legacy</td>
<td>Brick veneer</td>
<td>Tile</td>
<td>Gable, medium pitch</td>
</tr>
<tr>
<td>9</td>
<td>Legacy</td>
<td>Brick veneer</td>
<td>Metal sheeting</td>
<td>Hip, medium pitch</td>
</tr>
<tr>
<td>10</td>
<td>Legacy</td>
<td>Brick veneer</td>
<td>Tile</td>
<td>Hip, medium pitch</td>
</tr>
</tbody>
</table>
Case Study – The Group 4 House
Case Study – The Group 4 House

Failure when the load > strength: Failure Modes – Roof cladding: Batten-Rafter: Rafter-top plate:

Progression of failure – Load redistribution

<table>
<thead>
<tr>
<th>Connection Type</th>
<th>Mean Strength (kN)</th>
<th>CoV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheeting (For approx. 4 fasteners)</td>
<td>2.7</td>
<td>0.1</td>
</tr>
<tr>
<td>Batten to Rafter</td>
<td>1.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Rafter to Top Plate</td>
<td>5</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Loads, Resistance & Probability of Failure

\[ p_f = \int_{-\infty}^{\infty} F_R(W) f_W(W) dW \]

\[ F_R(W) = \int_{-\infty}^{W} f_R(R) dR \]
Connection Strengths

Connection Type Strengths

Connection Strength (kN)
Wind Tunnel Model Tests

Tests in Wind Tunnel at the Cyclone Testing Station, James Cook University. On representative houses at a length scale ($L_r$) of 1/50

$$X_i = \left( \sum_{j=1}^{N} \beta_j A_j p_j \right) = \left( \sum_{j=1}^{N} \beta_j P_j \right)$$
Single Realisation: Wind Pressures
Program Logic

1. Set up individual house and wind simulation
2. Apply wind pressures to building envelope
3. Calculate loads at connections and check for failure
4. Redistribute loads to other connections
5. Run debris simulation and check for internal pressurisation
6. Calculate water ingress and damage index
7. Increase wind speed to next increment
8. Save results
9. Set up new model
Single Realisation:

‘Heatmaps’ of Connection Failures

Wind Direction

Cladding Failures

Batten to Rafter Connection Failures

Roof to Wall Connections Failures

Heatmap of failure wind speed for sheathing of model 1
Single Realisation: Vulnerability Curve, SW Wind Direction

- Debris Impact on
- Window/door blow in
- Damage index of roof only
100 Realisations – SW Wind Direction
Participation 30+ from both Australia and New Zealand:-

- Insurers
- Brokers
- CatLoss modellers
- Engineering consultants
- Building industry organisations
- Government science agencies
- State government
- Academic researchers
- BNHCRC
Stakeholder Meeting – Sydney

Overall

• Value of the software as a research tool endorsed.
• Necessity and usefulness of the information produced validated.
• Future development to produce information in forms useable to wider group.

Specifically:-

• Range of software refinements proposed.
• Need for more user friendlier version with improved graphics.
• Recommendation for further effort to calibrate and validate the tool against actual damage.
• Request to include tiled roof cladding.
• Functionality to examine the effects of water ingress and debris damage independently.
• Expansion of the building types beyond non-residential
Next Steps

• Including structural system and capacity and wind loading data for all 10 generic house types and validating VAWS.

• Producing practical retrofit options and analysing using VAWS – including for Cost Benefit including broader metrics than avoided damage. Comparison with actual retrofit costs from Qld Government Household Resilience Program for validation.

• Presenting outcomes at the next Stakeholder Workshop in late 2019 / early 2020. This workshop is planned for presenting intermediate results for gaining feedback from Stakeholders (building, regulatory, insurance industries).

• Disseminating project outcomes.
Thank You