Improving the Resilience of Existing Housing to Severe Wind Events

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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.
Cyclone Tracy - 1974

Cyclone Yasi - 2011
Brisbane Thunderstorm -2008

Cyclone Vance Exmouth WA -1999
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>
Wind Loads on Houses

\[ p, f = (0.5 \rho_{air}) \left( V_{des, \theta} \right)^2 C_{fig} C_{dyn} \]

- Structural response - Probability of failure
External Pressures on a Roof
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

\[
X = \left( \sum_{j=1}^{N} \beta_j A_j p_j \right) = \left( \sum_{j=1}^{N} \beta_j P_j \right) C_{pk}
\]
Loads, Resistance & Probability of failure

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

\[ F_R(W) = \int_{-\infty}^{W} f_R(R)dR \]
Case Study – The Group 4 House
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>Strength mean (kN)</th>
<th>CoV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet (For approx. 4 fasteners)</td>
<td>2.7</td>
<td>0.1</td>
</tr>
<tr>
<td>Batten to Rafter Connection</td>
<td>1.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Rafter to Top Plate Connection</td>
<td>5</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Connection Strengths

Connection Type Strengths

Connection Strength (kN)

- batten
- batteneave
- battenend
- collaraftercollar
- collarafterridge
- larrafterplate
- endafterridge
- endafterplate
- plainafterridge
- airafterplate
- sheeting
- sheetingcorner
- sheetingave
- sheetingable
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
Single Realisation:

‘Heatmaps’ of Connection Failures

Wind Direction

Cladding Failures

Batten to Rafter Connection Failures

Roof to Wall Connections Failures
Single Realisation: Vulnerability Curve, SW Wind Direction

- Debris Impact on
- Window/door blow in
- Damage index of roof only
100 Realisations – SW Wind Direction

Vulnerability Curve (n = 100)

Gust Wind Speed [m/s]

Damage Index

Gust Wind Speed [m/s]
Stakeholder Meeting – Sydney
Next Steps

• Including structural system and capacity and Wind loading data for all house types and validating VAWS

• Producing practical retrofit options and analyzing using VAWS – including for Cost Benefit

• 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)

• Investigating future opportunities