Knowing maintenance vulnerabilities to enhance building resilience

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Griffith University, Australia

7th International Conference on Building Resilience: Using scientific knowledge to inform policy and practice in disaster risk reduction (ICBR2017)
Bangkok, Thailand, 27-29 November 2017
Resilient buildings: Informing maintenance for long-term sustainability

SBEnrc Project 1.53
Project participants

Chair: Graeme Newton

Research team

- Swinburne University of Technology
- Griffith University

Industry partners

- BGC Residential
- Queensland Dept. of Housing and Public Works
- Western Australia Government (various depts.)
- NSW Land and Housing Corporation
An overview

• Project 1.53 – Resilient Buildings is about what we can do to improve resilience of buildings under extreme events
• Extreme events are limited to high winds, flash floods and bushfires
• Buildings are limited to state-owned assets (residential and non-residential)
• Purpose of project: develop recommendations to assist the departments with policy formulation
• Research methods include:
  – Focused literature review and benchmarking studies
  – Brainstorming meetings and research workshops with research team & industry partners – e.g. to receive suggestions and feedbacks from what we have done so far
Australia – in general

- 6th largest country (7617930 Sq. KM)
  - 34218 KM coast line
  - 6 states
- Population: 25 million (approx.)
  - 6th highest per capita GDP
  - 2nd highest HCD index
  - 9th largest immigrant population
Natural Disasters - Diverse complexities & many uncertainties...
### Extreme events in Australia – E.g. Cyclones

<table>
<thead>
<tr>
<th>State</th>
<th>Event Name</th>
<th>Event Date</th>
<th>Estimated Loss Value (2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QLD, NSW</td>
<td>Cyclone Debbie</td>
<td>March 2017</td>
<td>$1,403,000,000*</td>
</tr>
<tr>
<td>NSW, QLD, VIC, TAS</td>
<td>East Coast Low</td>
<td>June 2016</td>
<td>$421,696,229</td>
</tr>
<tr>
<td>NSW</td>
<td>East Coast Low</td>
<td>April 2015</td>
<td>$949,615,700</td>
</tr>
<tr>
<td>QLD</td>
<td>Severe Tropical Cyclone Marcia</td>
<td>February 2015</td>
<td>$544,163,458</td>
</tr>
<tr>
<td>VIC</td>
<td>Melbourne Severe Storm</td>
<td>February 2011</td>
<td>$526,651,637</td>
</tr>
<tr>
<td>QLD</td>
<td>Cyclone Yasi</td>
<td>February 2011</td>
<td>$1,531,573,196</td>
</tr>
<tr>
<td>QLD</td>
<td>Cyclone Tasha</td>
<td>December 2010</td>
<td>$393,000,000</td>
</tr>
<tr>
<td>NSW</td>
<td>East Coast Low</td>
<td>June 2007</td>
<td>$1,675,000,000</td>
</tr>
<tr>
<td>QLD</td>
<td>Cyclone Larry</td>
<td>March 2006</td>
<td>$799,000,000</td>
</tr>
<tr>
<td>QLD</td>
<td>Cyclone Justin</td>
<td>March 1997</td>
<td>$650,000,000</td>
</tr>
<tr>
<td>NSW</td>
<td>Sydney Region Storms</td>
<td>January 1991</td>
<td>$625,000,000</td>
</tr>
<tr>
<td>WA</td>
<td>Cyclone Joan</td>
<td>December 1975</td>
<td>$398,000,000</td>
</tr>
<tr>
<td>NT</td>
<td>Cyclone Tracy</td>
<td>December 1974</td>
<td>$4,090,000,000</td>
</tr>
<tr>
<td>QLD</td>
<td>Cyclone Althea</td>
<td>December 1971</td>
<td>$648,000,000</td>
</tr>
<tr>
<td>QLD</td>
<td>Cyclone Ada</td>
<td>January 1970</td>
<td>$1,001,000,000</td>
</tr>
<tr>
<td>QLD</td>
<td>Cyclone Dinah</td>
<td>January 1967</td>
<td>$877,700,000</td>
</tr>
</tbody>
</table>

*Original estimated insurance loss value

Dynamic Information – e.g. Sentinel hotspots
Impacts of extreme events in Australia

32-year period from 1967 to 1999 as per BTE (2001)
A snapshot of losses by region in Australia

32-year period from 1967 to 1999 as per BTE (2001)

<table>
<thead>
<tr>
<th>Category of extreme event</th>
<th>New South Wales</th>
<th>Northern Territory</th>
<th>Queensland</th>
<th>South Australia</th>
<th>Victoria</th>
<th>Western Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood</td>
<td>26.2%</td>
<td>5.7%</td>
<td>46.7%</td>
<td>39.2%</td>
<td>41.1%</td>
<td>4.1%</td>
</tr>
<tr>
<td>Severe storm</td>
<td>40.5%</td>
<td>---</td>
<td>15.6%</td>
<td>35.1%</td>
<td>24.3%</td>
<td>17.7%</td>
</tr>
<tr>
<td>Tropical cyclone</td>
<td>---</td>
<td>94.1%</td>
<td>0.2%</td>
<td>---</td>
<td>---</td>
<td>66.4%</td>
</tr>
<tr>
<td>Earthquake</td>
<td>29%</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>4.7%</td>
</tr>
<tr>
<td>Bushfire</td>
<td>3.5%</td>
<td>---</td>
<td>37.6%</td>
<td>25.8%</td>
<td>34.6%</td>
<td>7.1%</td>
</tr>
</tbody>
</table>
Disaster Resilience in Australia

• Policy papers & frameworks by Australian Government
  – e.g. National Strategy for Disaster Resilience, National Disaster Resilience Framework

• Design standards for buildings subjected to extreme events of a specific hazard

ASCE SmartBrief newsletter (dated 15th September 2017): “Stronger building codes might improve building resilience and potentially limit damages from extreme events, e.g. hurricane Irma and severe storms”
Targeted project deliverables

Our current project P1.53 has following target & scope:
• Resilience for high winds (Griffith – Rodney lead);
• Resilience for flash floods (Swinburne - Palaneeswaran lead), and
• Resilience for bush fire (Swinburne - Lam lead)

Each sub-project produces linked reports related to the three core deliverables:

**Deliverable 1:** Current state of knowledge: existing preventative maintenance practice, failures due to lack of maintenance etc. for the relevant extreme event.

**Deliverable 2:** Identification of critical preventative maintenance issues for the relevant extreme event (including inventory of vulnerable building stock typologies).

**Deliverable 3:** Implementation strategies – regulatory and non-regulatory means (i.e. policy/practice recommendations for governments, building asset managers and owners, insurance institutions, etc.)
Wind-driven rain and public housing envelope (GU feed)

• Improving resilience of public housing to non-structural damage from wind-driven rain due to extreme weather events (i.e. cyclone and severe storms)

• Focus on resilient design and enhanced construction inspection; specifically waterproofing standards of the building envelope (AS4654), windows and doors (AS2047) and Masonry (AS4773)

• In-depth inspection for building envelopes in regions vulnerable to cyclones (checklists)
## Window and roof failure modes

<table>
<thead>
<tr>
<th>Building elements</th>
<th>Failure Modes</th>
<th>Damage through components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window</td>
<td>Material / design</td>
<td>through louvre windows</td>
</tr>
<tr>
<td></td>
<td></td>
<td>through undamaged windows</td>
</tr>
<tr>
<td></td>
<td></td>
<td>through open gaps between sashes, frames and through seals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>through worn or damaged window seals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>around flashings, through linings</td>
</tr>
<tr>
<td></td>
<td>Bad installation / material / design</td>
<td>through weep holes, gaps and around seals</td>
</tr>
<tr>
<td>Roof</td>
<td>Material / design</td>
<td>through the window frame</td>
</tr>
<tr>
<td></td>
<td></td>
<td>eaves, gutter, gables</td>
</tr>
<tr>
<td></td>
<td>Bad installation / material / design</td>
<td>under flashings, gutters, eaves lining</td>
</tr>
</tbody>
</table>
Hardening options – low hanging fruit

• Focused on recommending some hardening opportunities that represent the best life cycle cost-benefit (e.g. window/door specification and inspection) for low density public housing

• Estimate life cycle cost for scenario of reduced incidence of non-structural wind and water ingress related damage due to extreme wind events for both the recommended strategies and BAU approach

• Determine the life cycle cost-benefit of the proposed resilience hardening strategy for critical building components in regions vulnerable to extreme wind events

Biondini & Frangopol (2016) ASCE
Maintenance for Resilience

- Risk based approach
- Whole-life resilience
- Cost (or Value) vs Benefit
- PESTEL analysis
- Regulatory governance & non-regulatory best practices
- Benchmarks & measures
- Classification & Priorities
- Frameworks for Inspecting, Monitoring, Controlling, and Auditing
- Opportunities for Redesign, Repair & Retrofit for better...
Summary of Observations & Persuasion

• Extreme events (e.g. cyclones, bushfire, flash floods) cause considerable damage to buildings and incur enormous repair costs

• Non-structural failure of certain weak building elements (e.g. roof sheeting fixings) leads to costly damage (e.g. water ingress) – *prevention can be less costly than repair/mitigation in many cases*

• Existing building inspection & maintenance largely unregulated, and where undertaken has limited focus on resilience

• Building inspectors review public buildings on a predefined basis; however, consideration for extreme event vulnerability and resilience hardening is not adequately considered

• Opportunity to improve current regulatory and non-regulatory regime for resilience related maintenance (both residential and non-residential)
An overview of key gaps

- Limited risk consideration in regulation
- Emerging risks & ripple effects
- Regulatory difficulties in handling durability risks
- Understanding of the nature of extreme events
- Understanding the vulnerabilities of buildings
- Coordination between responsible bodies
- Lack of as-built information on buildings
Feasibilities include...

• On new buildings (best opportunity)
  – Need to think beyond what are required by current regulation
  – Design for maintenance: make provisions for maintenance, provide guidance for maintenance

• On existing buildings:
  – Early detection with regular inspection
  – Risk assessment for specific categories
  – Rethinking rules & rationalising priorities
  – Guidance for maintenance with as-built information
Questions, Discussions & Collaborations?

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