Proposed Australian Building Stock Categorisation for Bushfire and Natural Hazards CRC Earthquake Project

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ABSTRACT

This paper presents the initial building vulnerability schema proposed for the Bushfire and Natural Hazards Collaborative Research Centre (BNHCRC) project entitled "Cost-Effective Mitigation Strategy Development for Building Related Earthquake Risk". The development of a building schema which categorises the Australian building stock into distinctive vulnerability classes is an integral part of the risk and impact assessment process. In undertaking this categorisation a review was undertaken of existing earthquake vulnerability schema found in the literature alongside a schema developed by an expert group for Australia. The schemas found in the literature were the HAZUS, the United Nations Global Assessment Report on Risk (UN-GAR), the RiskScape, the Global Earthquake Model (GEM), the US Geological Survey Prompt Assessment Global Earthquakes for Response (USGS PAGER), and the European Macroseismic Scale-98 (EMS-98). Also included was an Australian specific schema developed based on the recommendations made at a workshop in Melbourne in February 2001 (Stehle et al., 2001). Key building parameters from each of these were considered along with the building types found in the countries or regions where these schemas were developed. The proposed schema categorises buildings by the building attributes: Building Usage, Primary Lateral Load Resisting System, Height Range, Proximity to Coast, Wall Type, Wall Material, Roof Material, and Age. The draft schema has been developed in recognition of the current and projected ability to define national building exposure and of the parallel BNHCRC mitigation projects examining vulnerability to wind and riverine flooding. While vulnerability schemas are hazard specific, alignment has been sought with schemas for the other hazards where possible. The draft schema is considered to be a preliminary version, and is expected to evolve during the project as it develops new knowledge on vulnerability and mitigation options for key high risk Australian building types.

Keywords: Building categorisation, Earthquake, Vulnerability, Mitigation

1. INTRODUCTION

The Bushfire and Natural Hazards Collaborative Research Centre (BNHCRC) project entitled "Cost-Effective Mitigation Strategy Development for Building Related Earthquake Risk" will examine opportunities for reducing the vulnerability of Australian buildings. It will address the need for an evidence base to inform decision making on the mitigation of the earthquake risk posed by the most vulnerable Australian buildings and complements parallel BNHCRC projects for wind and flood. The project will make assessments of the reduction in loss that will ensue due to the implementation of a range of mitigation measures developed by the project. This research requires the framework of a building vulnerability classification, or schema. The schema takes the continuum of buildings spatially distributed nationally and discretises them into building classes or categories of similar, though not identical, vulnerability. This "pigeon holing" strategy makes research on mitigation more tractable in that vulnerabilities can be assigned to each class with the reduced variability within the class captured in the uncertainty of the model.

The classes identified within the schema have to represent the variety of building within the nation's building stock and, more specifically, the variation in vulnerability. There is little value in including building classes that may exist in other countries which are rare in Australian communities. For example, concrete roofed houses with unreinforced masonry walls may be common in some countries but are rare in Australia and, hence, are not considered in the proposed building schema. Furthermore, the schema must accommodate specific building classes for which the project will develop mitigation strategies.

In this paper, the development of building regulations for earthquake is summarised. Several schemas for categorising buildings for earthquake in the region are presented and discussed along with a schema previously developed for Australian buildings. Finally, key building attributes for assigning vulnerability to Australian buildings are selected and a draft schema for this project is presented.

2. BACKGROUND TO THE VULNERABILITY OF STRUCTURES TO EARTHQUAKE

The design and construction of building in Australia is regulated by the National Construction Code (NCC) of which Volumes 1 and 2 are the Building Code of Australia (BCA) and its State–specific Appendices. The BCA was first published in 1988 and has undergone many revisions since that year. It, and the Australian Standards referenced therein, represent the culmination of a long evolution of building standards in Australia. In 1979 the first Australian earthquake design code entitled 'Australian Standard for the Design of Earthquake Resistant Building AS2121-1979' was issued in response to the 1968 Meckering earthquake. However it was used in only two states, South Australia and Western Australia (Woodside, 1992). Later, AS1170.4-1993 was published in 1993 after the 1988 Tennant Creek and 1989 Newcastle earthquakes. However the BCA did not require building professionals to design to the new code until 1995 (Mike Griffith, personal communication, 6 June 2014). The current earthquake loading code is AS1170.4-2007. It incorporates a number of changes to the 1993 version and includes new design response spectra. Wilson et al. (2007) provide a history of the developments of Australian earthquake design standards. From historical Australian earthquake events it has been found that older low-rise Unreinforced Masonry Buildings are the most vulnerable building type which has not benefited from modern design standards (e.g., Edwards et al., 2010).

Poorly detailed reinforced concrete frame and shear wall systems are also expected to exhibit a greater vulnerability than current code compliant buildings.

3. EXISTING BUILDING SCHEMAS

A number of existing building schemas have been reviewed. Each building schema was developed using a set of key attributes with the aim of classifying building stock in the locality of application. For example, the building schema in HAZUS was primarily developed to classify the building stock in the US using four key building attributes while the United Nations Global Assessment of Risk (UN-GAR) building schema is designed to cover the various types of buildings in the Pacific and South East Asian part of the world with three key attributes. Table 1 summarizes the key features of the building schema reviewed.

Table 1. Summary of key features of the reviewed building schemas. Note that the Geoscience Australia building schema (Fulford et al., 2002) was developed based on the recommendations made at a workshop in Melbourne in February 2001 (Stehle et al., 2001)

Source	Target area	Key attributes
HAZUS (FEMA, 2007)	US	Structural system, Height range, Design level, Occupancy class
United Nations Global Assessment of Risk (UN-GAR) (Maqsood et al., 2013)	Pacific and South-East Asian region	Structural system, Height range, Seismic resistance level
RiskScape (RiskScape User Manual, 2010)	New Zealand	Construction type, Parapet, Storeys, Use category, Condition, Roof cladding class, Wall cladding, Year of construction
Global Earthquake Model (GEM) (Brzev et al., 2013)	World	Direction, Material of the lateral load-resisting system, Lateral load-resisting system, Height, Date of construction or retrofit, Occupancy, Building position within a block, Shape of the building plan, Structural irregularity, Exterior wall, Roof, Floor, Foundation system
US Geological Survey Prompt Assessment Global Earthquakes for Response (USGS PAGER) (Jaiswal et al., 2007)	World	Material, Lateral force resisting system, Occupancy type
European Macroseismic Scale-98 (EMS-98) (Grünthal et al., 1998)	Europe	Structural system, Earthquake resistance design level
Geoscience Australia (Fulford et al., 2002)	Australia	Structural system, Height range, Roof material, Wall material

Commonly used key attributes include structural system, height range, design level and building usage. The number of building classes in each building schema varies depending on the combinations of each of the key attributes. Key points from review of the building schemas are summarized below. More detailed review can be found in Ryu et al. (2014).

- Both the HAZUS and the UN-GAR schema address different seismic resistance levels for each type. The HAZUS attributes resistance on the expected code compliance level resulting from the combination of local hazard, design standard and construction practice. In contrast, the UN-GAR resistance level is more direct and is based on simple compatibility with the local hazard which is categorised into four classes.

- The HAZUS schema accommodates the effect of different building uses that can influence the losses that can be expected while the UN-GAR does not.
- The HAZUS and the UN-GAR schema are engineered building type dominated at the expense of other smaller residential types.
- Roof type is not considered in either the HAZUS or the UN-GAR schema for low rise structures where roof mass could be expected to influence structural demands.
- Both the RiskScape and the GEM schema, while comprehensive, are difficult to implement given their coarse granularity.
- The USGS PAGER schema differs significantly from others in the sense that it has many non-engineering building types and includes several that are not found in Australia.
- The EMS-98 schema is not considered suitable for adaptation due to its coarse nature.
- The GA schema is primarily based on the HAZUS schema, and it subdivides building types that are known to be vulnerable in Australia, but has the inherent limitation and engineered building biases that HAZUS has.

4. PROPOSED SCHEMA

While an almost infinite variety of individual building forms are found in Australian communities, these are categorised into a limited number of types based on the building features that influence vulnerability to earthquake. This work draws upon experience of building damage from the past earthquake events (e.g., Edwards et al., 2010) and data contained in Geoscience Australia’s National Exposure Information System (NEXIS) (Nadimpalli, K. 2009).

The common building attributes found in the reviewed building schemas are building usage, structural system, and height range. In addition to the common building attributes, proximity to coast, wall type, wall material, roof material, and age are selected as key attributes for Australian building schema.

Proximity to coast is selected to distinguish higher vulnerability of older masonry buildings built near to the coast due to corrosion from others. Roof material is included to differentiate vulnerabilities of domestic buildings with heavy and light roof materials. Wall material and wall types are included because buildings can exhibit different vulnerability due to different combinations of wall material and wall type. Age is chosen as a proxy of design level and to capture the effect of deterioration on building vulnerability. Age is broken into four periods: Pre-WW1, WW1-WW2, WW2-1995, Post-1995.

In summary the key attributes considered herein are: Building Usage, Primary Lateral Load Resisting System, Height Range, Proximity to Coast, Wall Type, Wall Material, Roof Material, and Age.

All attributes used in the schema to classify buildings are held within NEXIS apart from the primary lateral load resisting system. The proposed schema contains 92 possible classifications for residential, 232 for commercial, 80 for industrial, and 48 for carpark buildings. The proposed schema for residential buildings is set out in

Table 2. Proposed schema for commercial, industrial and carpark buildings can be found in Ryu et al. (2014).

Table 2. Proposed schema for Australian residential buildings for earthquake hazard. The dark shaded cells are those classes thought to be poorly represented. Note that Low-Rise corresponds to 1 to 3 storeys, Mid-Rise to 4 to 6 storeys, High-Rise to 7 storeys and above, respectively.

Primary lateral load resisting system	Wall Material	Height range	Roof Material	Proximity to Coast	Age			
					Pre WW1	WW1-WW2	WW2-1995	Post 1995
Unreinforced Masonry	Unreinforced load bearing masonry	Low-Rise	Heavy	< 10km				
				> 10km				
			Light	< 10km				
				> 10km				
URM with timber frame floor	All	Mid-Rise	All					
URM with reinforced concrete floor	All	Mid-Rise	All					
Timber frame	Masonry veneer	Low-Rise	Heavy	< 10km				
				> 10km				
			Light	< 10km				
				> 10km				
Timber frame with light cladding	Non-masonry	Low-Rise	Heavy	All				
			Light	All				
Steel Light Frame	Masonry veneer	Low-Rise	All	All				
	Non-masonry	Low-Rise	All	All				
Concrete Moment Frame	All	Low-Rise	All	All				
		Mid-Rise	All	All				
Concrete Frame with Shear Walls	All	Low-Rise	All	All				
		Mid-Rise	All	All				
		High-Rise	All	All				
Precast Concrete Frame with Concrete Shear Walls	All	Low-Rise	All	All				
		Mid-Rise	All	All				
		High-Rise	All	All				
Reinforced Masonry	Reinforced Masonry	Low-Rise	All	All				
		Mid-Rise	All	All				

5. SUMMARY

The development of a building schema which categorises the Australian building stock into classes with distinctive vulnerabilities is an integral part of the risk and impact assessment process. It also needs to capture the vulnerability of buildings for mitigation purposes. The schema must capture the wide variety of building types existing in Australia together with the variation in vulnerabilities observed in outwardly similar buildings.

The proposed schema categorises buildings by the building attributes: Building Usage, Primary Lateral Load Resisting System, Height Range, Proximity to Coast, Wall Type, Wall Material, Roof Material, and Age. With the exception of Primary Lateral Load Resisting System, these attributes are defined within Geoscience Australia's exposure database, NEXIS.

As the project progresses it is expected that the results of the research will drive modifications to the schema proposed herein. The research may indicate little or no variation in vulnerability between some proposed classes thus enabling the combining of two or more classes in the schema. Conversely the research may identify different types of buildings within a single class in the proposed schema that demonstrate significantly different vulnerabilities. This would necessitate an expansion of the proposed schema, and, possibly, the capture of further building attributes into the exposure database to enable the new building classes to be identified within the Australian building stock.

Furthermore, the research will examine the predominance of buildings within communities across Australia that fall into the various classes. Some classes may be so poorly represented that they may be removed from the schema. For a better guidance on the use of the proposed schema, a "data dictionary" where users can look up definition of each of the structural attributes and photos of typical buildings of each of the defined classes will be developed in near future.

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