HAZARD **NOTE**

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TOPICS IN THIS EDITION | ENGINEERING | MITIGATION | CYCLONE | EARTHQUAKE | FLOOD

STRENGTHENING INFRASTRUCTURE FOR NATURAL HAZARD IMPACTS

ABOUT THESE PROJECTS

This is an overview of the *Hardening buildings and infrastructure* cluster of Bushfire and Natural Hazards CRC research projects. This cluster has five linked studies:

1. **Cost-effective mitigation strategy development for building-related earthquake risk –** Prof Michael Griffith, Prof Mark Jaksa, A/Prof Abdul Sheikh, Dr Mohamed Ali, Dr Togay Ozbakkaloglu, Dr Alex Ng, Dr Phillip Visintin, University of Adelaide; A/Prof Nelson Lam, A/Prof Helen Goldsworthy, University of Melbourne; Prof John Wilson, Prof Emad Gad, Dr Hing Tsang; Swinburne University; Mark Edwards, Dr Hyeuk Ryu, Martin Wehner, Geoscience Australia. Contact michael.griffith@adelaide.edu.au
2. **Cost-effective mitigation strategy development for flood prone buildings –** Dr Tariq Maqsood, Martin Wehner, Dr Ken Dale, Geoscience Australia. Contact tariq.maqsood @ga.gov.au
3. **Improving the resilience of existing housing to severe wind events –** Dr David Henderson, A/Prof John Ginger, Dr Daniel Smith, James Cook University; Martin Wehner, Dr Hyeuk Ryu, Mark Edwards, Geoscience Australia. Contact david.henderson @jcu.edu.au
4. **Enhancing the resilience of critical road infrastructure: bridges, culverts and floodways –** Prof Sujeeva Setunge, Prof Chun Qing Li, Prof Darryn McEvoy, A/Prof Kevin Zhang, Dr Jane Mullett, Dr Hessam Mohseni, RMIT University; Prof Priyan Mendis, Dr Tuan Ngo, Dr Nilupa Herath, University of Melbourne; Prof Karu Karunasena Dr Weena Lokuge, Dr Buddhi Wahalathantri; University of Southern Queensland; Prof Dilanthi Amaratunga, University of Huddersfield. Contact sujeeva.setunge @rmit.edu.au
5. **Natural hazard exposure information modelling framework –** Dr Krishna Nadimpalli, Geoscience Australia; Dr Itismita Mohanty, Dr Yogi Vidyattama, University of Canberra; Dr Mohsen Kalantari, Prof Abbas Rajabifard, University of Melbourne. Contact krishna.nadimpalli@ga.gov.au

CONTEXT

This cluster is assisting communities, builders, governments and emergency services make informed decisions about how they can mitigate the risk of building and road damage from natural hazards. Focusing on existing high risk components of the built environment, the research is investigating the vulnerability of buildings and key infrastructure across a range of natural hazards, including earthquake, flood, cyclone and bushfire. The overall aim is to provide cost-effective solutions that will reduce damage, injury, community disruption and the future cost of natural hazards, as well as how new construction can be more appropriate for mitigating risks.

COST-EFFECTIVE MITIGATION STRATEGY DEVELOPMENT FOR BUILDING-RELATED EARTHQUAKE RISK

BACKGROUND

The risk posed by earthquakes to buildings in Australian cities is significant, with the World Insurance Market rating a modest magnitude 6 earthquake in Sydney to be in their top 10 financial risks worldwide. This is because Australia did not design buildings for earthquake-induced forces until 1995, so a large portion of buildings are vulnerable.

Drawing upon and extending existing research and capability within both academia and government, this study is developing information that will inform policy, business and private individuals on their decisions concerning reducing building vulnerability. It will also draw upon New Zealand initiatives

Above: TECHNICIAN JOHN AYOUB WORKING AT THE EXPERIMENTAL SITE IN ADELAIDE. THIS RESEARCH IS HELPING TO STRENGTHEN THE CONSTRUCTION OF BUILDINGS.

that make use of local planning as an instrument for effecting mitigation.

RESEARCH ACTIVITY

This study is investigating the relative vulnerabilities to earthquake for the most common forms of building construction across the country, as well as learning from the Christchurch experience to find out what retrofitting techniques did and did not work. These Christchurch examples will be used as a starting point to develop economically feasible retrofitting options for Australian buildings. Proof of concept testing has been conducted on some of the most promising retrofit techniques.

Damage and economic loss models have been used to undertake a risk assessment case study of the Melbourne metropolitan area. Recommendations for retrofit guidelines and policy will be developed based on the evidence gathered.

While the overall focus of the project is on buildings, many of the outputs will also be relevant for other infrastructure such as bridges, roads and ports.

RESEARCH OUTCOMES

At the invitation of the South Australian Department of Planning, Transport and Infrastructure the team was provided access to test brick cavity walls and chimneys in four unreinforced masonry houses that have since been demolished as part of the South Australian Government's South Road Corridor project in Adelaide. Information collected from the testing will enable fragility curves to be developed for such buildings.

Studies on lightly reinforced concrete walls are also being conducted. Experimental works have been undertaken to assess the global out-of-plane buckling and the local buckling of vertical reinforcement failure mechanisms of reinforced concrete walls, and the general instability failures of lightly reinforced concrete walls. An analytical study is currently being undertaken to develop a model for the fragility of such walls.

Results from this project are being utilised by the *Decision support system for assessment of policy and planning investment* project, led by Prof Holger Maier, which will aid in the development of consistent national policies for the application of seismic design of new buildings and retrofit of existing buildings.

COST-EFFECTIVE MITIGATION STRATEGY DEVELOPMENT FOR FLOOD PRONE BUILDINGS

BACKGROUND

During the 2011 and 2013 Queensland floods, many buildings were damaged due to inappropriate development on floodplains and a legacy of high risk building stock in flood prone areas. While the vulnerability and associated flood risk is being reduced for newer construction by adopting new building standards, building controls and land use planning, existing buildings are still prone to flood damage. This project is targeted at assessing mitigation strategies to reduce the vulnerability of these existing residential buildings, and is developing the evidence base required to inform decision making on the mitigation of the flood risk posed by the most vulnerable houses. This evidence base will assist both government policy makers and property owners by providing information on the cost-effectiveness of mitigation strategies involving alterations to existing buildings.

Left: MANY OF OUR HOUSES ARE LOCATED IN FLOOD PRONE AREAS, AND THIS STUDY IS DEVELOPING MITIGATION STRATEGIES FOR DIFFERENT BUILDING TYPES. PHOTO: VICTORIA SES

RESEARCH ACTIVITY

Existing building schema have been assessed, both national and internationally. This led to the development of a new building classification schema to categorise residential buildings into a range of typical storey types. This is a fundamental shift from describing the complete building as an entity to one that focuses on sub-components. The proposed schema divides each building into the sub-elements of foundations, bottom floor, upper floors (if any) and roof to describe its vulnerability. This approach makes it possible to assess the vulnerability of structures with different usage and/or construction material used in different floors, and also to assess the vulnerability of tall structures with basements where only basements and/or bottom floors are expected to be inundated.

A further literature review investigated existing mitigation strategies, looking at evaluating strategies that will suit Australian building types and typical catchment behaviours. The mitigation options assessed were elevation, relocation, dry flood-proofing, wet flood-proofing and flood barriers. Costing of mitigation options for a number of building types have also been undertaken.

RESEARCH OUTCOMES

A flood-proofing matrix has been developed to assess appropriate strategies for the five selected building types. Elevation of a structure is one of the most common mitigation strategies, while relocation of a building is the most dependable. Unsurprisingly, relocation is generally the most expensive.

Dry flood-proofing consists of measures to seal the portion of a structure that is below the expected flood level to make it substantially impenetrable to floodwaters. Dry flood-proofing is generally not recommended in flood depths exceeding one metre, and may also be inappropriate for light timber frame structures, structures with raised timber floors and structures which are not in good condition that may not be able to withstand the forces exerted by floodwater.

Wet flood-proofing includes modifying the building by replacing existing building components with more water-resistant materials, adapting to the flood hazard by raising key services and utilities to a higher level and installing flood openings to equalise the pressure exerted by floodwaters on the interior and exterior of the building – reducing the chance of building failure.

Flood barriers can be permanent or temporary, and are built around a single building. Flood barriers may be inappropriate for structures with raised floors because of the high cost of barriers for height more than 1m.

All appropriate strategies have been costed for the selected building types through the engagement of quantity surveying specialists.

IMPROVING THE RESILIENCE OF EXISTING HOUSING TO SEVERE WIND EVENTS

▲ **Above:** THE TEAM ON DEPLOYMENT NEAR COOKTOWN IN QUEENSLAND TO ASSESS CYCLONE *NATHAN* IN 2015. PHOTO: DANIEL SMITH.

BACKGROUND

Typically, older Australian houses built prior to the mid 1980s do not offer the same level of performance and protection during severe wind as houses constructed to contemporary building standards. Given that these older houses will represent the bulk of the housing stock for many decades to come, 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.

This project is developing the evidence base for risk mitigation by devising simple practical and economic upgrading options for existing houses. The outcomes will promote retrofit investment by homeowners and provide a basis for incentives to encourage this action through insurance and government initiatives. The importance of homeowners incorporating mitigation measures to reduce risk has been highlighted with the release of the Northern Australia Insurance Premiums Taskforce's report in March 2016.

RESEARCH ACTIVITY

A number of cyclones and thunderstorms have been analysed, with the team conducting reports following cyclones *Nathan*, *Marcia* and *Olwyn* in 2015, as well as a severe thunderstorm in Brisbane in November 2014.

Storms outside of the tropics are also the focus of the study, with the team conducting surveys in Adelaide and Canberra. In Adelaide, 16 houses that were due to be demolished were surveyed and their connection details and structural systems recorded, providing valuable data. The performance of aged timber connections is not well understood, and examples were collected to be performance tested in the laboratory.

The geometry of houses in south east Australia is the least understood, and to address this the team undertook a desktop examination using aerial imagery and Google Street View of 467 houses in Canberra to determine the most common geometries from houses constructed in the 1960s. Houses that are obviously constructed at a later date or original houses that have undergone obvious alterations, such as extensions, were excluded.

The team has also collaborated with the insurance company Suncorp to analyse 25,000 insurance claims from cyclones *Larry* (2006) and *Yasi* (2011), with the purpose of gaining a better understanding of the drivers of cyclone damage.

RESEARCH OUTCOMES

For cyclones *Nathan*, *Marcia* and *Olwyn*, observed wind speed was lower than the speed housing is designed for in each area in most cases, but significant structural damage occurred from *Marcia* and the Brisbane thunderstorm. Hail damage was considerable in Brisbane, while water entry caused the most damage during *Olwyn*.

Wind loads on the roof of representative houses were obtained from a wind tunnel model study carried out in a boundary layer wind tunnel. The pressure fluctuations on the roof system (e.g. batten to rafter and rafter to top plate) are being analysed and tested in detail to inform understanding of roof performance, potential failure modes and opportunities to implement retrofit options.

A webinar series has also been piloted, allowing home owners to understand the importance of of making appropriate decisions at various stages of the building process, and providing information on various aspects of building to resist wind loads for builders, certifiers and designers to become aware of issues that have caused failures previously.

ENHANCING RESILIENCE OF CRITICAL ROAD INFRASTRUCTURE: BRIDGES, CULVERTS AND FLOODWAYS

BACKGROUND

Natural hazards cause major damage to road networks, with hundreds of millions of dollars spent in recent years to repair damage. A major gap in the current research is the lack of assessment techniques and tools to inform assessment of the vulnerability of this infrastructure, and to focus resilience efforts to enhance both community and structural resilience. This project is developing tools and techniques to enhance the resilience of roads to floods, bushfires and earthquakes.

RESEARCH ACTIVITY

The study is undertaking research to:

- Advance the understanding of the factors required for quantifying impact of hazards on road structures.
- Understand failure mechanisms under different hazards and vulnerable structural forms, with structures grouped according to vulnerability.

Case studies have been completed and numerical analyses have been conducted to understand the vulnerability of roads to different hazards.

RESEARCH OUTCOMES

Case studies have been utilised to develop and demonstrate vulnerability modelling methodology to road infrastructure.

Left: KAPERNICKS BRIDGE IN THE LOCKYER VALLEY, QUEENSLAND, HAS BEEN ASSESSED FOR ITS VULNERABILITY TO EARTHQUAKES, AS WELL AS RETROFITTING OPTIONS. PHOTO: HESSAM MOHSEN.

Flood, bushfire and earthquake have been investigated, with two case studies on bridges, and one on floodway failure. The bushfire case study focused on a bridge in Victoria, constructed in 1958, and found that if the bridge was exposed to fire for less than 90 minutes, it could be repaired to its pre-fire standard. After 120 minutes of fire exposure, however, all bridge columns would require full replacement. For earthquake, a concrete girder bridge in Queensland constructed in 1976 was analysed for 24 different types of earthquake. The most vulnerable section was the deck joint, and retrofitting techniques can be applied improve the strength of these joints. For flood, 64 floodways damaged by the 2013 flood in the Lockyer Valley were considered. Scour downstream of the floodway was the onset of the failure of the structure and the cut off wall was the most vulnerable element.

Australian design standards for bridges and floodways have been examined and a comparative study of international standards undertaken, along with an analysis of design standards and applied loads on road structures under extreme events. A field study was also undertaken to understand the social and economic impact due to failure of road structures during Queensland's Lockyer Valley floods in 2011 and 2013.

The next stage of the study will expand the vulnerability modelling and develop a GIS tool which can be used to demonstrate the benefits of the approaches developed.

END-USER STATEMENT

This research will assist stakeholders, from governments and emergency management agencies, through to individuals, make informed decisions about how they can best mitigate damage to buildings and crucial road infrastructure. Incorporating flood and storm vulnerability, the research will provide an important evidence base about the most cost-effective ways to reduce damage to buildings and ensure our roads can withstand natural hazards, allowing local communities to resume business as usual as quickly as possible. For earthquake, our most vulnerable infrastructure is unreinforced masonry and low ductility reinforced concrete frames, and testing will achieve practical outcomes to strengthen our buildings.

– Leesa Carson, Branch Head Community Safety, Geoscience Australia

NATURAL HAZARD EXPOSURE INFORMATION MODELLING FRAMEWORK

BACKGROUND

This project is identifying the fundamental data requirements and modelling framework to derive exposure information to enable a better understanding of the vulnerability of people, buildings and infrastructure to different hazards. It is a significant step towards developing national exposure information capabilities in Australia. The framework will support impact assessments on people, economy, infrastructure and the environment caused by bushfires, floods, cyclones and earthquakes.

RESEARCH ACTIVITY

A number of nationally consistent frameworks are being developed, which will help a diverse range of end-users. The frameworks include:

- Built environment exposure – considers the attributes of assets to assess their vulnerability to natural hazards. The building exposure considers usage, type, structural system, number of storeys, size, age, attachments, replacement value and contents value. The infrastructure sectors considered are transportation, energy, communication, urban water supply, waste management, hazardous substances and major industries. The primary industries considered are agriculture, fishing, forestry and mining sectors.
- Business and economics exposure – consists of business definitions, assets and activities which are deemed necessary for assessment of business continuity, disruption, resilience and recovery indicators in disaster management.

RESEARCH OUTCOMES

The project has reviewed current exposure information provision capabilities to identify key issues, needs, gaps, overlaps and deficiencies. An extensive literature review has been undertaken, along with stakeholder consultations to identify comprehensive list of information requirements. A survey with end-users identified significant gaps in the availability of existing data and the translatation into meaningful information for evidence based disaster decision making.

The built environment exposure information framework has been completed. To reduce the complexity, it categorises the information into three levels depending on the requirements of the user: policy and planning; response and recovery; research and analysis.

The framework presents the fundamental characteristics of exposed assets to natural hazards as components, elements and attributes. The exposure components considered in the framework are buildings, people, businesses and infrastructure.

The Bushfire and Natural Hazards CRC is a national research centre funded by the Australian Government Cooperative Research Centre Program. It was formed in 2013 for an eight-year program to undertake end-user focused research for Australia and New Zealand.

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