A FRAMEWORK FOR UNDERSTANDING POST-EARTHQUAKE DECISIONS ON MULTI-STOREY CONCRETE BUILDINGS IN CHRISTCHURCH, NEW ZEALAND

by

Frederic Marquis

B.Eng., University of Sherbrooke, 2012

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF APPLIED SCIENCE

in

THE FACULTY OF GRADUATE AND POSTDOCTORAL STUDIES

(Civil Engineering)

THE UNIVERSITY OF BRITISH COLUMBIA

(Vancouver)

July 2015

© Frederic Marquis, 2015

Abstract

The 2010-2011 Canterbury earthquakes, which involved widespread damage during the February 2011 event and subsequent aftershocks, left this community with more than $NZD 40 billion in losses, demolition of approximately 60% of multi-storey concrete buildings, and closure of the core business district for over 2 years. This thesis presents a framework to understand the issues and complexities in relation to post-earthquake decisions (repair or demolish) on multi-storey concrete buildings in Christchurch. The primary research data for this thesis were collected through in-depth investigations on 15 case-study buildings using 27 interviews with various building stakeholders in New Zealand. As expected, the level of damage and repairability (cost to repair) generally dictated the course of action. There is strong evidence, however, that variables such as insurance, business strategies, perception of risks, uncertainty, and building regulations have significantly influenced the decision on a number of buildings. The decision-making process for each building is typically complex and unique, not solely driven by structural damage.

The analysis of the case-study buildings and the interviews have shown that the main driving factors in the predominance of building demolitions in Christchurch were the ambiguous wording of insurance policies offered in New Zealand, the changes in building regulations following the earthquakes, and the lack of criteria for the evaluation of the residual capacity of damaged structures. Because of inadequate insurance cover, conservative engineering evaluations due to uncertainties in structural damage and capacity, and the difficulty of satisfying policy clauses, buildings were often considered uneconomical to repair. Furthermore, most property investors interviewed considered it a favourable outcome if their building was declared a total loss by their insurer and subsequently demolished, because of the availability, flexibility, and rapidity of cash settlements. This thesis also argues that the absence of clear criteria for the repairability of earthquake-damaged buildings implicitly counteracts resilience and sustainable development objectives of building codes. This lack of standards contributed to the demolition of potentially salvageable buildings, resulting in a substantial loss of the built environment.

Preface

The primary research for this thesis was conducted in collaboration with Dr. Kenneth J. Elwood and Dr. Stephanie E. Chang at the University of British Columbia, and Dr. Erica Seville and David Brunsdon at Resilient Organisations, a multi-disciplinary team of over 20 researchers associated with the University of Canterbury and the University of Auckland in New Zealand. During the course of this study, Dr. Kenneth Elwood moved to New Zealand and is currently Professor and MBIE Chair in Earthquake Engineering at the University of Auckland.

Portions of this thesis (within all chapters) have been published as preliminary findings in:

Journal Publication:

> Marquis, F., Kim, J. J., Elwood, K. J., & Chang, S. E. (2015) Understanding post-earthquake decisions on multi-storey concrete buildings in Christchurch, New Zealand. Bulletin of Earthquake Engineering. (Article in Press). The final publication is available at Springer via http://dx.doi.org/10.1007/s10518-015-9772-8.

Conference Poster and Paper:

> Marquis, F., Kim, J. J., Elwood, K. J., & Chang, S. E. (2015) Post-earthquake decisions: A case-study of multi-storey concrete buildings in Christchurch. New Zealand Society for Earthquake Engineering Conference, Paper P-33, Rotorua, New Zealand, 10–12 April 2015.

This thesis is based on field work conducted in New Zealand in 2013 and 2014 by the author, Frederic Marquis. With the assistance of my thesis supervisors and local research partners, I was the co-team leader for conducting the semi-structured interviews with building stakeholders in Christchurch, Wellington, and Auckland. I was also responsible for all the data collection and analysis, as well as the writing and editing of the published materials. The design of the conceptual framework and interview questions are my own. Professor Kenneth Elwood, my primary supervisor, and Professor Stephanie Chang, my co-supervisor, were involved throughout the project and actively contributed to manuscript edits and supervision. This research project was conducted in parallel to a companion study carried out by Jenna Jihyun Kim, a master's student from the University of British Columbia, who was also involved in the data collection process and manuscript edits for this research.

The primary research for this thesis received ethics approval from the University of British Columbia Behavioral Ethics Research Board (ID: H14-01332) as well as the University of Auckland Human Participants Ethics Committee (ID: 012911). The results and conclusions presented herein are the product of academic research and only reflect the views of the author.

Table of contents

List of tables

List of figures

Acknowledgements

I would like to express my gratitude to all the people who offered assistance and support during the production of this master's thesis. In particular, I am truly grateful to Professor Ken Elwood, my main supervisor, for his continuous support, leadership, wisdom, and advice throughout the research journey. I have been extremely lucky to have a supervisor who cared so much about my work and I owe him a very special thank you for giving me the opportunity to learn and travel the world at the same time. It has been a privilege to work with Ken, and he has inspired me to pursue tremendous goals. Special thanks are accorded to Professor Stephanie Chang, my co-supervisor, for her guidance, patience and unwavering interest in the research topic. Stephanie has provided insightful discussions about the research and I have learned a lot from her background. Sincere thanks to Jenna Jihyun Kim for her significant contribution with the interviews and data collection in Christchurch. I also would like to thank my mentor, Professor Pierre Labossière, for his guidance and time over the last two years, both in my home country and overseas. I also wish to acknowledge the precious help and suggestions provided by my friend Yumi Nakajima. Lastly, I want to thank my family, friends and classmates at UBC for their support throughout this process.

I gratefully acknowledge the contribution of Erica Seville and Dave Brunsdon from Resilient Organisations in discussing the research design and context, developing an appropriate list of interviewees, and providing logistical assistance. I also acknowledge the generous cooperation and time provided by the interviewees and local engineers throughout this study. Special thanks to Rob Snook (Canterbury Earthquake Recovery Authority), Chris van den Bosch (Christchurch City Council), John Hare and Bruce Galloway (Holmes Consulting Group), Mike Stannard (Ministry of Business, Innovation, and Employment), and Professor Suzanne Wilkinson (University of Auckland).

Likewise, this research would not have been possible without the financial support from the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Fonds de recherche du Québec Nature et technologies (FRQNT).

I dedicate this thesis to my parents, Sylvie and Régent, who have supported me throughout my years of education, both spiritually and financially, and encouraged me to pursue graduate studies.

Chapter 1: Introduction

Building owners in Christchurch, New Zealand were faced with unexpected and challenging decisions after the 2010-2011 Canterbury earthquake sequence. As evidenced in this thesis, the decision on an appropriate course of action (whether to repair or demolish) for a building damaged during an earthquake depends on a number of interrelated factors. This research explores the factors surrounding the decision-making process for multi-storey concrete buildings in the post-earthquake Christchurch Central Business District (CBD). Although the rationale behind such decisions is typically complex, a simple model may be used to introduce the research problem (Figure 1). Scenario "A" refers to a building that has insignificant damage (i.e. little to no effects on the structural integrity, stability, and building contents), and where the remediation costs, expressed as a ratio of the insured value of the building, are significantly low to justify a repair decision without any detailed analysis. On the opposite side, scenario "B" implies a heavily damaged building where the demolition is the only course of action available, both from a technical and economical perspective. These two scenarios (A and B) are relatively simple and straightforward in terms of the decision process. The "intermediate" scenario, however, represents an area of uncertainty (grey zone) and complex decision-making, where a wide range of damage may be observed and different variables and alternatives need to be considered by the building stakeholders. The aftermath of the Canterbury earthquakes has revealed the importance to understand the conditions surrounding decisions on damaged buildings. This thesis explores the boundaries and implications of these scenarios, with a focus on the complexities associated with the "intermediate" scenario.

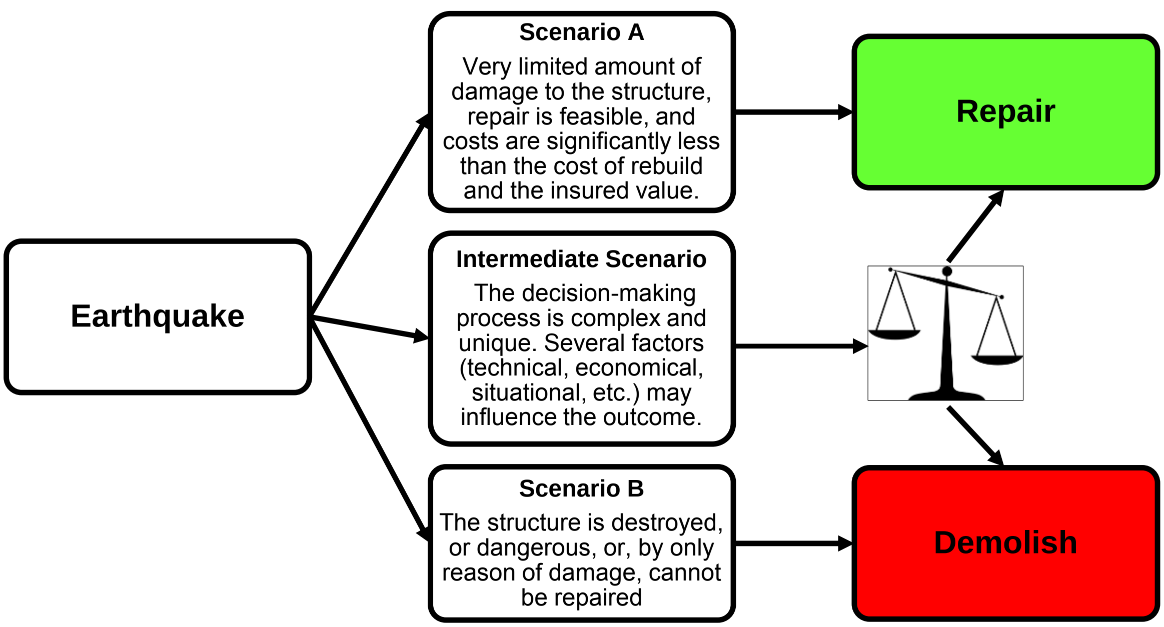


Figure 1: Possible courses of action on earthquake-damaged buildings - simple model

This chapter will first introduce the theme of performance-based seismic design and the scientific rationale for this thesis, and finally present the research objectives and organization of the thesis.

1.1 Rationale for the study

Structures designed according to modern building codes (e.g. National Building Code of Canada, New Zealand Building Code) are expected to achieve specific seismic performance objectives. The first objective of seismic design is to protect the life and safety of building occupants and the general public as the building responds the strong ground shaking (NRCC 2010). According to the NBCC, a strong ground shaking is considered to be a rare occurrence and defined as having a probability of exceedance of 2% in 50 years at median confidence level. Second, seismic design shall limit building damage during low to moderate levels of ground shaking. Finally, a third objective is to ensure that post-disaster buildings can continue to be occupied and functional following strong ground shaking, although minimal damage can be expected in such buildings. With regard to the first objective (minimizing loss of life), it is generally considered both unnecessary and uneconomical to design and construct buildings that will not be damaged during a strong ground shaking, given the structure is expected to retain some margin of resistance against collapse. Nevertheless, a wide range of damage is expected to structural components as well as to non-structural elements, and building contents. Despite the risk of collapse being very low, the structure may be heavily damaged and may have lost a substantial amount of its initial strength and stiffness. Furthermore, such damage levels may represent substantial economic losses for building owners and occupants in terms of cost of repair, downtime, and business disruptions. Building occupancy may be disrupted for a few days or up to several years, and in some cases, a structure may need to be demolished and replaced. In addition, such impacts may have long-term consequences for a community, as evidenced by the widespread disruption and closure of the Christchurch CBD in the aftermath of the Canterbury earthquakes (Chang et al. 2014, King et al. 2014). As a result, increased attention is being placed on strategies to design facilities that account for both life-safety of building occupants and expected future losses associated with repair costs and loss of functionality.

Performance-based seismic design (PBSD) aims to provide probabilistic estimates of losses from future earthquakes to enable informed decision making regarding structural design or investments in seismic mitigation (Yang et al. 2009). The recent development of PBSD has increased interest in the consideration of economic losses in the engineering design process for building structures, rather than a sole focus on a life-safety performance objective. The PBSD procedure integrates the seismic hazard at a site (from selected ground motions), the response of the building in terms of engineering demand parameters (such as drift ratio or floor accelerations), resulting damage using fragility curves, and losses (repair costs, downtime, etc.) associated with restoring the building to its pre-earthquake conditions (Figure 2). The PBSD framework may also consider the repairability of the building based on the response and damage analysis, for instance, if the building has not collapsed or is deemed repairable given a building repair fragility curve.

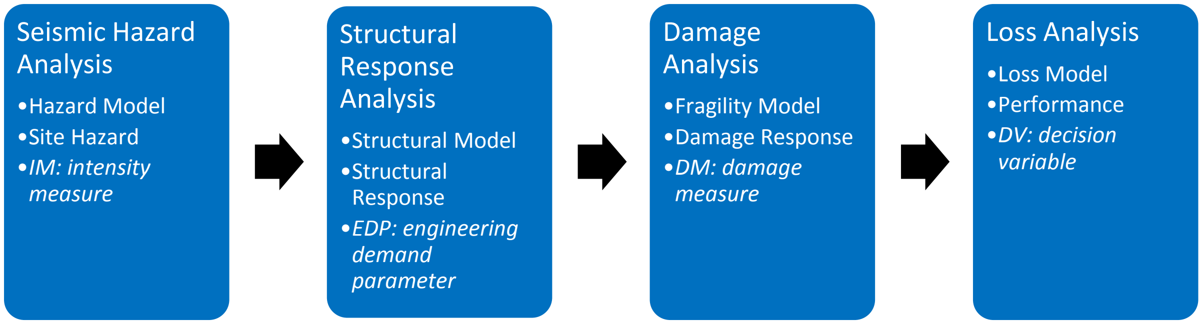


Figure 2: Performance-based design framework (Source: adapted from Yang et al. 2009)

Nevertheless, the current approach to PBSD (FEMA P-58 2012) does not consider the multitude of factors influencing losses in a post-earthquake environment. The methodology proposed by FEMA P-58 considers the scenario of demolition by assuming that the probability of a building being demolished is solely dependent on the residual drift; and thus, assumes a damage measure is the only factor affecting the losses and demolition decisions. The conditions in post-earthquake Christchurch have clearly demonstrated, however, that the course of action for each building is complex and unique, not solely driven by structural damage. Chang et al. (2014) reported that some of these factors may have facilitated demolitions that were convenient for building owners rather than out of necessity. As a result, recovery challenges and financial risks facing building owners, occupants, insurers, and other building stakeholders after an earthquake are potentially misunderstood by the engineering community. The aftermath of the Canterbury earthquakes brings evidence that the complexity of post-earthquake decisions should be considered in the determination of expected losses for building structures. The implementation of a comprehensive demolition scenario in the PBSD framework is expected to enable an improved and more realistic evaluation of the risks involved and potential losses. Notably, the costs and downtime associated with demolition are usually different in comparison to a repair scenario. The PBSD framework should emphasize reduction of post-earthquake socio-economic impacts and foster resilience, with consideration of appropriate outcomes and variables discussed in this thesis, in addition to protect structures against collapse during rare and large earthquakes.

Furthermore, the societal expectation of seismic performance is another important rationale for this study. Although the response of modern multi-storey buildings in the CBD appeared to be satisfactory from the perspective of expected design performance and life-safety, the Canterbury earthquakes have left Christchurch with more than $NZD 40 billion in losses, demolition of approximately 60% of multi-storey concrete buildings (3 storeys and up), and closure of the core business district for over 2 years. Despite the severe nature of the earthquake sequence (high intensity of ground shaking, and multiple events over a long period of time), such outcomes and economic losses are arguably not satisfactory for building owners, occupants and insurers. There is evidence that Christchurch communities and businesses have been significantly disrupted by the widespread damage to building structures, suggesting that targeting life-safety is clearly not enough for a society. The relatively high number of building demolitions in the CBD has also given impetus to the research project (see Chapter 2 for details). The demolition of multiple multi-storey buildings within a cordoned urban area is a long and costly operation that has significant impacts on the long-term recovery of a city. The high number of demolitions has also created significant uncertainties for residents, businesses, and other building stakeholders involved in the recovery. Moreover, this event highlighted the key role that insurance plays within disaster recovery and the need for structural engineers to understand policy wordings. A better understanding of the financial impacts of urban earthquakes will ultimately enable a more effective communication with building owners and occupants on seismic risks, and contribute to clear, consistent, and acceptable performance objectives for individual buildings. An improved appreciation of such impacts may also enhance community resilience by mitigating business interruption, displacement of people, economic impacts, and loss of the built environment.

Finally, the circumstances of the Canterbury earthquakes brought several unique features (extent and severity of damage, availability of data, willingness of building owners and engineers to share their experience, high insurance penetration, etc.) enabling the analysis of post-earthquake decisions. The lessons from Christchurch are important not only within New Zealand, but also for other earthquake-prone cities around the world given the similarity of construction and seismic codes with many other countries (e.g. United States, Canada).

1.2 Research objectives and scope

The aftermath of the Canterbury earthquakes has revealed the complexity and uniqueness of the decision-making process leading to the demolition or repair of building structures in a post-disaster environment. In particular for Christchurch, the circumstances of the earthquake sequence exposed several unique features compounded by complicating issues for building owners. First of all, the high intensity of ground shaking (including strong vertical acceleration, widespread soil liquefaction and lateral spreading), the number of strong aftershocks, and the extended period over which such events repeatedly caused substantial damage were unexpected in Christchurch and unprecedented elsewhere in the world (Bradley et al. 2014; King et al. 2014). As discussed in Chapter 2, the changes in building regulations following the earthquake sequence, the establishment and longevity (2½ years) of the CBD cordon, and the relatively high ratio of insured losses to total direct economic losses are also among the factors that have exacerbated the complexities of the decisions and challenges for building owners (Chang et al. 2014).

From this perspective, this thesis explores the steps and associated issues involved in the decision-making process as to whether an earthquake-damaged building should be demolished (and potentially rebuilt) or repaired (and/or strengthened). Specifically, it considers the multitude of factors influencing the possible courses of action for multi-storey concrete buildings in the Christchurch CBD. The research project also considers how the socio-economic and regulatory conditions in pre-earthquake and post-earthquake Christchurch may have incentivized building owners and/or insurers to demolish, and how this has impacted the recovery of the wider community. Thus, the thesis presents a collection of empirical data on observed damage for building structures, post-earthquake decisions regarding the fate of the buildings, and resulting impacts on building stakeholders.

To address the research problem specified in this study, the main questions guiding this research are:

- *How did building owners, insurers and structural engineers make (or influence) decisions on earthquake-damaged buildings, and what are the factors driving such decisions?*
- *Based on the lessons that can be drawn from these decisions, how should the earthquake engineering field take action to significantly reduce post-earthquake impacts for building stakeholders and communities?*

The first research question emphasizes the need for empirical studies on earthquake-damaged buildings, by investigating the rationales behind building owner's decision-making strategies and engineering recommendations on specific buildings. The first question also investigates earthquake insurance policies and their importance in the selection of the appropriate course of action. The second research question is defined more broadly and focuses on the limitations and gaps of modern building codes and performance-based methodologies to minimize financial impacts of urban earthquakes. This question also acknowledges the current substantial lack of standards and guidance directed towards the evaluation and repair of earthquake-damaged buildings (FEMA 306 1998). The question aims to identify areas of further study in relation to the factors investigated in the first research question. Answers to these questions will provide vital information for understanding the factors influencing the likelihood of demolition on building structures. Complemented with further research, the findings are also expected to help building owners and occupants to make informed decisions on performance goals for future earthquakes, and may provide guidance for enhancing community resilience by mitigating economic impacts of urban earthquakes.

Specific goals of the project include the investigation of the following:

- Identification of the factors contributing to post-earthquake decisions, based on a detailed assessment of case-study buildings
- Correlation of structural characteristics of buildings with post-earthquake decisions (including the influence of the seismic force resisting system, ductility, pre-earthquake seismic capacity)
- Correlation of observed damage and placards with post-earthquake decisions
- Correlation of post-earthquake decisions with insurance and building regulations

Furthermore, it was necessary to develop a comprehensive framework that adopts a holistic perspective and allows an empirical analysis of the factors influencing post-earthquake decisions on building structures. The development of the framework is the result of an iterative process using information gathered from the review of literature and interviews. The goals of the framework are to scope and organize the data collection process, illustrate the relation among the variables influencing post-earthquake decisions, and identify the organizations and players involved in the decision process. Additionally, the topic of insurance and its role in decision-making regarding damaged buildings is addressed in this research. The thesis also examines the mandate of the Canterbury Earthquake Recovery Authority (CERA), explicitly in relation to its power to commission building demolitions. As aforementioned, the focus of this research project is on multi-storey reinforced concrete (RC) buildings (commercial and multi-unit residential buildings) in the Christchurch CBD. This research focus achieves a satisfactory representativeness of the building stock in term of structural characteristics, the majority of multi-storey buildings within the CBD being RC structure (as opposed to other types of construction materials such as steel or timber frames). This scope also provides consistency in terms of the complexity of post-earthquake decisions and engineering assessments, levels of damage, legislation (building code) and compliance requirements, and insurance policies.

To achieve the objectives being pursued in this study, two exploratory research approaches are adopted considering the nature of the research problem and the very limited literature addressing the topic of interest. A multiple case studies analysis is adopted in addition to semi-structured face-to-face interviews. This research method is beneficial at filling the gap of each approach, and thus provides a synergistic and more robust research design. The multiple case studies approach is crucial to understand the different decision-making variables and business strategies that may have influenced the course of action for specific buildings. The interviews were used as the main data collection technique, but have also proven to be an opportunity to appreciate the context of the property market in Christchurch (ownership, insurance structure, socio-economics, etc.). As a result, the primary research data for this thesis were collected through in-depth investigations on 15 case-study buildings using 27 semi-structured interviews with various property owners, property managers, insurers, engineers, and government authorities in New Zealand. Thus, the research is conducted from mainly the perspective of building owners and other stakeholders involved in the post-disaster decision-making process.

1.3 Organization of thesis

This thesis is organized into six chapters with five appendices. The chapter outlines are provided below.

Chapter 1 provides a general overview of the research investigation by giving adequate background information on the rationales of the research problem. The research objectives and scope are stated.

Chapter 2 provides a detailed background of the conditions in Christchurch, including a description of the built environment and the building ownership in the CBD, insurance structure, building regulations, the earthquake recovery act, and building post-earthquake assessments. It also provides an overview of the 2010-2011 Canterbury earthquake sequence and the building demolitions in the CBD.

Chapter 3 describes the research methodology and design. It presents a short review of the literature and corresponding gaps, discusses the development of the conceptual framework, and presents the qualitative method employed in this study for data collection.

Chapter 4 presents an overview of the multiple case studies selected for this research project, followed by an analysis of data from interviewees, relevant documents, and engineering reports for each case-study building.

Chapter 5 discusses the findings from the multiple case studies and interviews. Specifically, it focuses on the four decision-making themes identified in the framework (insurance, damage and residual capacity, decision-making strategies, and legislation) in addition to discussing the recovery progress in Christchurch.

Chapter 6 provides a summary and conclusions from the research investigation. It presents a review of the research questions, practical implications of the results, and provides suggestions for further research.

Chapter 2: Christchurch context

In order to understand the factors influencing demolition and repair decisions in Christchurch, it is important to appreciate the context of the Christchurch physical, regulatory, and economic environment. The following sections provide a summary of the built environment that existed prior to the earthquakes, along with an overview of the city's commercial building ownership profile. Then, a brief outline of the 2010-2011 Canterbury earthquake sequence is presented. The implications of the Canterbury Earthquake Recovery Act are discussed, followed by a description of the building demolitions in the CBD (commercial and multi-unit residential buildings). Finally, this chapter provides a background on earthquake insurance in New Zealand, building regulations, and post-earthquake building assessments.

2.1 Built environment

The city of Christchurch is New Zealand's second largest city and the largest city on the South Island (population of 370,000 in 2011). The Christchurch CBD encompasses approximately 600 hectares and is defined by the grid road network bounded by the four avenues: Deans, Bealey, Fitzgerald, and Moorhouse (Figure 3). There were at least 3000 buildings within the Christchurch CBD, consisting of predominantly commercial and light-industrial buildings (58%) in addition to a significant number of residential buildings (42%), particularly towards the north and east edges of the CBD (Pampanin et al. 2012).

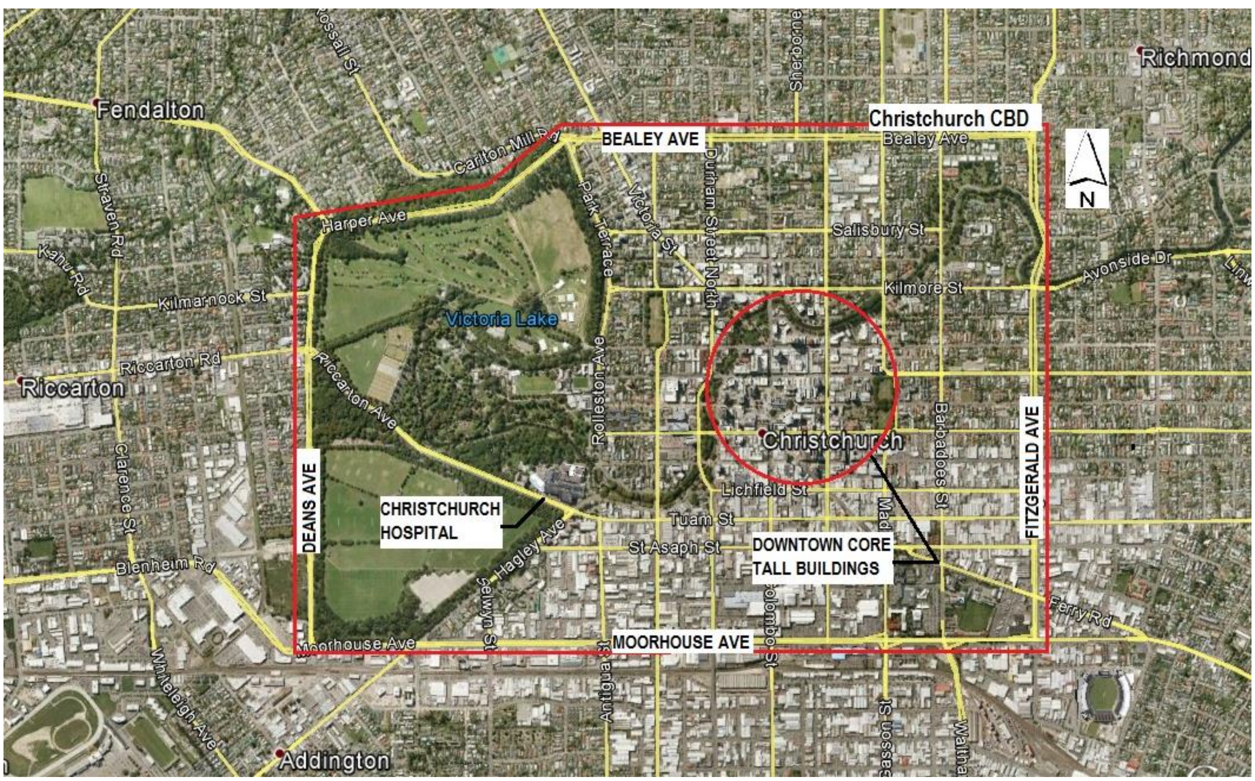


Figure 3: Map of Christchurch central business district (Source: adapted from Image © 2015 DigitalGlobe, Google Earth, imagery date: 3/3/2009)

In terms of building characteristics, Christchurch had a mix of newer multi-storey RC buildings with modern detailing and older non-ductile RC structures. A companion study including a database of 223 RC buildings that are 3-storey and higher within the Christchurch CBD demonstrated that 45% of such buildings were constructed before 1975 (Figure 4) (Kim 2015). This database accounts for approximately 88% of buildings within the CBD having similar characteristics (buildings with no or very limited available information were excluded from the database) and represents approximately 34% of all RC buildings in the CBD. Furthermore, low to mid-rise RC buildings were dominant in the CBD (58% are 3-5 storeys) and very few were taller than 10 storeys. The city's tallest building was the Pacific Tower, a steel moment frame of 23 storeys (86 m high). The tallest RC building was the Hotel Grand Chancellor at 85 m (26 storeys). Finally, commercial occupancy was typically dominant (69%) in the CBD, followed by residential (10%) and hotel buildings (9%) (by number of buildings) (Kim 2015).

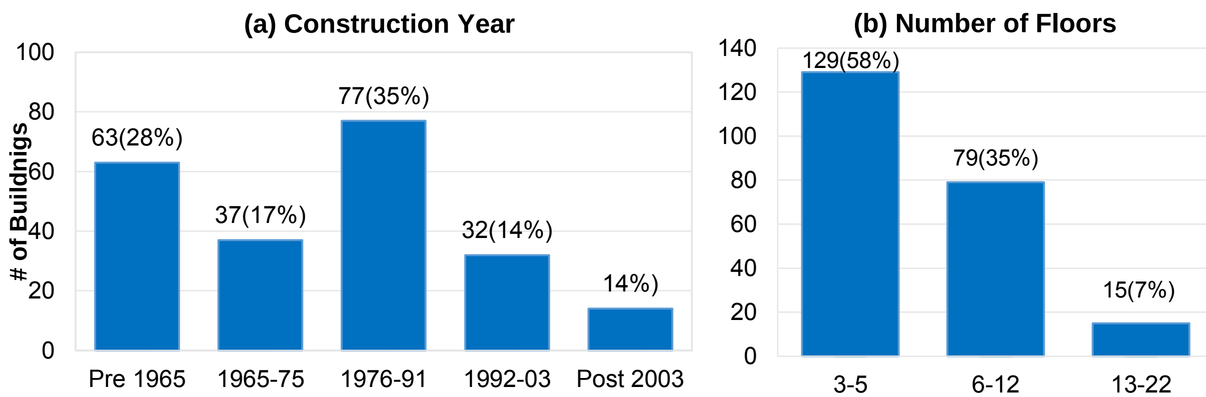


Figure 4: Construction year (left) and storey distribution (right) for RC buildings within the CBD (3 storeys and up) (Data source: Kim 2015)

2.2 Ownership profile in Christchurch CBD

Property ownership in Christchurch is important to understand as it provides historical background of the commercial property market which existed prior to the Canterbury earthquake sequence. According to Ernst and Young (2012), the vast majority of commercial office buildings in the CBD were owned by local investors and developers, which comprise a mix of high net worth individuals and families and informal groups of individuals, including a number of farmers. Only 13.4% of owners (by net lettable floor area) were based overseas (Figure 5). Because of the nature of the local economy (largely driven by agriculture with very few large corporate headquarters located in Christchurch) and the pre-earthquake surplus of commercial office space in a large CBD area, Christchurch had a low rent commercial office market in comparison to Auckland or Wellington. As a result, major corporate and institutional investors have withdrawn from office building ownership in the CBD over the last three decades due to the inability to attract higher rent tenants. In relation to this study, the economic context prior to the earthquakes may have also influenced post-earthquake decisions, since lower income streams generated from office buildings may have incentivized investors to demolish.

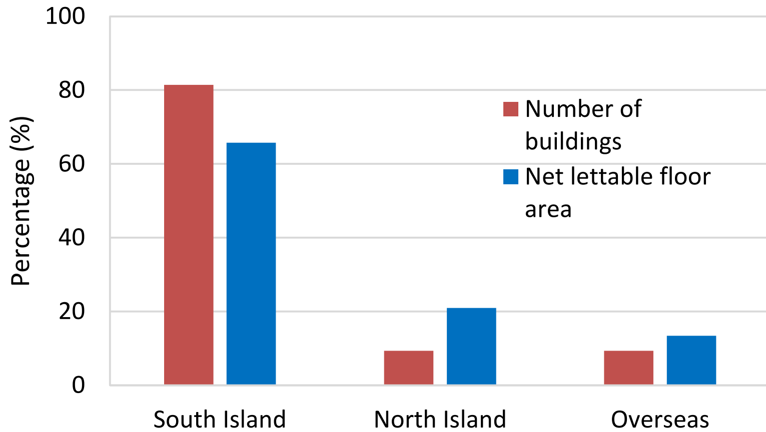


Figure 5: Commercial (office) ownership profiles in Christchurch before Feb. 2011 (Data source: Ernst and Young 2012)

As of September 2010, the central city office stock comprised approximately 446,000 square meter (sqm), with an average vacancy rate of about 14%. Office buildings in the CBD were categorized into six quality grades (A+, A, B, C, D, and E) and rental prices determined accordingly. For instance, the pre-earthquake rental levels were in the range from \$NZD 315 to \$NZD 400 per sqm for ‘A+’ grade buildings and \$NZD 270 to \$NZD 300 per sqm for ‘A’ grade buildings (Ernst and Young 2012). The city and region also operates as a hub for the South Island tourism industry (accounting for roughly 20% of total tourist arrivals in New Zealand). Prior to the earthquakes, a significant proportion of hotel rooms were situated within the CBD; including international hotel chains such as Grand Chancellor, Millennium Hotels and Resorts, Holiday Inn, Accor, Rydges, Rendezvous, and Intercontinental (Ernst and Young 2012). There were approximately 3,400 hotel rooms in Christchurch prior to the earthquakes based on a floor space ratio of 40 sqm per bed, accounting for about 130,000 sqm of floor space. For reference purposes, the number of hotel rooms in the city decreased by approximately 75% after the earthquakes, with only 825 hotel rooms available in May 2012 (The Press 2012).

2.3 Overview of the Canterbury earthquake sequence

The most significant events of the 2010-2011 Canterbury earthquake sequence occurred on 4 September 2010 (M7.1, 10km deep, 35km W of Christchurch CBD), 26 December 2010 (M4.9, 12km deep, within 5 km of the Christchurch CBD), 22 February 2011 (M6.2, 5km deep, 10km SE of Christchurch CBD), 13 June 2011 (2 events: M6.0 and M5.2, 9km and 6 km deep, 10km SE of Christchurch CBD), and 23 December 2011 (2 events: M5.9 and M5.8, 8km and 6 km deep, 20 km E and 10 km E of Christchurch CBD). The 22 February 2011 event occurred at 12.51pm during a weekday and was the most severe and damaging event of the sequence due to the proximity of the epicenter to the CBD, shallow depth, distinctive directionality effects (steep slope angle of the fault rupture), and incremental damage from preceding earthquakes (September and December 2010) (Bradley et al. 2014).

The February earthquake caused significant shaking across Christchurch, especially in the CBD, eastern suburbs, Lyttleton, and the Port Hills (Figure 6). The epicenter of the February 2011 earthquake is indicated by the red star. Substantial damage to commercial and multi-unit residential buildings, including permanent tilting due to ground deformation, occurred in the CBD (Pampanin et al. 2012). Two multi-storey concrete buildings collapsed and hundreds of unreinforced masonry buildings (URM) experienced partial or total collapse, resulting in 185 fatalities and many seriously injured. The government declared a state of national emergency and Civil Defence became lead agency, with a cordon established around the CBD area. Chang et al. (2014) provides a detailed description of the impacts of the CBD cordon which had been reduced to about half its original size by July 2011 and removed entirely in June 2013. For reference purposes, Figure 7 shows the extent of the CBD cordon at various timeframes. The continued aftershocks contributed to the longevity of the cordon, with the 13 June 2011 earthquakes causing further damage to previously damaged structures (including partial collapse of at least two CBD buildings) and the 23 December 2011 earthquake also causing substantial land damage around Christchurch.

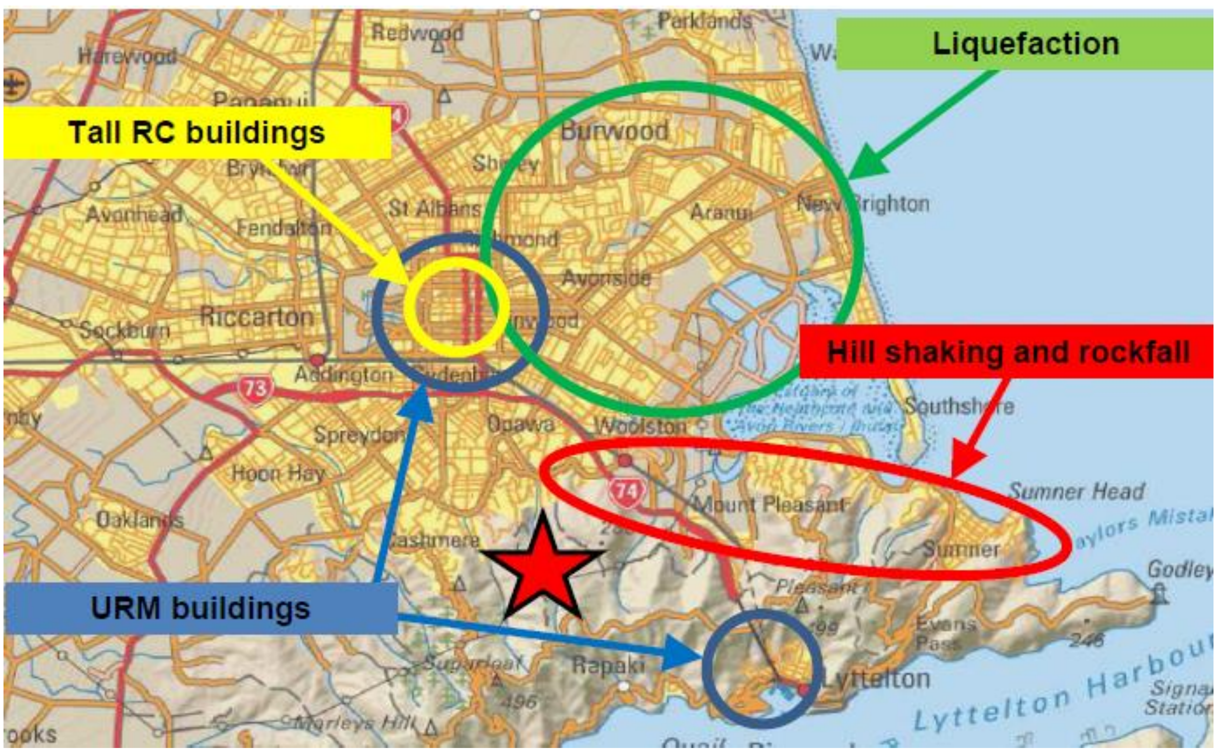
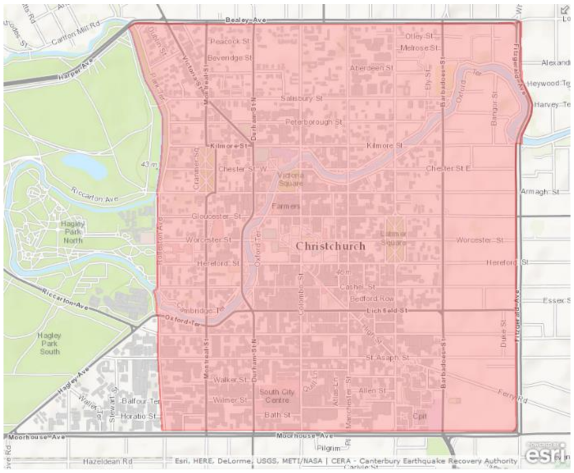
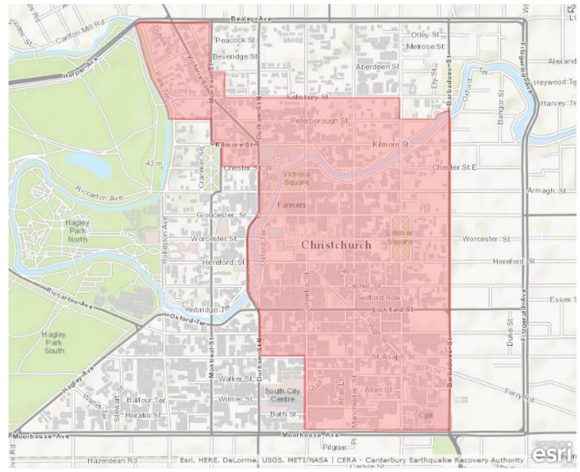


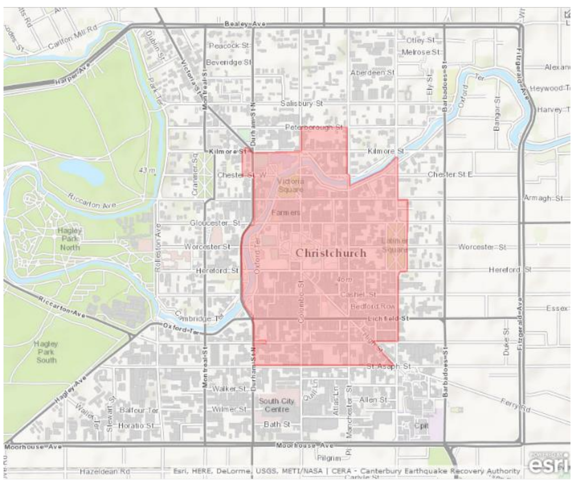
Figure 6: Impact of the 2011 February earthquake on the built environment (Source: after Pampanin et al. 2012)



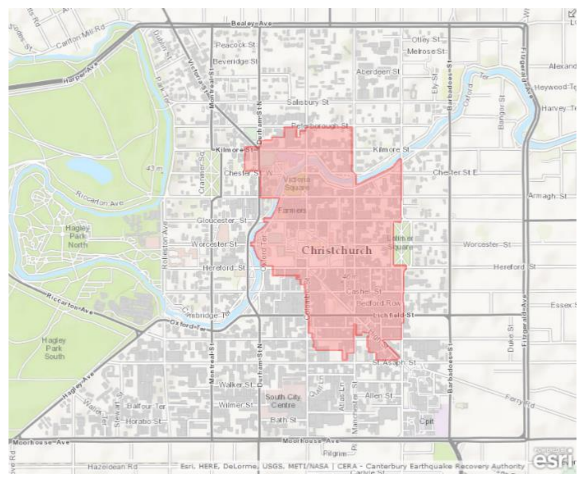
February 2011



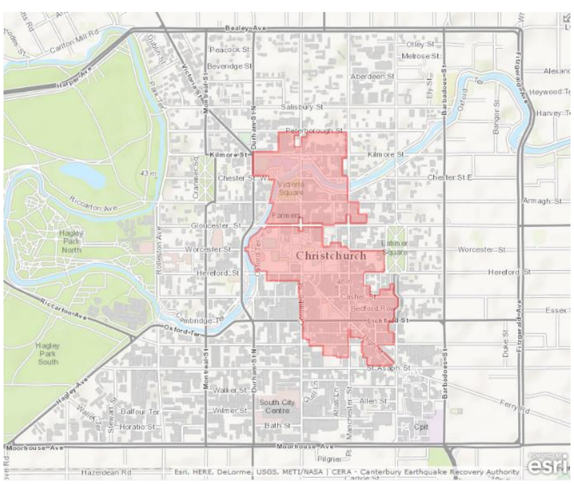
March 2011



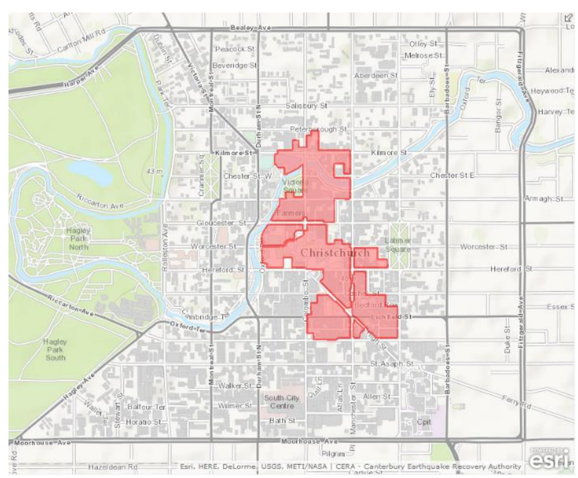
June 2011



March 2012



June 2012



May 2013

Figure 7: Extent of central business district cordon, February 2011 to May 2013 (Source: after Canterbury Earthquake Recovery Authority, http://cera.govt.nz/maps)

2.4 Canterbury Earthquake Recovery Authority (CERA)

The Canterbury Earthquake Recovery Authority (CERA) was established in April 2011 under the Canterbury Earthquake Recovery (CER) Act 2011 to facilitate the recovery of Christchurch. The CER Act provided CERA with a range of powers to enable a focused and expedited recovery. Under this Act, CERA has powers with respect to verifying building safety and requiring demolition. Further details on the organisational structure of CERA and its impacts on the recovery of Christchurch are provided in Taylor et al. (2012). Particularly relevant sections for this study are (CER Act 2011, as of 5 August 2013):

Section 38 – Works and Section 39 – Provisions relating to demolition or other works[1]

> CERA may carry out or commission works, including *a) erection, reconstruction, placement, alteration, or extension of all or any part of any building, b) the demolition of all or part of a building, and c) the removal and disposal of any building*. CERA does not require building consents from the City Council for such works within the CBD.
>
> Under Section 38, CERA can require a building owner, with 10 days' notice, to identify how and when they intend to demolish a building. If the owner fails to respond in 10 days then CERA may commission the demolition and may recover the costs of carrying out the work from the owner. The amount to be recovered becomes a charge on the land on which the work was carried out. Building owners may also elect to have CERA manage the demolition work for them.
>
> Under Section 39 (Urgent Demolition) no notice needs to be given if the demolition of the building is necessary because of *(a) sudden emergency causing or likely to cause i) loss of life or injury to a person; or ii) damage to property; or iii) damage to the environment; or (b) danger to any works or adjoining property.*

Section 51 – Requiring Structural Survey[1]

> CERA may require any owner of a building that has or may have experienced structural change in the Canterbury earthquakes to carry out a full structural survey of the building. The survey shall be carried out before it is re-occupied for business or accommodation.

2.5 Christchurch Central Development Unit (CCDU)

In accordance with CERA's lead role in recovery, the Christchurch Central Development Unit was created to develop and implement the Central City Recovery Plan (released to the public on 30 July 2012) (CCDU 2012). The CCDU was also created to help build confidence in the future of the downtown and the city. The

[1] Copies of letters sent to building owners under section 38 and section 51 were graciously provided by CERA and reproduced in Appendix A. There have been a number of versions and variations for each of these letters.

key principle in design was a central city delivering a more compact core, including a new urban frame and several anchor projects (e.g. Precincts, Stadium, Bus Interchange, Central Library, etc.). Under the CER Act 2011, CCDU also has the power to acquire parcels of land for earthquake recovery related purposes and provide compensation for the compulsory acquisitions. The pre-earthquake and post-earthquake designated parcels of land in the CBD are shown in Figure 8 (CERA 2012).

As detailed in section 2.6, compulsory acquisitions under the Christchurch Central Development Unit Recovery Plan accounted for approximately 10% of the demolitions of significant buildings (generally commercial and multi-unit residential buildings over five storeys) in the CBD. Similarly, the companion study which included 223 reinforced concrete buildings that are 3-storey and higher within Christchurch CBD revealed that only 9% of such buildings have been demolished to enable the CCDU's plan (Kim 2015). The buildings demolished under CCDU were left out of the research scope and the case-study buildings because the decision outcome on such buildings is solely based on the city's development plan and not under the control of the owner or related to the variables in consideration (e.g. building damage).

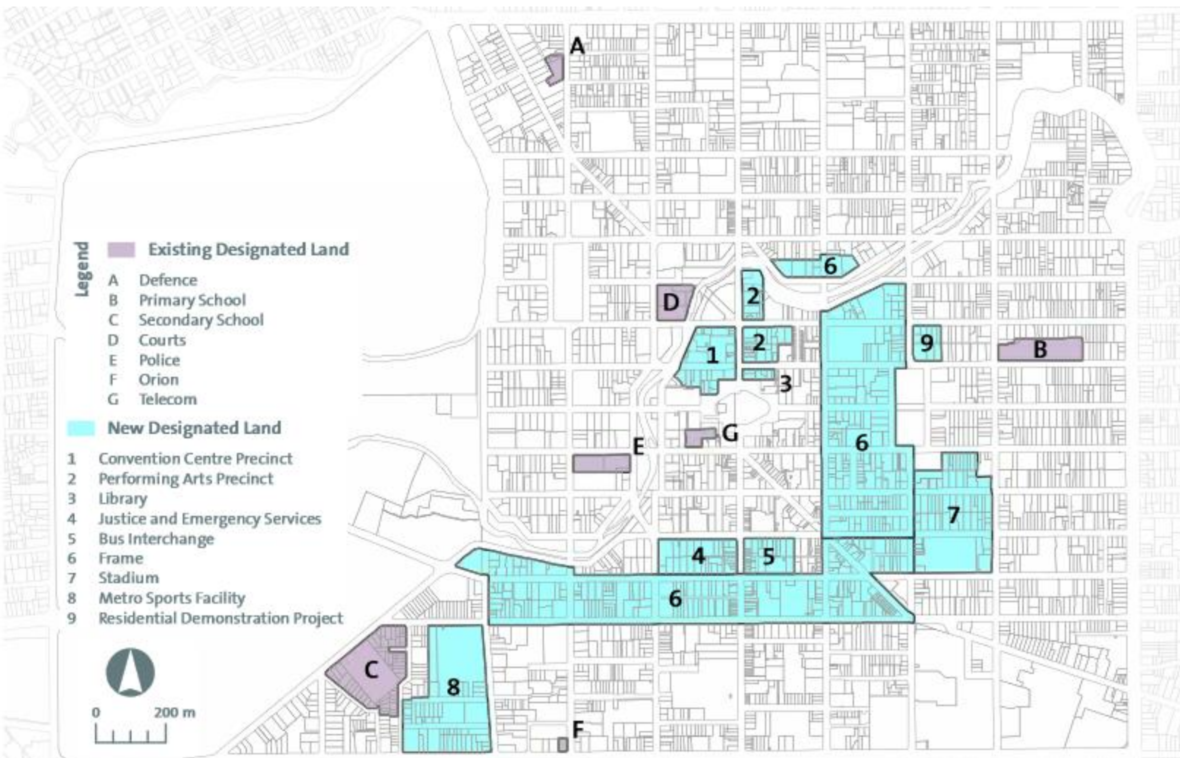
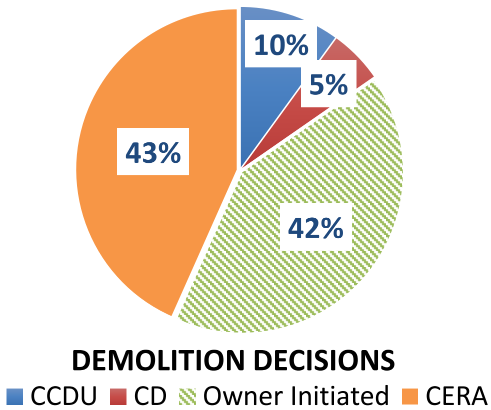


Figure 8: Central city recovery plan: existing and new designations (Source: after Canterbury Earthquake Recovery Authority 2012)

2.6 Building demolitions in Christchurch CBD

The response of modern (mid-1980s and onwards) multi-storey reinforced concrete structures, the dominant type of multi-storey commercial building in the CBD, was satisfactory from the perspective of expected design performance and life-safety, in particular when considering the high intensity of shaking experienced during the Canterbury earthquake sequence, high inelastic behaviour, and large displacement demands (Kam and Pampanin 2011). Modern buildings in Christchurch were designed under well-defined and well-enforced seismic code provisions. As per capacity design principles, plastic hinges formed in discrete regions, allowing the buildings to dissipate energy and people to evacuate. However, a significant number of modern multi-storey buildings with a low damage ratio (defined here as the estimated cost of repairing the damage to cost of replacing the structure) were deemed uneconomic to repair, declared a total insurance loss, and consequently demolished.

In September 2014, the Canterbury Earthquake Recovery Authority (CERA) reported that approximately 150 significant buildings (generally commercial and multi-unit residential buildings over five storeys in the CBD) had been demolished, representing about 65% of the significant buildings in the CBD and immediately surrounding neighborhoods. This number includes Civil Defence (CD) demolitions immediately after the February earthquake and compulsory acquisitions under the Christchurch Central Development Unit (CCDU) recovery plan, accounting for 5% and 10% of the demolitions of significant buildings, respectively (Figure 9). The majority (~80%) of demolished significant buildings were reinforced concrete structures, with the dominant seismic force resisting systems being moment frames (MF) and shear wall (SW), representing approximately 46% and 29% of the considered buildings, respectively (Figure 9). Only nine steel structures with more than 5-storeys were recorded in the CBD and three such buildings have been demolished. The geographical distribution of commercial and residential building demolitions (including partial demolitions, i.e. the removal of part of a building for immediate safety reasons) within Christchurch CBD is presented in Figure 10. CERA has issued demolition notices (Section 38 Notice) on approximately 65 significant buildings which have been identified as dangerous (out of 150 demolitions). According to the CERA database, a similar number of demolitions (62 significant buildings) were initiated by the owners, although the buildings were not declared dangerous by CERA.



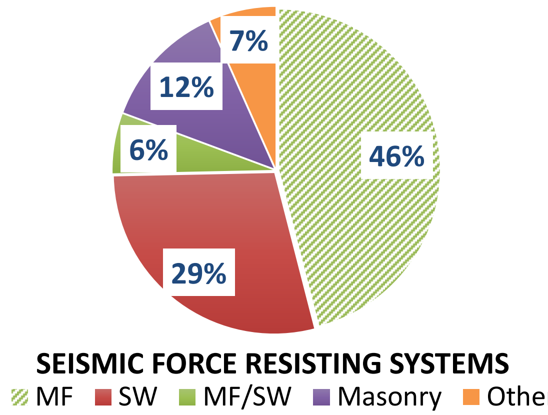


Figure 9: Summary - Significant building demolitions (out of 150 demolitions)
(Data source: Canterbury Earthquake Recovery Authority, Silverfish Database)
(Legend - CCDU: Christchurch Central Development Unit; CD: Civil Defence; CERA: Canterbury Earthquake Recovery Authority; MF: Moment Frame; SW: Shear Wall; MF/SW: Mixed system with both moment frames and shear walls)

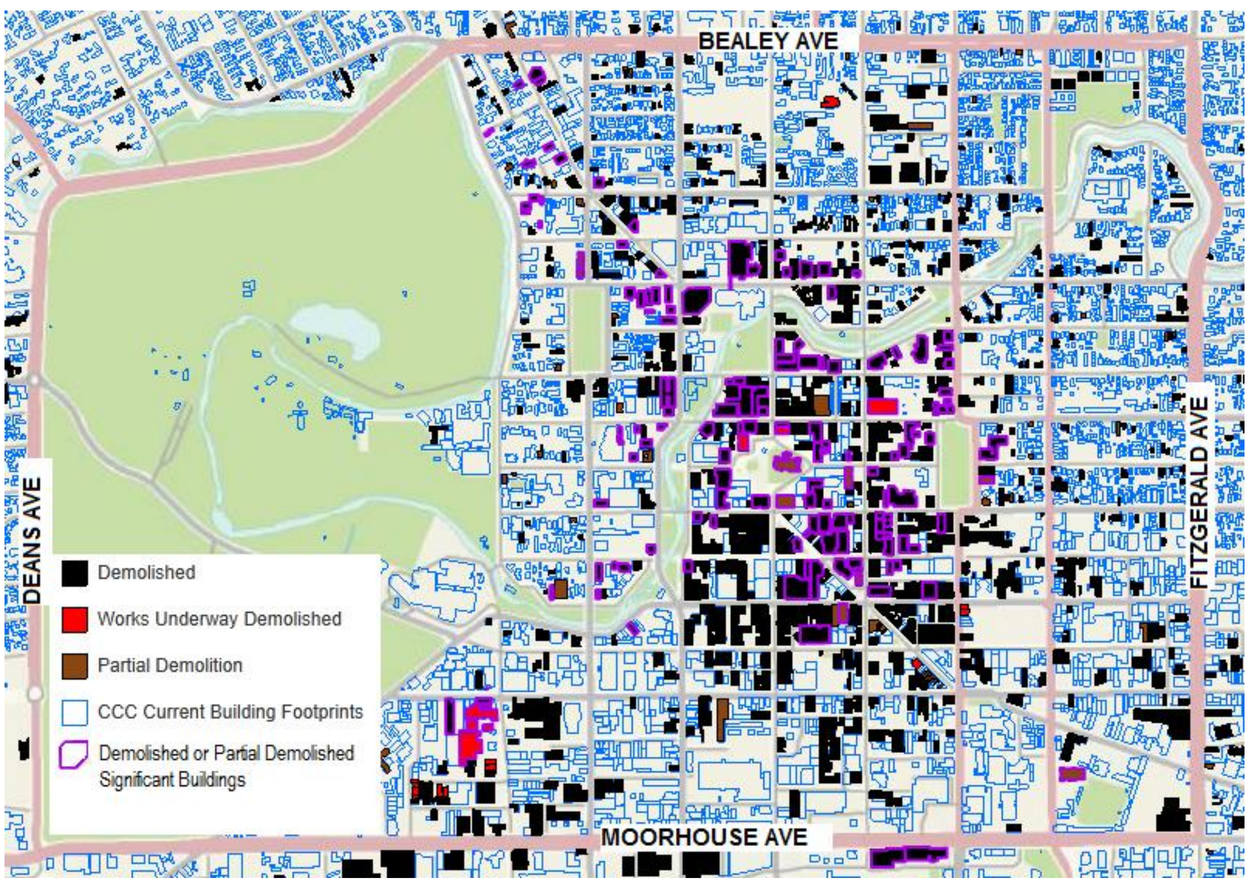


Figure 10: Overview of building demolitions in Christchurch CBD - November 2014
(Source: after Canterbury Earthquake Recovery Authority, http://cera.govt.nz/maps)

2.7 Earthquake insurance in New Zealand

New Zealand has a long history of natural disasters and has also one of the highest insurance penetration rates in the world. Specifically in terms of earthquake insurance, the penetration level (defined as the insurance gross premiums written expressed as a ratio of the Gross Domestic Product (GDP) of the country) is relatively high for both the residential and commercial sectors, equivalent to 0.07% and 0.09% of the GDP, respectively. California, for instance, has a slightly lower residential earthquake penetration, where premiums are equivalent to 0.05% of the California GDP, and much lower in the commercial sector (at 0.03% GDP), whereas Chile has a higher penetration for commercial property at 0.25% of their GDP (SwissRe 2012). Insurance penetration rates for a specific country typically depend of various factors, such as the earthquake hazard, risk perception and awareness, government involvement, type of coverage (high versus low deductible and premiums, sum insured, etc.), in addition to the value of the built environment and other economic factors. Furthermore, on the basis of estimates produced by the Insurance Council of New Zealand, the 2010-2011 Canterbury earthquake sequence was by far the largest insured loss in New Zealand's history (Table 1). The estimated $NZD 29 billion of total damages comprises $NZD 17 billion of private insurance costs and $NZD 12 billion from the Earthquake Commission (EQC) (note that the value of insurance claims associated with the Canterbury earthquakes in Table 1 is an indicative estimate as claims were still being processed at the time of writing) (ICNZ 2015). As of December 2014, $NZD 8.2b had been paid to settle commercial claims and $NZD 5.7b for residential claims (ICNZ 2015).

Table 1: Largest natural disasters in New Zealand by insurance costs (1968-2014) (Data source: Insurance Council of New Zealand 2015)

Event	Year	Insured Losses (million $NZD)
Canterbury Earthquakes	2010-2011	29,000
Bay of Plenty Earthquake	1987	371
Wahine Storm	1968	221
Lower North Island Storm	2004	140
Invercargill/Southland Flood	1984	140
Nationwide Storm	2013	75
North Island Storm	2007	69
Cyclone Bola	1988	68
Queenstown Lake District Flood	1999	64
Canterbury Storms	1975	62

In contrast to other earthquake-prone countries, a much greater percentage of the damage caused by the Canterbury earthquakes was insured and therefore a high percentage of the losses were borne by the insurance industry. According to Swiss Reinsurance Company (2012), approximately 80% of the economic losses in Christchurch were covered by insurance, considerably higher than other major earthquake disasters worldwide (e.g. 27% for 2010 Chile earthquake, 17% for 2011 Tohoku (Japan) earthquake and tsunami, 14% for 2009 L'Aquila (Italy) earthquake, and 4% for 2011 Van (Turkey) earthquake) (Figure 11).

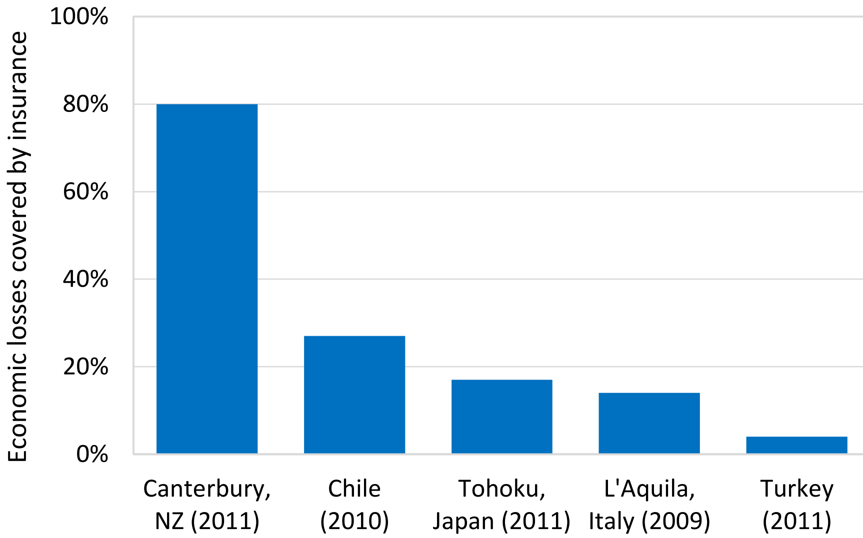


Figure 11: Recent major earthquake events and insurance industry contribution (Data source: SwissRe 2012)

As a result the high insurance penetration in New Zealand and the high coverage of losses following the Canterbury earthquake sequence, it is critical to understand how insurance policies and the response of the insurance industry may have shaped post-earthquake decisions for building structures in Christchurch. The following sections provide background on insurance for both the residential and commercial sectors in New Zealand, in addition to comparing commercial earthquake insurance policies with coverages offered in Canada. Although commercial insurance is more relevant with respect to the objectives of this research (due to the relatively low number of multi-unit residential buildings in Christchurch compared to larger international cities, e.g. Vancouver), a summary of the residential insurance scheme is useful in providing a general context for insurance and understanding decisions on multi-unit residential buildings.

2.7.1 Residential earthquake insurance

The New Zealand residential insurance market is unique, with losses from natural disasters managed under a dual-model between the Earthquake Commission (EQC) and private insurers. The EQC is a government-owned entity that provides natural disaster insurance to homeowners (including condominium owners and tenants) in New Zealand through the Natural Disaster Fund. Since 1993, the EQC insures all residential properties which are insured against fire against the additional perils of earthquake, landslip, volcanic eruption, hydrothermal activity, tsunami and fire caused by any of these (EQC 2015). The EQC also covers the land on which the buildings stand and the land within 8 meters of the buildings against damage caused by seismic perils, plus storm and flood. The EQC cover operates on a first loss basis (primary insurer) and is subject to the following limits per event[2]:

Buildings (or for each unit in multi-unit buildings) - the lesser of:

- the reinstatement sum insured
- $NZD 1,000 per square meter of floor area
- $NZD 100,000 + GST

Contents - the lesser of:

- the sum insured
- $NZD 20,000 + GST

The EQC cover is an automatic extension to fire policies purchased through private insurers, and private sector insurers top up the EQC limits to the sums insured under the policyholder's home policy. Consequently, New Zealand enjoys a high level of insurance penetration in the residential market which is largely attributed to the EQC: about 90-95% of dwellings in New Zealand have earthquake insurance (EQC 2015). Although the EQC offers natural disaster insurance to residential properties only, the feature of 'mandatory' endorsement to standard fire policies may have contributed to promote public awareness of earthquake risks and the availability of cheap insurance in the country. Prior to the Canterbury earthquakes, the maximum premium payable was $NZD 60 per year, and by February 2012, the maximum total levy that a policyholder pay per residence tripled to $NZD 150 for home policies and $NZD 30 for contents policies (excluding GST). Cover for land is included at no cost. EQC buildings cover is subject to a deductible of 1% of the claim, with a minimum contribution of $NZD 200 and a maximum of $NZD 1,150, and EQC contents claims are subject to a flat deductible of $NZD 200. The deductible for the land is 10% of the amount of the claim, subject to a minimum of $NZD 500 and a maximum of $NZD 5,000 (EQC 2015). One important feature of EQC is an insurance cover guaranteed by the Central Government. In the event that the Natural Disaster Fund is fully exhausted after a major disaster, the Crown Guarantee is activated and therefore the government will meet further claims. Following the Canterbury earthquakes, this feature had to be activated since the insured losses were in excess of the claims-paying capacity of the EQC.

2.7.2 Commercial earthquake insurance

As opposed to residential insurance, earthquake insurance schemes for commercial buildings are not automatically provided with fire insurance, and commercial property owners can decide on the type of insurer and policy plan. Commercial property insurance policies in New Zealand are written on an all-risks basis and provide either reinstatement cover, indemnity, or a combination of both (Axco 2014). The leading

[2] A 2011 High Court decision ruled that the private insurer only becomes liable when the cost for a single event exceeds the cap – usually $100,000 + GST. EQC remains liable for the entire cost of other below-cap events, even if the total cost of their damage exceeds $100,000 + GST (see EQC 2015 for further details).

commercial insurers in the New Zealand market are IAG, Vero Insurance, ACE Insurance, AIG (Chartis), QBE Insurance, Allianz, and Zurich.

Typically, reinstatement cover includes the cost of replacing the building with its equivalent in new condition. If the building is repairable, reinstatement cover will provide for the restoration of the damaged portion of the property to a “condition substantially the same as, but not better or more extensive than, its condition when new” (Vero 2007, Zurich 2009). In other words, the policyholder is entitled (subject to certain conditions) to receive a repaired property which is largely the same in appearance, quality, and working order as it was “when new”. In addition, the repairs have to comply with current building regulations. Very few policies include a “constructive total loss” clause which covers for total loss where a property is repairable but cannot be occupied for its original purpose (Brown et al. 2013). A “constructive total loss” clause was used for only one case-study building (see Chapter 4). For indemnity cover, the insurer is only responsible for paying for the cost of repairing the building to the condition it was in before the damage. Therefore, indemnity value is in most cases less than the reinstatement (replacement) value because of depreciation. The exact definitions depend on the wording of the insurance policy. Furthermore, damage covered by insurance typically included “damage occurring as the direct result of earthquake”, but also “fire occasioned by or through or in consequence of earthquake”, and “damage occurring (whether accidentally or not) as the direct result of measures taken under proper authority to avoid the spreading or reduce the consequences of any such damage, excluding any damage for which compensation is payable under any Act” (Vero 2007).

The vast majority of commercial building owners in Christchurch (and all case-study buildings) held reinstatement cover (replacement) for the Material Damage policy with extensions such as Loss of Rents or Business Interruption. Most commercial policies typically specify a sum insured which is the maximum insurer’s liability for each earthquake occurrence during the policy period. The sum insured was typically based on a percentage of the depreciated value of the asset (building value) and should reflect the replacement value of the building (equivalent building as nearly as practicable) including demolition costs in order for the policyholder to receive full reinstatement.

2.7.3 Overview of earthquake insurance in Canada

Insurance penetration rates are on average lower in Canada, and therefore the role insurance would play in financing re-construction after an earthquake would be less significant compared with the Christchurch experience. We note, however, that while some wordings are different, similar features/restrictions are observed in both countries in relation to earthquake cover offered for commercial buildings. Table 2 aims to provide an overview of the key similarities and differences between commercial earthquake insurance policies from New Zealand and Canada. This table includes copyrighted material of Insurance Bureau of Canada, used with permission.

Table 2: Comparison - Earthquake insurance in New Zealand and Canada (commercial buildings)
(Data source: Air Worldwide 2013, Axco 2014, IBC 2014, and Vero 2007)

Definitions	**New Zealand**	**Canada**
Earthquake Event	A series of events arising during any period of 72 consecutive hours (3 days)	A series of events arising during any period of 168 consecutive hours (7 days)
Earthquake Coverage (Material Damage)	Most policies provide coverage for natural disaster damage, including the following perils: earthquake, landslip, volcanic eruption/activity, hydrothermal activity, and tsunami. Coverage applies to: the damage directly or indirectly caused by or resulting from natural disaster, including fire damage resulting from earthquakes.	Coverage typically applies just to the shock or tremor damage, or other earth movements occurring concurrently with and directly resulting from an earthquake shock. Fire damage resulting from earthquakes (and leakage from fire protective equipment) is covered separately by other types of commercial insurance.
Deductibles (Material Damage)	Earthquake deductibles in Christchurch range from 2.5 to 5% of the sum insured, with some cases as high as 10%. Before 2010, the deductibles were a percent of damage (typ. 2.5-5.0%).	Deductibles range from 3% of the sum insured (minimum of $CAD 100,000) in most of Canada to 15% - 20% of the sum insured (minimum $CAD 250,000) in Richmond and Delta, BC. Deductibles in Vancouver: 10% (typ.)
Basis of Cover	Replacement value (sum insured)	Replacement value (sum insured)
Condition of Average	Typically, not applicable. Insurers pay for damage costs up to the sum insured regardless of the underinsurance.	Typically, applicable. Claims are reduced in the same proportion as the amount of underinsurance.
Seismic Strengthening Endorsement	Before the Canterbury earthquakes, yes. The costs to reinstate up to the level of seismic capacity prior to the damage is covered, but the extra cost to comply with current earthquake standards is no longer automatic.	Typically, not covered. Some commercial insurance policies insure against the application of local by-laws (including seismic capacity) that results in an increased cost of re/construction.
Automatic Reinstatement of Loss Cover	Before the Canterbury earthquakes, yes. No longer automatic.	Typically, yes. The limit potentially apply to separate earthquake events within one policy period in the case of most insurers.
Reinstatement	Reinstatement is based on the amount of damage. Where a property is damaged but not destroyed, reinstatement means the restoration of the damaged portion to a condition substantially the same as its condition when new. Destroyed means so damaged that the property, by reason only of damage, cannot be repaired.	Typically, the definition of reinstatement is independent of the amount of damage. Reinstatement (replacement) cost refers to the least of the cost of replacing, repairing, constructing or re-constructing the property on the same site with new property of like kind and quality and for like occupancy without deduction for depreciation.

2.8 Building regulations and local government policy

This section provides a brief overview of the regulatory context for earthquake-damaged buildings, including some relevant features of the New Zealand's Building Act and Building Code, in addition to discuss the Christchurch's Earthquake-Prone Building Policy.

2.8.1 Building Act and Building Code

The Building Act (DBH 2004) governs the building industry in New Zealand and requires all new building work to comply with the New Zealand Building Code. Earthquake standards were introduced in New Zealand in 1935 as a result of the 1931 Napier earthquake and several amendments have since been adopted. The New Zealand Building Code features a performance-based approach, with a particular focus on addressing life-safety, controlling damage in minor and moderate earthquakes, and preventing collapse in a major earthquake. Each local authority sets its own standards within the context of the national standard, with the degree of earthquake hazard for the design being related to the seismicity (or "Z" factor) of the immediate area.

The Act applies to the construction of new buildings as well as the alteration and demolition of existing buildings; however, this document does not explicitly consider the repair of earthquake-damaged buildings. With regard to this study, some sections of the Building Act need to be highlighted in order to clarify the regulatory framework which existed throughout the Canterbury earthquake sequence (version as of March 2012). First, section 112 - Alternation to Existing Buildings – requires that a building subject to an alteration continue to comply with the relevant provisions of the Building Code to at least the same extent as before, in addition to comply as nearly as practicable to the new building standard regarding means of escape by fire, and access and disabled facilities. Section 115 - Change of Use – requires that the territorial authority (e.g. Christchurch City Council) be satisfied that the building in its new use will comply with the relevant sections of the Building Code "as nearly as is reasonably practicable". Section 122 - Meaning of Earthquake Prone Building - deems a building to be "earthquake prone" if its ultimate capacity would be exceeded in a "moderate earthquake" and it would be likely to collapse causing injury or death, or damage to other property. For the purpose of the Act, a moderate earthquake is "an earthquake that would generate shaking at the site of the building that is of the same duration as, but that is one-third as strong as the earthquake shaking (determined by normal measures of acceleration, velocity, and displacement) that would be used to design a new building at that site" (Building Act 2004). For simplicity, an earthquake-prone building is commonly considered to refer to structures with a lateral resistance less than 33% of the capacity of an equivalent new building, expressed as % New Building Standard (%NBS). If a building is found to be earthquake prone, the territorial authority has the power under Section 124 - Power of Territorial Authorities - to require strengthening work to be carried out, or to close the building and prevent occupancy. A major feature of the Building Act 2004 (Section 131 – Earthquake Prone Building Policy) was the introduction of a requirement for local authorities to develop and implement a specific policy to address earthquake-prone buildings (see section 2.8.2 for Christchurch City Council). The general objective of this legislation was to reduce the level of earthquake risk to the public over time and target the most vulnerable buildings (DBH 2005). This provision allowed each territorial authority in New Zealand to set its own policy to tailor for local conditions. The EPB Provisions of the Building Act 2004 are currently under review by the New Zealand Government and will be changed later in 2015.

Furthermore, an important amendment to the New Zealand Building Code clause for Structure (B1) was published following the February Earthquake (DBH 2011). This amendment contained changes to the seismic design loads for Canterbury, including a 36% increase in the basic seismic design load for Christchurch (the Hazard Factor or “Z” factor increased from 0.22 to 0.3) and increased serviceability limitations for new buildings. As a result, a building constructed in 2010 to comply with the Building Code could have a capacity of just 73% in comparison with the new seismic load levels.

2.8.2 Christchurch’s earthquake-prone building policy

The Christchurch City Council (CCC) is the local government authority for Christchurch. As required by section 131 of the Building Act 2004, CCC had in place an Earthquake-Prone, Dangerous and Insanitary Building Policy. Before the 2010 September earthquake, this policy required all earthquake-prone buildings for which there was a change of use or significant modification to be strengthened at least up to 34% NBS within a timeframe varying from 15 to 30 years. As a result of the September 2010 earthquake, CCC amended their policy and raised the level that a building was required to be strengthened to from 34% to 67% NBS (CCC 2010). This requirement was qualified as a ‘target level’ specifying that the actual strengthening level for each building deemed earthquake-prone should be determined in conjunction with the owners on a building-by-building basis. The amendment included a section covering the repair of buildings damaged by an earthquake, also including a target of 67% NBS for a repaired building. Although the 67% NBS was considered as a target rather than a requirement, exemptions from achieving this requirement were typically limited when applying for a building consent for earthquake repairs, with significant heritage value or other relevant considerations the only reasons for non-compliance. Therefore, by combining the increase in the basic seismic design load for Christchurch and the CCC’s strengthening ‘target level’ for earthquake-prone buildings, the differential between pre-September 2010 and post-February 2011 earthquake design loads was significantly raised for such buildings, as illustrated in Figure 12. As discussed in this thesis, the minimum seismic standard adopted by the Building Act and the CCC‘s recommendation of a higher seismic performance level has created misinterpretation among building owners and other stakeholders (e.g. insurers) regarding appropriate strengthening level for the repair of EPBs. The liability for the increase in repair costs was also a critical issue, since insurance policies for commercial buildings typically stated that the repair of the building, including additional costs necessary to comply with current regulations, are covered but such increase in costs were not included in earthquake insurance risk models.

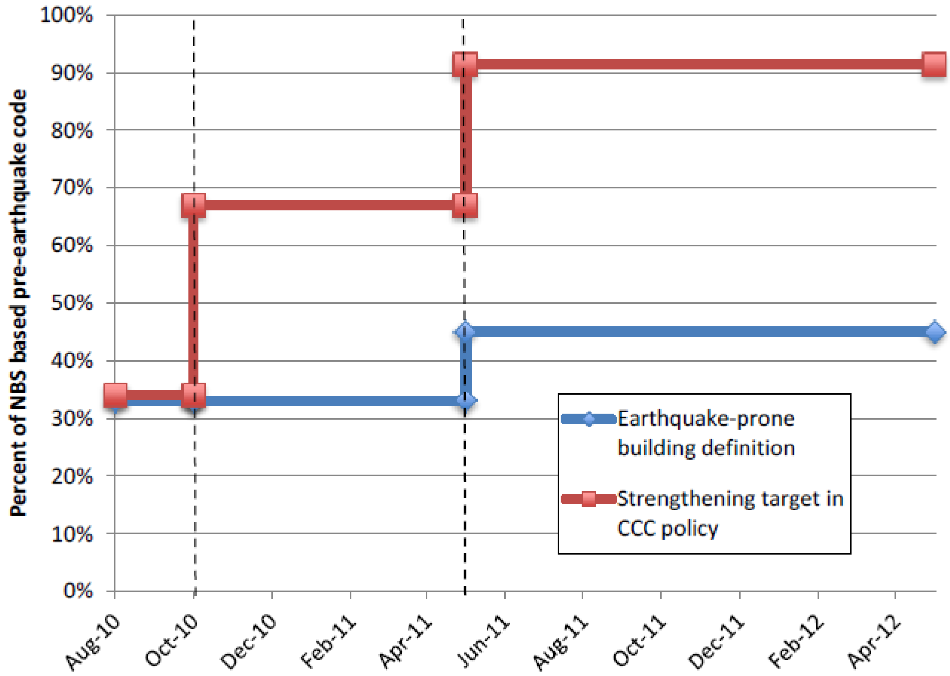


Figure 12: Impacts of the legislation changes and EPB policy since September 2010 (Source: Taylor 2013)

Furthermore, the repair of earthquake damage was considered by the Council as an alteration under the Building Act – Section 112 (because of the absence of any specific legislation for the repair of damaged buildings) and as a result, the assessment and upgrade of fire systems and accessibility features were also triggered. The consequence is that even minor repairs of earthquake damage often required the installation of new fire systems and/or access ramps/lifts, especially for older buildings.

2.9 Post-earthquake building evaluation process

The relevant engineering evaluations used in the aftermath of the Canterbury earthquakes are summarized below, with additional information provided in references. The following sections applied to all non-residential and multi-unit residential buildings located in Christchurch.

2.9.1 Post-earthquake safety evaluations

After each earthquake event, safety evaluations were conducted and the degree of damage was evaluated in accordance with Guidelines for Building Safety Evaluation prepared by the New Zealand Society for Earthquake Engineering (NZSEE 2009). The Guidelines include Level 1 and Level 2 assessments, which were developed based on the ATC-20-2 (ATC 1995). A Level 1 rapid assessment involves a brief external visual inspection of the building to assess the type and extent of a building's structural damage. A Level 2 rapid assessment is still relatively brief but importantly, requires access to the interior of the building for more extensive observations plus reference to available drawings (Galloway and Hare 2012). The Level 2 assessments were typically required on all critical facility buildings, multi-storey buildings, and any other buildings where the Level 1 identified the need for further and detailed inspection. We note that the percentage of New Building Standard (%NBS) is not calculated in this process.

As part of the response to the national emergency following the February earthquake, Civil Defence placed placards on residential and commercial buildings indicating that a rapid assessment had been carried out on the structure. As shown in Table 3, a Level 1 assessment resulted in a building being tagged Inspected (Green), Restricted Use (Yellow), or Unsafe (Red), whereas the Level 2 included further classifications into six grades (Green: G1, G2, Yellow: Y1, Y2, Red: R1, R2) (Uma et al. 2013). Some buildings were red tagged (and categorized as R3) despite having suffered little damage, because of threat from adjacent damaged buildings and ground liquefaction. Under section 45 of the CER Act, CERA has also prohibited or restricted access to commercial buildings which were previously subject to a Civil Defence placard (CERA issued yellow and red placards only).

Furthermore, the rapid assessments (Level 1 and Level 2) include a damage ratio indicator which is a visual estimate of building damage as a ratio of repair cost to replacement cost (excluding contents). This ratio is expressed in ranges of 0-1%, 2-10%, 11-30%, 31-60%, 61-99%, or 100%. Typically, this metric is not intended to be an exact indicator of the repair costs, but provides an estimate to interpret and compare damage levels across buildings, and will be used as a standard damage measure for the case study buildings in Chapter 4. Both Level 1 and Level 2 assessments also included structural, non-structural, and geotechnical damage sub-indicators, assessed by severity: Minor/None, Moderate, and Severe. A copy of the Level 2 rapid assessment form used in post-earthquake Christchurch is provided in Appendix B.

Table 3: Definition of different building color tagging categories (Source: after Uma et al. 2013)

<table>
<tr><th colspan="6">Level 1 rapid assessment</th></tr>
<tr><th colspan="2">Green (G)</th><th colspan="2">Yellow (Y)</th><th colspan="2">Red (R)</th></tr>
<tr><td colspan="2">Inspected. Apparently OK, may need further inspection or repairs</td><td colspan="2">Restricted use. Safety concerns, parts may be off limits, entry only for short periods of time for retrieving important goods</td><td colspan="2">Unsafe. Clearly unsafe, do not enter. Further assessments or evaluation required before any use</td></tr>
<tr><th colspan="6">Level 2 rapid assessment</th></tr>
<tr><th>Green (G1)</th><th>Green (G2)</th><th>Yellow (Y1)</th><th>Yellow (Y2)</th><th>Red (R1)</th><th>Red (R2)</th></tr>
<tr><td>Occupiable no immediate further investigation required</td><td>Occupiable repairs required</td><td>Short term entry only</td><td>No entry to parts until secured or demolished</td><td>Significant damage repairs strengthening possible</td><td>Severe damage demolition likely</td></tr>
</table>

Further to the statistics previously provided in this chapter, we emphasize that 62 demolitions of significant building in the CBD were initiated by the owners and the majority of them (~80% or 51 buildings) presented a damage ratio from the Level 2 assessments of less than 30%. Such statistics clearly demonstrate that many factors other than level of damage may have influenced post-earthquake decisions, especially for demolished buildings not declared dangerous by CERA.

2.9.2 Detailed Engineering Evaluation (DEE)

Detailed Engineering Evaluations (DEE) culminate the post-earthquake building evaluation process and were typically carried out regardless of the outcome of a Level 1 or Level 2 rapid assessment. A DEE is completed in two parts (qualitative and quantitative) and involves a full structural survey of the building to determine the %NBS of the building (pre- and post-earthquake). In addition, the DEE includes a completed standardised spreadsheet. As part of the qualitative procedure, an Initial Evaluation Procedure (IEP) may be completed as an initial step. The IEP consists of a standardised screening tool to approximately assess the building capacity in terms on %NBS (based on age, construction type, primary load path, and any obvious structural damage), and thus aims at determining if a building is potentially earthquake-prone. Moreover, one fundamental aspect of the IEP is the identification and assessment of the effects of any aspects of the structure that would be expected to reduce the performance of the building, such as Critical Structural Weaknesses (CSWs).

On the other hand, the quantitative procedure is typically triggered by the qualitative procedure (typically for cases where there is significant damage, and/or when the building capacity is less 33% NBS). The quantitative procedure is intended to assess the residual capacity of the building in its damaged state by detailed calculations. A quantitative assessment involves the comparison of the Ultimate Limit State (ULS) capacity of the structure with the current Building Code requirements for a new building constructed on the site, expressed as a %NBS. The lack of definitions and assistance, however, considerably limited this methodology in assessing the residual capacity of damaged buildings. The existing guidelines are still in development, and mainly focus in mitigating the seismic risk of existing buildings designed prior to capacity design principles. Methods for incorporating observed damage into the evaluation are largely qualitative and significant issues need to be addressed to enable a more accurate analysis of earthquake-damaged buildings. The Canterbury earthquake sequence also raised the issue of the effect of incremental damage on the residual capacity (due to multiple damaging earthquakes), which is not addressed in the current methodology. Further details on the Initial Evaluation Procedure and the Detailed Engineering Evaluation are provided in EAG (2012) and NZSEE (2006).

Under Section 51 of the CER Act, CERA required all commercial and multi-unit residential building owners in the CBD to provide a DEE of their building. The DEE spreadsheets were designed to provide a consistent and reliable standard damage measure. According to the companion study (Kim 2015), only 35% of the multi-storey concrete buildings in Christchurch CBD had on file a DEE spreadsheet at the time of the interviews (October 2014). Heavily damaged buildings did not have DEE data because demolitions on these buildings were initiated prior to full development of the DEE spreadsheet. Many moderately damaged buildings had no DEE spreadsheet, or it was often incomplete (no %NBS post-earthquake), because of the difficulty to accurately quantify the residual capacity and categorically state the exact strength of the building in terms of % NBS. Also, a DEE was not necessary if a decision was already made that the building was going to be demolished. Reportedly, CERA stopped requiring DEEs to be completed in November 2014 as they no longer contributed to the recovery process. The poor availability of DEE data across a range a damage states considerably limited the value of this data source to compare damage levels across a large subset of buildings.

Chapter 3: Research methodology and design

A conceptual framework was developed to understand the variables influencing post-earthquake decisions (repair or demolish) on multi-storey concrete buildings, and the details on the development of the framework are provided in this chapter. The framework was necessary to illustrate the complex inter-relationships among the identified variables and was developed using an iterative approach with the information gathered from the review of literature and semi-structure interviews.

In terms of progression of the research, the study commenced with a preliminary literature review, identification of the research problem, and collection of empirical data in Christchurch in 2013. This was later followed by a more in-depth literature review and analysis of the Christchurch regulatory context and insurance policies (Chapter 2). Case-study buildings were subsequently selected among the available data for further study. A preliminary framework was created and interview questions were developed based on literature and knowledge gaps needing additional investigation. Interviews with building stakeholders were conducted in New Zealand from September to November 2014. The outcome of these interviews provided a focus for clarifying linkages among the several factors affecting post-earthquake decisions on earthquake-damaged buildings and further allowed the framework to be refined. The final version of the conceptual framework is presented herein.

3.1 Decision-making theories on seismic risks

The literature provides various models and frameworks for understanding the factors influencing decision-making processes in relation to the selection of earthquake risks mitigation strategies and implementation of seismic retrofit (May 2004; Petak and Alesch 2004; Egbelakin et al. 2011). Very few researchers have studied, however, organisational behaviors and decision-making schemes in a post-earthquake environment for infrastructure owners and property managers. It is of critical importance to appreciate how building owners actually make decisions after a disaster, when time, money, resources, or other factors may impose pressures and influence the decision-making process. The examination of this process will provide opportunities for understanding the factors affecting property owners' decisions in relation to earthquake-damaged buildings, and consequently provide insights into how to enhance seismic resilience by preventing demolition of potentially salvageable buildings and substantial loss of the built environment. Nevertheless, because of the very limited literature addressing the topic of interest (specifically post-earthquake decisions), a review of the literature on seismic mitigation decisions was useful for understanding how individuals and organizations (group of individuals, businesses, etc.) analyse complex information and make decisions in relation to extreme events such as earthquakes. This section provides a summary of the relevant literature on this topic.

Theories from social psychology and decision-making are essential to understand how people and organizations seek out, collect, and process information before reaching a decision given definite business objectives and financial constraints. First of all, May (2004) analyzed decisions about seismic performance from the perspective of organizations, and emphasized that the type of organization may influence such decisions. For instance, private and public entities, large and small firms, firms with single facilities and those with distributed facilities, and those with essential and non-essential facilities may have different needs and expectations in terms of earthquake performance of their properties. These organizations are not only different in size and revenue, but they may also have different business strategies, preferences in terms of instruments for addressing earthquake risks (structural retrofit, insurance, alternative use of facilities, etc.), time-horizon perspective (how long a building owner is expected to own the property, future investments, etc.), and tolerance for risk and uncertainty. For instance, the author notes that large companies and those that owned property, rather than leased facilities, are more likely to take greater preparedness efforts in seismic mitigation. From this perspective, the selection of case-study buildings in this thesis included a wide range of ownership type (local, national, international, private, public, non-profit, owner occupiers and not occupiers) to capture the different decision-making variables that are dependent of the nature of the organization (see Chapter 4 for details).

May (2004) suggests that organizational choices are the outcome of joint decision making among individuals in key positions within an organization, influenced by a set of procedural and cultural considerations. Individual decision making is found to be shaped by various biases, for instance the preference and experience of top-level decision-makers, and heuristics, defined as the shortcuts that individuals make in processing complex information and uncertainty. When making choices about earthquake performance, one other important bias is that people have generally a difficult time in addressing uncertainties associated with small samples and probabilities, such as the recurrence of earthquakes (namely the *overconfidence bias)*. The author also discusses how individuals perceive risks for low-probability, high-consequence events, such as earthquakes. The literature suggests that earthquake risks are usually perceived as a binary terms: a risk is perceived or not. Furthermore, individuals involved in the analysis of seismic risk mitigation measures tend to be myopic in their decision making, placing little value on the future benefits of such measures, and overemphasize the initial costs. Individuals also tend to hold off on uncertain investments, especially if the additional risk can be shifted through the purchase of insurance. The latter argument is particularly important for post-earthquake Christchurch, given the high insurance penetration in the country, and the relative uncertainty created by natural disasters, which may have had consequences for post-earthquake decisions. The data collection protocol presented in this thesis included interview questions on these topics (recovery status in Christchurch, perception of risks, and the role of insurance in post-earthquake decisions). Despite differences among organizations and the relevance of different factors shaping choices, May also observed a common sequence in the decision process which can be divided in three major phases: (1) the framing of issues; (2) the interpretation of information; and (3) choices. The details of this decision-making sequence served as a basis for the development of the conceptual framework presented in this thesis (see section 3.2).

Biases and decision heuristics may lead to the selection of less-than-optimal choices from a strictly rational perspective, which are particularly relevant for Christchurch given the lack of clear relationship between structural damage and the high ratio of building demolitions. Slovic et al. (1974) demonstrated this concept in a document addressing the human understanding of probabilistic events, perception of hazards and uncertainties, and the process involved in balancing the risks and benefits when assessing risk mitigation strategies. The authors have explored theories of decision-making within the context of natural hazards, namely decision theory (better alternatives and maximizing utility) and bounded rationality (perception and the limit of cognitive capability). Bounded rationality is typically tied to crises-oriented behavior, misperception of risks, denial of uncertainty, individual as opposed to collective management, etc. Interestingly, an optimal decision is defined as not necessarily the best decision, but the decision that faithfully reflects the decision-maker's personal values and opinions. In other words, the goal of a decision-maker is the achievement of a satisfactory, rather than maximum, outcome. The authors also suggest that even when the risks and benefits are explicitly known, decision-makers have difficulty in integrating data from multiple sources (due to the intellectual limitations of humans and tendency to oversimplify the information), and thus subtle aspects of the information may bias the decision.

Furthermore, past research has demonstrated that decision processes within organizations are guided by the assessments of urgency (survivability) and feasibility (affordability) (Meszaros 1999). Although this study focused on decisions related to reducing risks due to catastrophic accidents in large chemical facilities, general findings can be extrapolated for other low-probability, high-consequence events (e.g. earthquakes). The concept of survivability is used to assess how urgently a particular risk or problem needs to be considered, and affordability relates to the feasibility of taking action. Meszaros (1999) suggests that organizations are typically unwilling to invest in risk-reduction measures that are costly and uncertain if such investments are likely to lead to insolvency. For building owners in Christchurch, the urgency of action was rapidly triggered by the state of national emergency declared after the February 2011 earthquake, the extent of damage in the CBD, and pressures steaming from the authority in charge of the rebuilding of the city (CERA). On the other hand, the feasibility or affordability of taking action was dependent on various factors, such as the insurance coverage, extent of damage, and costs of repair or demolition/rebuild. This thesis seeks to identify and explore such variables.

Additionally, Petak and Alesch (2004) have developed a model to understand decisions about enhancing seismic safety in healthcare facilities in California. Their research focused on a legislation (called SB 1953) requiring hospital facilities built before 1973 to be strengthened up to modern seismic standards (to ensure continued operation after a seismic event) or to be withdrawn from service as acute care facilities. Introduced in February 1994 after the Northridge earthquake, this seismic retrofit program affected more than 1,000 individual buildings, representing about 38% of the hospital buildings in the state. The authors interviewed more than 40 professionals in California including hospital administrators, engineers, policy implementers, and staff to understand the responses of various healthcare organizations to this substantial change in the seismic provisions of the building code. The model suggests that action for the adoption and implementation of risk reduction measures is not taken unless five prerequisites are addressed by the decision-makers (indicated as “Key Element” in Figure 13). The first prerequisite is that the organization must be aware of the issue. Second, decision-makers must believe that is possible for the organization to mitigate the risk (or the consequences) of the issue. Third, decision-makers must believe that it is in the best interests to act now rather than later or not at all. Fourth, an acceptable solution must exist that is compatible with the organization’s values, missions, goals, strategy, and constraints. Finally, the organization must have the capacity to take action, with sufficient resources at a specific time and place. The model also acknowledges that healthcare organizations have to make trade-offs between mission (delivery of services), long-term business objectives, immediate affordability, corporate strategy, and complying with regulations. The model also illustrates that the decision-making process is non-linear, with most organizations addressing the issue of complying with the legislation iteratively, circling back to earlier assumptions. A more detailed description of the flowchart (decision process) is provided in Petak and Alesch (2004).

Possible courses of action included changing the type of occupancy of the structure (from acute care to administration, dorms, etc.), building a new facility, disposing the existing facility, closing the facility, or simply choosing not comply with the regulations and seeking other arrangements. This reference is extremely relevant for this research given the data collection methodology (interviews) and the modelling approach for a wide range of variables. Also, the impacts of the seismic retrofit program (SB 1953) for building owners in California are comparable in certain respects to the consequences of the Christchurch’s Earthquake-Prone Building Policy for building owners in Christchurch, in terms of issues steaming from a recent legislation change. More importantly, one hospital facility is included in the selection of case-study buildings presented in this thesis (see Chapter 4 for details). The research findings discussed in Petak and Alesch (2004) are especially valuable in assessing the complexity of decision-making for healthcare facilities. Although not explicitly detailed in Figure 13, the authors noted other complicating factors in terms of decision process. For instance, most hospitals are part of larger corporations and therefore, each facility do not get to make mitigation investment decisions by themselves. The hospital building presented in the case studies is part of a similar ownership structure.

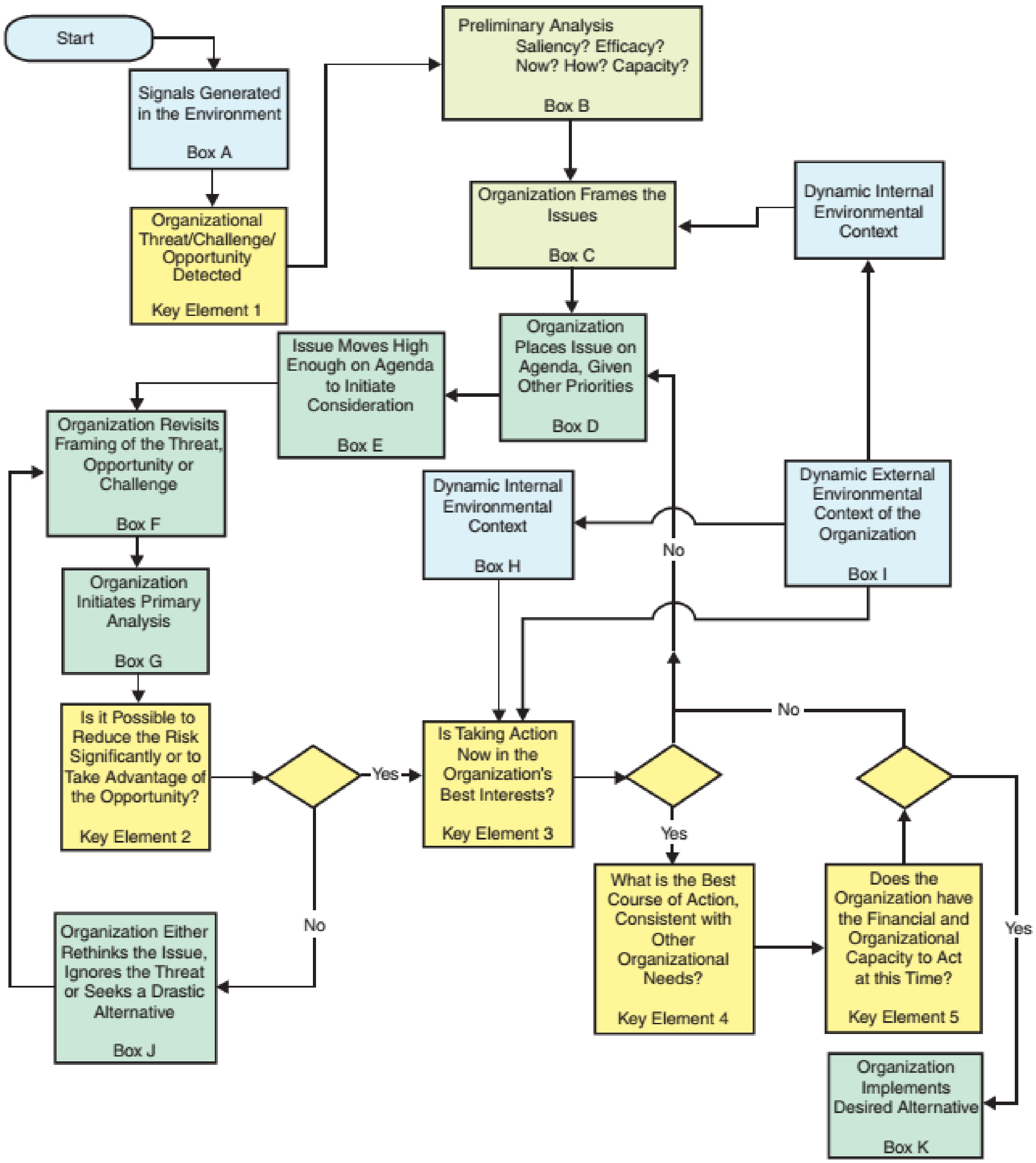


Figure 13: Model of seismic safety decision-making for healthcare organizations (Source: Petak and Alesch 2004)

Similarly, a New Zealand study has examined the relationships among the factors affecting seismic mitigation decision and potential motivators to enhance building owners' risk mitigation decisions (Egbelakin et al. 2011). The data collection methodology included case studies (four cities in New Zealand) and semi-structured interviews conducted with various stakeholders involved in seismic retrofit decisions. The study found that owners of earthquake-prone buildings (as defined in Chapter 2 of this thesis) are unwilling or lack motivation to adopt adequate mitigation measures to reduce the vulnerability of their buildings to seismic risks. A comprehensive conceptual framework (Figure 14) illustrates that the decision process within organizations considering seismic mitigation options is made up of three sequential phases: (1) intention formation, (2) decision formation, and (3) adoption and implementation of seismic adjustments. The retrofit intention (phase 1) is conceptualized as a precursor to the decision-making and analysis process, while the retrofit decision (phase 2) refers to the willingness of a building owner to implement a seismic retrofit strategy which can be influenced by several factors, as indicated in the framework. Extrinsic interventions (see phase 2 in the figure) are particularly important for this thesis because they may have similar roles in terms of post-earthquake decisions. These factors include financial incentives (analogous to the financial benefits of insurance and the role of repair costs in the decision to repair or demolish), creating value for seismic risks in the property market (e.g. % NBS of the building and low level of perceived economic benefits from retrofitted EPBs) and building trust among building stakeholders. Interestingly, the authors argue that there is a lack of trust in design engineers and the efficacy of seismic retrofits from the perspective of building owners. This was partly explained by inconsistencies and disparities among consulting engineers in New Zealand in terms of recommended action for earthquake-prone buildings, creating uncertainties in the decision process. This argument reiterates previous observations where individuals tend to hold off on uncertain investments (May 2004). This thesis seeks to identify and explore such variables. The utility of the framework lies in its function to examine how individuals make decisions regarding seismic mitigation and how motivational factors are related to the voluntary adoption of seismic mitigation. From this perspective, a sequential approach is also proposed in this thesis to conceptualize the relationship among the variables influencing demolition decisions and to describe the players involved in the decision process.

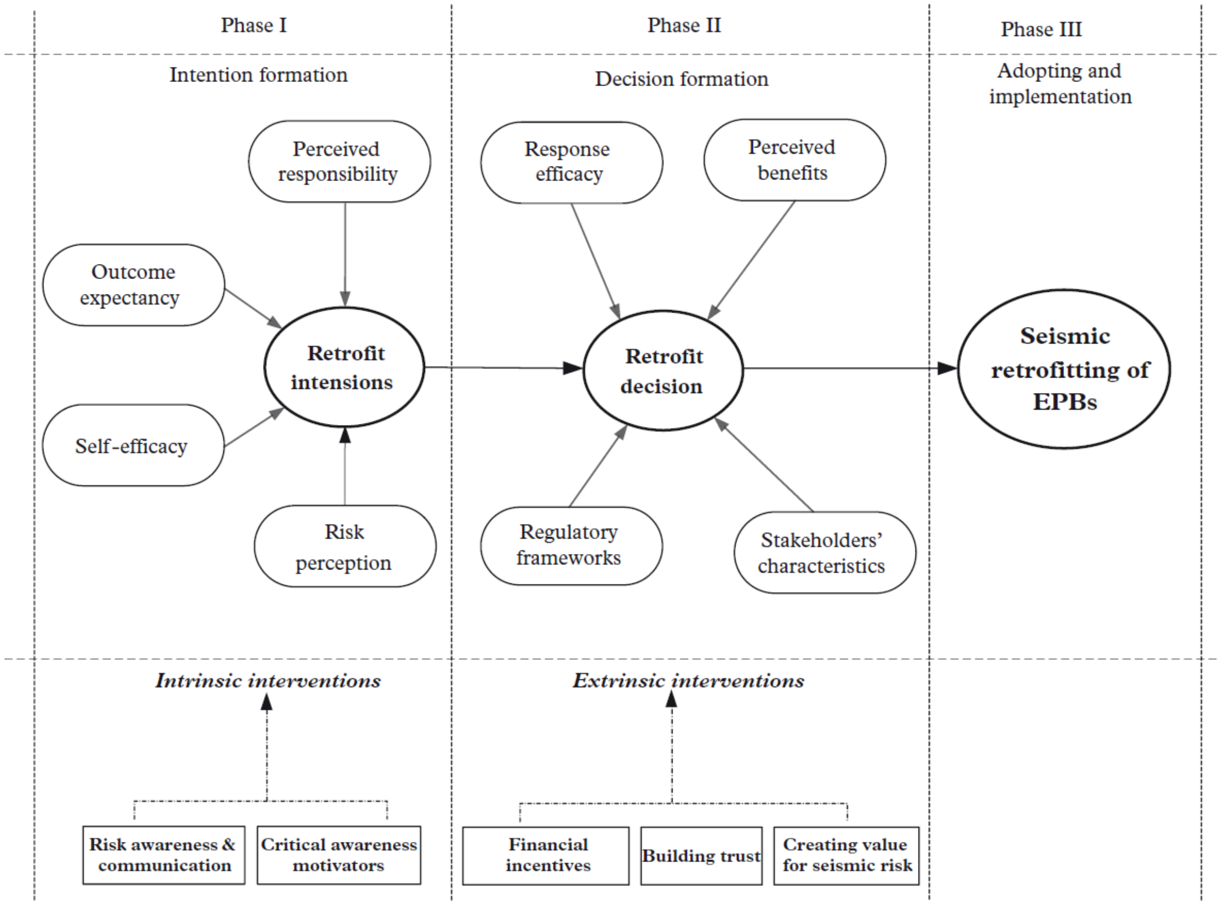


Figure 14: Seismic risk mitigation decision framework (Source: Egbelakin et al. 2011)

3.2 Conceptual framework

A conceptual multi-phase framework was developed prior to the interviews and refined based on observations from the interviews and data collection (Figure 15). The framework is a tool to study how building owners and organisations responded to the Canterbury earthquakes and made decisions on the future of their buildings, with consideration given to the different players involved in the process (engineers, insurers, tenants, etc.).

The sequential phases of the framework facilitated the organisation of the data collection process in a chronological order, from post-earthquake visual inspections to subsequent impacts on building stakeholders, together with possible outcome scenarios. For the sake of completeness, a contextualisation phase defines the pre-earthquake conditions of the building, ground conditions, ownership details, and insurance policy (material damage and business interruption). The framework adopts a holistic perspective by providing the necessary background for a specific building, in addition to taking into account any particularities of the built environment or socio-economic conditions that may have influenced the final decision (as discussed in sections 2.1 and 2.2). Although some variables may be more significant than others in relation to a specific building, findings from the study suggest that decision-making variables influencing the course of action on earthquake-damaged buildings may be grouped into four themes: insurance, damage and residual capacity, decision-making strategies, and legislation. Observations from the interviews revealed that the interrelation of these factors, in addition to the unique features of the earthquake sequence and uncertainties in the recovery of Christchurch, added complexity in determining appropriate courses of action. Results presented in this thesis are organized based on these four interacting themes (Chapters 4 and 5).

A comprehensive list of factors that were considered for the design of the interview protocol and the analysis of post-earthquake decision-making processes across the case-study buildings is presented in this section (Tables 4 to 8). Factors are classified in relation to the categories and sub-categories presented in the framework. The list of factors and descriptions were refined based on the outcome of the interviews.

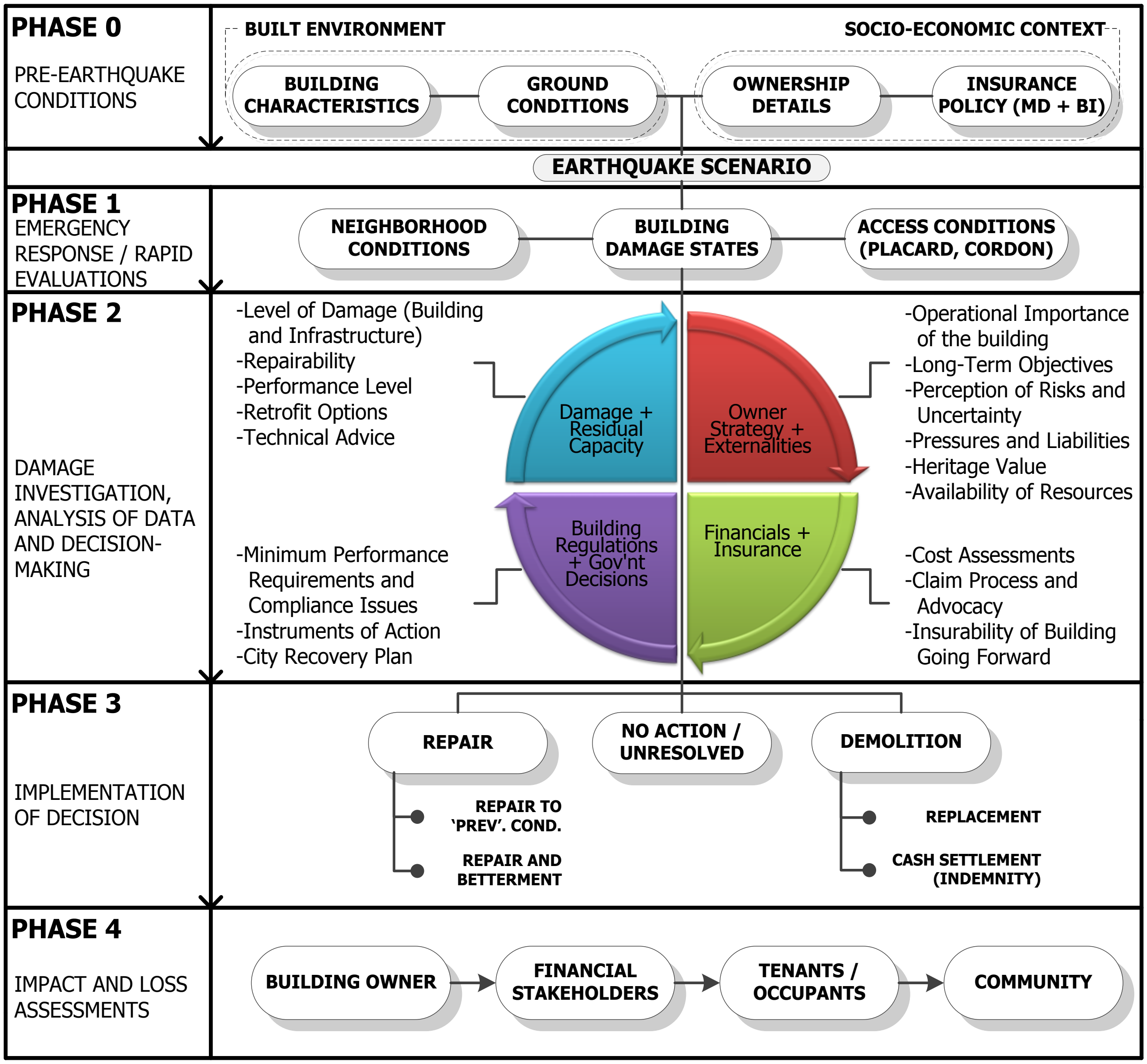


Figure 15: Conceptual framework for studying variables influencing post-earthquake decisions

Table 4: Framework - Pre-earthquake conditions (phase 0)

Building Characteristics	
Location	▪ Building Name and Address (presented by a code)
Geometry and General Characteristics	▪ Number of floors ▪ Construction age/year of design ▪ Importance Level (IL) and Heritage building classification (if any)
Structural System	▪ Gravity system and configuration + foundation type ▪ Primary lateral load resisting system, ductility (μ), and configuration ▪ Struct. irregularities / critical structural weaknesses (CSW) (if any) ▪ Level of overall strength in relation to current code - pre-earthquake conditions (ratio of New Building Standard),
Non-structural Components	▪ Stairs, wall and roof cladding, glazing, and ceilings characteristics ▪ Any other relevant details
Ground Conditions	
Soil properties	▪ Soil Type and Site Class + any other relevant details
Ownership Details	
Occupancy	▪ Building occupancy ▪ Tenants (owner/non-owner tenants)
Owner Characteristics	▪ Owner type (private, public, non-profit, investor, institution, local, national, international, small, large, etc.), ▪ Owner portfolio and line of business
Financials	▪ Property/Market value (building only)
Insurance Policy (MD + BI)	
Generalities	A brief description of the insurer (NZ/overseas, single/multiple, etc.) and any other non-typical details of the policy enabling an in-depth qualitative analysis of the relation between the insurance coverage and the decision.
Material Damage (MD)	Material Damage (MD) policies cover physical damage caused by the direct (and indirect) result of the earthquake and provide indemnity and/or reinstatement cover. Most New Zealand commercial policies typically specify a sum insured. For the purposes of this study, the following factors are of interest: ▪ Nature of the cover (full replacement, indemnity, other) ▪ Sum insured
Business Interruption (BI)	Business Interruption (BI) policies cover a building owner for any income losses resulting from earthquake damage to the property. Usually, cover for business interruption is linked to the Material Damage provisions in the policy: cover is provided if material damage occurs in the building and the type of damage causing the interruption is not excluded. Business interruption policy wordings are relatively standard in New Zealand, however the following factor is of interest: ▪ Indemnity period (number of months)

Table 5: Framework - Emergency response and rapid safety evaluations (phase 1)

Building Damage States (Level 2 rapid assessment)
Building damage states are determined from visual assessment of damage and defined as the: ▪ Overall building damage level (very approximately intended to represent a ratio of the repair cost to the building replacement value, excluding contents) Building damage states are extracted from the Level 2 rapid assessment forms (NZSEE 2009) and classified under the following categories (adapted from *ATC-20 Procedures for post-earthquake safety evaluation of buildings* by the Applied Technology Council): ▪ 1- Overall Hazards/Damage 2- Structural Hazards/Damage ▪ 3- Non-Structural Hazards/Damage 4- Geotechnical Hazards/Damage Damage indicators are descriptive as well as quantitative. The severity of damage for each variable is categorized as [minor/none], [moderate], or [severe]. The overall building damage level is an estimation based on visual observations and judgement, and defined as [None], [0-1%], [2-10%], [11-30%], [31-60%], [61-99%], or [100%] of the building estimated value. Note: the term damage, when used in this framework, refers to the damage suffered during the damaging earthquake by the building in its existing condition immediately before the earthquake. It is important to note that prior effects of environmental deterioration and service conditions are considered to be pre-existing conditions and not part of the earthquake damage states. The interpretation of damage resulting from earthquakes is complex and requires experience and judgement. The Level 2 rapid assessment form provide a tool for an engineer to apply experience and to formulate judgment on the effects of earthquake damage on future performance. A copy of the Level 2 rapid assessment form used in post-earthquake Christchurch is provided in Appendix B.
Neighborhood Conditions
The neighborhood conditions refer to building damage in the vicinity of the studied building. This is expressed as a percentage of buildings that are located within a 100 m radius which have been demolished. This information is collected qualitatively from the interviews (impacts in terms of the decision) and quantitatively from the CERA database (actual percentage of demolition).
Access Conditions (placard and cordon)
The access conditions refer to the amount of time a specific building was inside the CBD cordon, in addition to the type of placard (notice). To determine how long each building was inside the cordon and had restricted public access, the date that cordon was lifted for each building was obtained and the number of months inside the cordon was calculated. The placard code is: red (access is prohibited), yellow (access is restricted) or green (inspected). Placards issued by Civil Defense indicate that a basic safety assessment had been carried out and as a result, the structure is classified as [red: R1, R2, R3], [yellow: Y1, Y2] or [green: G1, G2]. Access conditions data are collected qualitatively from the interviews, and quantitatively from the Level 2 rapid assessments and from Kim (2015).

Table 6: Framework - Damage investigation, analysis of data and decision-making (phase 2)

Damage and Residual Capacity	
Damage sustained to structure and services and ease of repair	A detailed damage assessment provides a description of the level of structural damage and defines the scope of repair required (and likely cost and time for the repairs to be made). The form of this information may include an engineering report (e.g. a Detailed Engineering Evaluation spreadsheet for Christchurch). Damage indicators are both qualitative and quantitative, and include: ▪ Level of overall strength in relation to current code - post-earthquake conditions (ratio of New Building Standard) (if available) ▪ Critical Structural Weaknesses (if any) ▪ Residual capacity or damage ratio as defined in the DEE.
Expected performance for future earthquakes and ease of retrofit	The expected performance of the building in future earthquakes is defined as how the structure is expected to perform in future earthquakes and whether the building has sufficient structural integrity to maintain its performance objective (life-safety or higher). Where retrofit is required to improve performance, details include the feasibility of retrofit options, likely costs and time required, and how retrofit options might impact on the current use and functionality of the space.
Technical Advice	This item includes any technical advice (from structural and geotechnical engineers) given to building owners, insurers and authorities in relation to the building damage, scope of repair and expected performance in future earthquakes.
Owner Strategy and Externalities	
Nature of pre-existing use and availability of alternative sites	This factor looks at the function of the building under normal business operations, and the ease to find temporary or permanent alternative space. Some building uses are more difficult to move to alternate space than others (hospital versus office buildings). Additionally, this factor may be more relevant to the decision outcome if the building owner is a tenant of the studied building.
Level of disruptions on business operations	This factor is defined as the level of impacts and ability to maintain business operations, whilst repairs are undertaken or building replaced, given the line of business and availability of alternative sites. This factor may be more relevant to the decision outcome if the building owner is a tenant of the studied building.
Importance of use to overall strategy	This factor looks at how critical the activities likely to be impacted in relation to the organization's overall recovery strategy and ongoing or future operations. Furthermore, the framework aims to capture whether the owner has expected to continue leasing/utilizing the building or that it was envisaged to sell/replace the building in the medium term. This factor may correlate to the pre-earthquake socio-economic context of the city (Christchurch: low rents, surplus of office space, etc.).
Current functionality of space	This factor looks at the expected remaining life of the studied building before major refurbishment or alterations might be required. The framework aims to capture how fit-for-purpose was the building before the earthquake and if a major refurbishment (or replacement) was already needed.

Table 6: Framework - Damage investigation, analysis of data and decision-making (cont'd)

Owner's Performance Requirements	This factor is defined as the level of compliance with the current code and how this level has affected the outcome from the owner's strategy perspective. There are many advantages of investing in strengthening to a higher standard than the minimum required, or simply replace an old building with a new building. This is especially important in the competitive market of Christchurch where there will be many new buildings built to 100% NBS or higher in the CBD.
Heritage / Character value	This factor is defined as the extent to which the building architecture or unique features make it iconic within the context of the organization or the city and how this level has affected the outcome. The emotional attachment to the building (from the building owner and/or tenants' perspective) is also of interest.
Perception of building safety by staff or tenants	This factor determines to what degree the tenant's preferences and decision influenced the outcome from the owner's perspective. Specifically for Christchurch / New Zealand: building owners are only required to strengthen if the building's seismic capacity falls below the level of 33% NBS under current legislation, however some tenants may put pressures for having premises at more than 34% NBS.
Financial liabilities and ethical responsibility	This factor determines to what degree the preferences or pressures from shareholders, lenders and other organizations having a financial stake in the building may have affected the outcome.
Uncertainty about the future	This item discusses the uncertainties faced by building owners following the earthquakes (e.g. Canterbury Earthquakes: the impacts of the CCDU recovery plan and its implementation timeline, the social and economic recovery of Christchurch, the numerous demolitions in the CBD, the uncertainties on how to ensure a building will remain profitable, lettable and insurable in the future, uncertainties surrounding tenants' preferences and market conditions, etc.). This factor determines to what degree uncertainties in the recovery affected the decision outcome from the owner's perspective.
Availability of Resources	As with any disaster event, resources are constrained and this may impact post-earthquake decision-making processes. For instance, engineers may have to be brought in from overseas to assess building damage, which potentially result in different approaches and interpretation of local building standards. Resources shortages may also result in delays for the claiming process and recovery.
Financials and Insurance	
Operating and Maintenance Costs	Factor related to the ongoing lifecycle of the building in its pre-earthquake conditions: costs to operate and maintain the building and any major expenditures planned on the building in the medium term.
Cost to Repair / Strengthen	Factor defined as the cost to repair and/or retrofit the structure to meet minimum performance requirements (or higher performance level desired by the owner) and maintain occupancy whilst repairs are undertaken (or costs for temporary premises).
Cost to Demolish	Factor defined as the cost to demolish the structure and remove debris from the demolition site.

Table 6: Framework - Damage investigation, analysis of data and decision-making (cont'd)

Cost of Replacement / Rebuild	Factor defined as the cost estimate for the different options where possible replacement / rebuild scenarios have been identified.
Funding	The total cost is compared to the cost for the building owner net any insurance payouts (and government compensation, if any) that can be applied to the works on the particular building [Percentage of the overall costs recovered].
Claim process and advocacy	Factor related to the insurance claiming process that may have significantly influenced the decision outcome in relation to a specific building, such as claim practices, underinsurance, disparities in recommendations among owner's and insurer's engineers or experts, delays, etc.
Insurance issues going forward	This item discusses to the affordability and accessibility of insurance going forward and any particular conditions stipulated within post-earthquake insurance policies that may have influenced the outcome on a specific building from the owner's perspective. For instance, the cost of owning and operating buildings that do not meet current seismic design requirements may have gone up because insurance premiums have gone up significantly for such buildings.
Building Regulations and Government Decisions	
Minimum performance requirements	This item refers to the level of compliance with the current code (e.g. earthquake-prone building policy) and how building regulations (and changes in the regulation since the earthquakes) have affected the outcome for specific buildings. Minimum performance requirements may have significant effects on the scope and costs of the repair, the insurability of the building (cover will almost certainly change in the future if it is determined that a building is earthquake-prone) and the market value (difficult to attract tenants or future investors without strengthening works for buildings with low %NBS). Compliance to other requirements such as fire protection or disability access may be triggered when applying for a building consent for earthquake repairs. These requirements may also result in additional expenses covered by insurance.
Instruments of action – Demolition Works	Specifically for Christchurch: The Section 38 and Section 39 of the Canterbury Earthquake Recovery Act 2011 are determining instruments of action influencing post-earthquake decisions in Christchurch CBD. The Act provides CERA the power to carry out or commission demolition works to a building which has been identified dangerous or likely to cause loss of life or injury, or damage to property or the environment, or danger to any works or an adjoining property. The Act also provides CERA the power to carry out demolition works on any buildings to enable a focused and expedited recovery, and facilitate the rebuilding of the city.
City Recovery Plan	Specifically for Christchurch: The Christchurch Central Development Unit (CCDU) is part of CERA with a mandate to plan and facilitate the rebuild of the Christchurch CBD. CCDU has the power to acquire parcels of land in specific areas of the CBD to enable the Christchurch Central Recovery Plan. CERA determines if the land is designated for compulsory acquisition under the CCDU program, and the building is consequently demolished. The building owner receives financial compensation for the land and the building (insurance and/or government compensation).

Table 7: Framework - Implementation of decision (phase 3)

Decision	
Repair / retrofit	A repair scenario (or repair and upgrade to a percentage of the building code) is selected and implemented. Typically, material damage insurance policies would provide the value of repairs to 'when new' conditions: the restored building should behave in future earthquakes as it would have in its pre-event condition. An upgrade may also be implemented to improve the seismic performance of the building compared to its pre-event condition, in order to comply with current regulations or to achieve a desired performance level.
No action / Unresolved	Alternatives, iterations, and trade-off decisions are required. No action may also refer to buildings having no/slight earthquake damage. The owner may accept the building for continued use in its damaged condition.
Demolition	The building is demolished. Subsequently, the building owner may : ▪ Reinstate/Replace the property on the same site or elsewhere, or ▪ Accept a Cash Settlement (based on the indemnity value and sum insured)

Table 8: Framework - Impact and loss assessment (phase 4)

Impacts and Losses	
Building Owner	Economic Impacts: ▪ Overall losses (including loss of rent/profit) associated with the decision net any insurance payouts or government compensation. ▪ Long-term losses not covered by insurance ▪ Affordability and accessibility to insurance going forward ▪ Opportunity to rebuild better, capitalize from insurance payouts or revise business strategy and portfolio Social Impacts: ▪ Assistance to staff / loss of clients / uncertainty / emotional impacts
Financial Stakeholders	Economic Impacts: ▪ Overall losses for businesses and financial stakeholders (e.g. lenders) net any insurance payouts or government compensation.
Tenants / Occupants	Economic Impacts: ▪ Business disruptions (including loss of profit) for tenants ▪ Loss of asset and associated issues Social Impacts: ▪ Displacement of staff, emotional impacts (e.g. stress, uncertainty)
Community	Economic Impacts: ▪ Business disruptions / Movement of businesses / Economy Social Impacts: ▪ Displacement of people, opportunity for the revitalization of the city, etc. Environmental Impacts: ▪ Loss of familiar built environment, change of urban landscape ▪ Debris from demolition + impacts related to the re-construction

3.3 Methodological approach and data collection

This section discusses the research design, methods and procedures employed in this study to address the research objectives and to enable the data collection. As noted in the literature review (section 3.1), very few researchers have studied decision-making processes for commercial building owners in a post-earthquake environment. As a result of the lack of theoretical framework and substantial empirical studies, an explanatory approach was required for this research. Hence, a qualitative approach strategy was selected to assess the nature of the research problem, including multiple case studies and semi-structured interviews. Personal face-to-face interviewing was adopted as the main data collection technique to enable an in-depth understanding of the research topic.

3.3.1 Multiple case studies approach

A multiple case studies research approach using semi-structured interviews was chosen to allow different building owners and other stakeholders involved in post-earthquake management to describe the complexities of the decision-making process for specific buildings. This methodology enabled the refinement of the framework presented in this chapter and a qualitative assessment of the key factors influencing demolition decisions in Christchurch. This process also allowed the comparison of the participants' opinions across the cases, thus providing a holistic perspective of examining the research problem. With the assistance of locally-based research partners, the research team conducted 27 interviews to gather in-depth qualitative and quantitative data on the decision-making process regarding the demolition or repair of buildings, including resulting impacts on building stakeholders, lessons learned, and challenges going forward. For exploratory analysis, interviewees were grouped into four categories by their relation to the decision, the building, and type of organisation (Appendix C). The sample of stakeholders selected was selected to balance different views and opinions from building owners and senior representatives, engineers, insurers, and governmental organisations that have been involved with post-earthquake decisions. The interviewees were selected on the basis of either their professional decision-making roles in relation to the case-study buildings or their roles as representatives of groups influencing post-earthquake decisions.

The primary criterion used for case selection in this study is the direct relevance to the research problem and objectives. Because of the prevalence of concrete structures in Christchurch, the focus was on multi-storey concrete buildings in the Christchurch CBD. Specific building owners were invited to participate in the project, selected on the basis of their interest in the project (agree to participate), availability, and a list of candidate buildings. Candidate buildings were selected in 2013 with the help of engineering consultants involved with post-earthquake assessments of Christchurch buildings. Case studies were chosen to achieve variation on relevant features such as age, size, structural systems, occupancies, damage levels, ownership, and outcome.

Also, criteria for the selection of candidate buildings included the following:

- Decision is made (Demolish or Repair)
- Insurance process completed
- Owner willing/agree to share story
- Engineering consultant/building owner willing to make files available (if any)
- Detailed damage survey available
- Drawings available
- Performance not dominated by one specific and very unique condition

The study also includes the collection of detailed data (structural drawings, damage evaluation reports, insurance policies, financials, etc.) to explore the range of factors influencing the decision, offering explanations regarding the relationships found among the identified factors. Data were collected through various methods: extraction of information at Christchurch City Council (Level 2 rapid assessments, building consents, and property details) and CERA (Silverfish database), technical reports from CERA and research organisations, reports from the Canterbury Earthquakes Royal Commission, popular media articles, and data sharing with structural engineering consultants.

3.3.2 Interviews and interview protocol

A semi-structured interview protocol (questionnaire) consisting of pre-determined open-ended questions was used as the data collection instrument (Appendix D). The interview protocol focused on post-earthquake decisions for building structures and allowed for spontaneous and follow-up questions on the research topic. The interview protocol is important to compare responses among participants, and assist to clarify linkages between the factors identified in the framework.

The interview questions were designed with the following objectives:

- To investigate the range of factors influencing building owners' post-earthquake decision-making regarding the fate of earthquake-damaged building (case-study buildings)
- To examine the influence of the regulatory environment and insurance policies that may have incentivized building owners to demolish rather than repair
- To facilitate the data collection process for the case-study buildings

The research team and industry experts reviewed the interview protocol and identified specific areas to probe during the interviews. Potential participants were first contacted by email to explain the nature of the research using a letter of contact. Non-responding potential participants were later contacted with follow-up emails or phone calls to solicit participation and arrange for interviews. The participant information sheet and consent form were attached in the invitation email.

All of the interviews were conducted in-person in Christchurch, Wellington, or Auckland from September to November 2014. The majority of the interviews (22 out of 27), which typically lasted for 90 minutes, were audio-recorded with permission and transcribed. Interview questions focused on the respondents' perspectives on post-earthquake decisions, sought to document building damage data, and enabled the interviewees to 'tell the story' for specific case-study concrete buildings. The interviews typically took place in the interviewee's respective offices within the different cities. The questions were similar for all the participants but a few questions were reworded to reflect the different stakeholders' perspectives (see Appendix D). All of the interviewees were asked about their own roles in the post-earthquake response and recovery, how well they considered Christchurch's recovery to be proceeding, what steps and issues were involved in the decision making process, and finally what lessons the disaster had provided in terms of risk mitigation strategies.

The transcripts provided a complete record of the interviews, which facilitated the analysis of the discussions (identification of key arguments, themes, and linkages among the factors influencing the decisions). Some participants were re-contacted by email or phone to clarify the relevant section of the transcript that was unclear or for missing data. In addition to semi-structured interviews, some participants provided documents such as seismic assessment reports, financial reports, and insurance policies which were useful in filling the gaps of the data collection and enabled a thorough analysis of post-earthquake decisions. The research team has reviewed the documents, notes and transcripts for consistency with the audiotape. The analysis of the relevant documents, notes and transcripts provided insights and interpretations of the themes discussed in the framework and helped to clarify some factors influencing post-earthquake decisions. The findings are reported in Chapter 4 (case-study buildings) and Chapter 5 (overall results).

Chapter 4: Case studies

This chapter presents in-depth investigations on 15 case-study buildings and specifically addresses the factors influencing post-earthquake decisions (repair or demolish). The objective of the multiple case studies approach was to provide insight into the research problem and ensure that the most important factors are included in the analysis. A summary of the case-study building characteristics is provided, in addition to a detailed description of the cases, including ownership, insurance, damage levels, and any other necessary data for the analysis of the decision process. The comments provided by the different building owners and review of the relevant engineering reports were used as evidence and facts throughout the study. Findings from this chapter provided variables needed for the refinement of the framework (Chapter 3) and strengthened general observations from other interviewees. Overall results from the interviews are presented in Chapter 5 of this thesis.

4.1 Summary of cases

Fifteen multi-storey reinforced concrete buildings distributed throughout the Christchurch CBD and immediately surrounding neighborhoods were selected and specific information such as structural drawings, insurance coverage, detailed engineering evaluations, and damage assessment reports were collected (if available) for each building (Table 9 and Table 10). For anonymity purposes, buildings are identified by a code, where the letter indicates that the building was demolished (D) or repaired (R), and the numbering refers to a database entry (except for buildings R901 and R902, absent from the database) (Kim 2015). According to the companion study, this subset is found to be roughly representative of the CBD concrete building stock having similar characteristics (Figure 16). The companion study included a database of 223 RC buildings that are 3-storey and higher within the CBD, and included information such as building identification information, decision outcome, damage indicators, seismic force resisting system, duration in cordon, construction year, heritage status, footprint area, number of floors, and type of occupancy (Kim 2015). In terms of outcomes, 62% (138 buildings) were demolished and 29% (65 buildings) were repaired, while the decisions for the remaining 20 buildings were unknown at the time of the data collection. For comparison purposes, approximately half of the case-study buildings have been repaired (7), while the balance has been demolished (8), including a mix of owner-initiated and authority-mandated demolitions (required by CERA under s38). As aforementioned, buildings demolished under the Christchurch Central Development Unit (CCDU) and Civil Defence (CD) were left out of the research scope (for the case-study building subset) because the decision process was more straightforward and intuitive. Among the demolished buildings, a similar proportion of buildings were declared dangerous by CERA in both studies, accounting for approximately 40% of the cases. All buildings are RC structures, with the dominant seismic force resisting systems being moment frames (MF) and shear wall (SW), representing approximately 46% and 27% of the case-study buildings, respectively. The proportion of shear wall buildings was much higher in the companion study (44%), representing a higher proportion of low-rise buildings in the database (58% are 3-5 storey high). Out of 223 buildings, 61% (135 buildings) were assessed to have a damage ratio from the Level 2 assessments of less than 10%, and 47 % of them were demolished. Similarly, 71% of the case-study buildings (10 cases) have a damage ratio of less than 10%, of which 40% were demolished. Finally, out of 223 buildings, 35% received green, 46% received yellow, and 19% receive red placards, and likewise, the selection of case-study buildings achieved comparable proportions of placards with 40% green, 40% yellow, and 20% red placards.

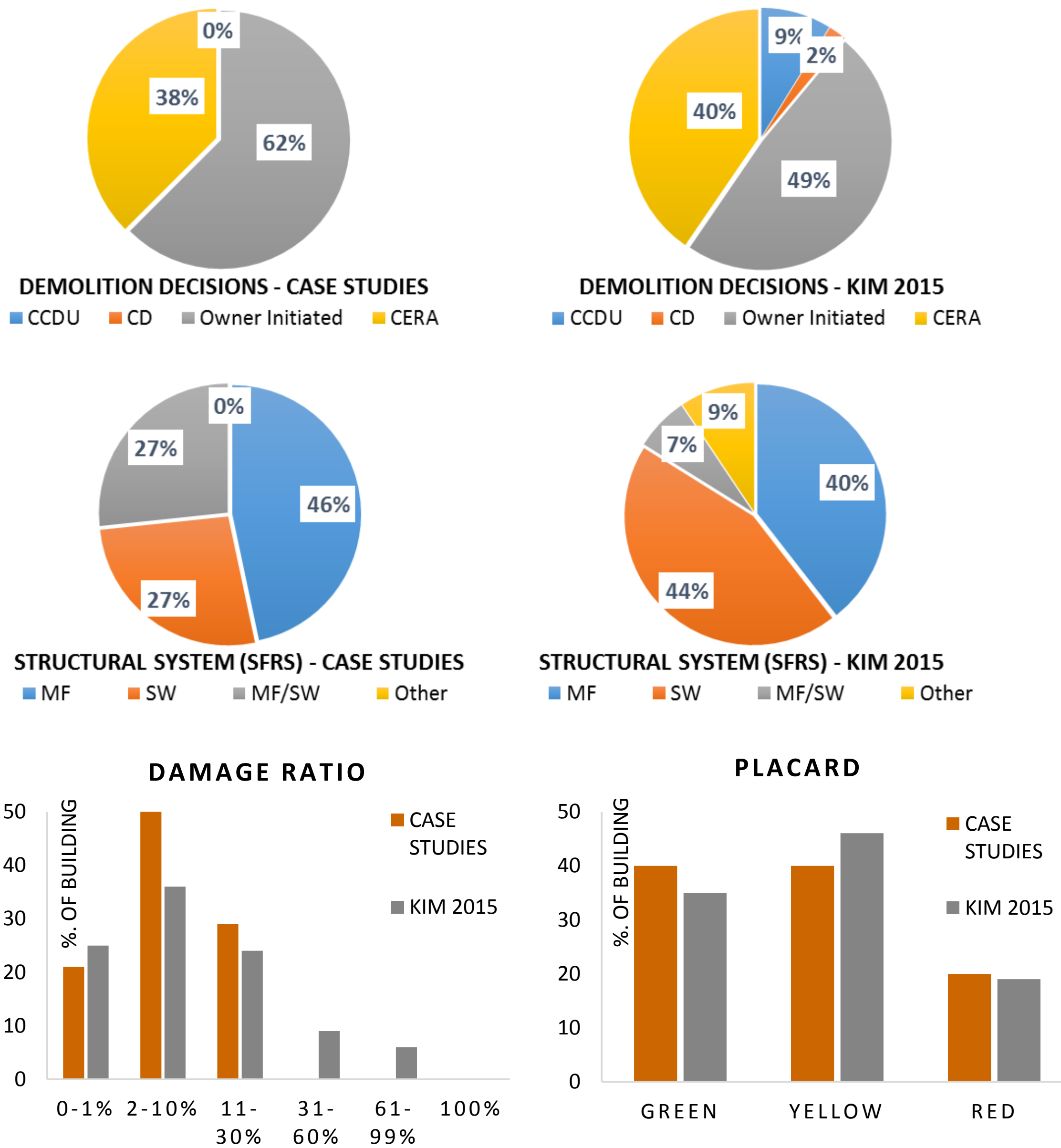


Figure 16: Overview of building characteristics – Case-study buildings and companion study (Data source: Canterbury Earthquake Recovery Authority – Silverfish Database and Kim 2015)

One case-study building is yet to be demolished at the time of writing (D210). Among the five owner-initiated demolitions, being out-of-plumb (between 130 mm and 230 mm) due to foundation settlement was reported as the governing damage for three buildings (D11, D49, and D201), and demolition and reconstruction of the entire structure appeared to be the only viable option because of the high degree of risk and uncertainty associated with grout injection and soil stabilisation. Two demolished buildings (D73, D210) suffered limited structural damage, however, significant strengthening would have been required to achieve the owner's desired performance level (>34% NBS) which rendered the repair uneconomic or impractical. Three significantly damaged buildings (D117, D192, and D196) have been demolished under a Section 38 of the CER Act due to safety concerns and the risk of partial collapse, based on the observed structural damage and the likely behaviour of the structure in future aftershocks.

Among the buildings that have been repaired, four buildings (R74, R86, R202, and R902) performed relatively well (limited structural damage, however extensive non-structural damage) and the final repair costs varied between 10% and 20% of the sum insured. Specifically for building R902, the owner took the opportunity to upgrade the foundation system (base isolation) and therefore the overall costs (repair and improvements) were much higher. One property (R163) was found to be earthquake-prone (less than 33% NBS) in its damaged condition and the restoration costs, including strengthening to achieve compliance to building regulations, represented approximately 65% of the sum insured. The final cost of repair for two buildings (R113, R901) was not available at the time of the interviews. For the demolished cases, the final estimated repair costs were typically much higher than the cost ratio provided from the Level 2 rapid assessment forms, in part because of the approximate nature of the Level 2 assessment and uncertainties in the repair costs, but also due to post-disaster demand surges and resources shortages in the construction industry not taken into account in the Level 2 forms. For instance, the repair and strengthening costs for building D73 ranged between 45% and 70% of the sum insured (estimate).

As shown in Table 10, buildings with CERA-mandated demolitions presented a concentration of severe damage whereas the majority of buildings with owner-initiated demolitions had similar damage states in comparison to repaired buildings (most damage descriptors have a minor/moderate hazard). The concentration of severe damage for authority-mandated demolitions suggests that recommendations from CERA were primarily based on the dangerous nature of the building caused by earthquake damage. An earthquake-prone building should not be deemed dangerous in terms of the CER Act if it remained undamaged. Specifically for building D49, the level of observed damage was relatively severe in comparison to other owner-initiated demolitions, however the building was not declared dangerous since the seismic force resisting system remained relatively undamaged and the building was expected to perform in a ductile manner without collapse in future aftershocks. Moreover, one demolished building (D210) suffered minor structural/non-structural damage, however a significant strengthening upgrade was desired by the owner which rendered the repair uneconomic or impractical. Figure 17 shows a plan of the CBD indicating the location of the buildings (blue triangle) relative to the extent of the CBD cordon at various timeframes. Further details for each case-study building are provided in the next section.

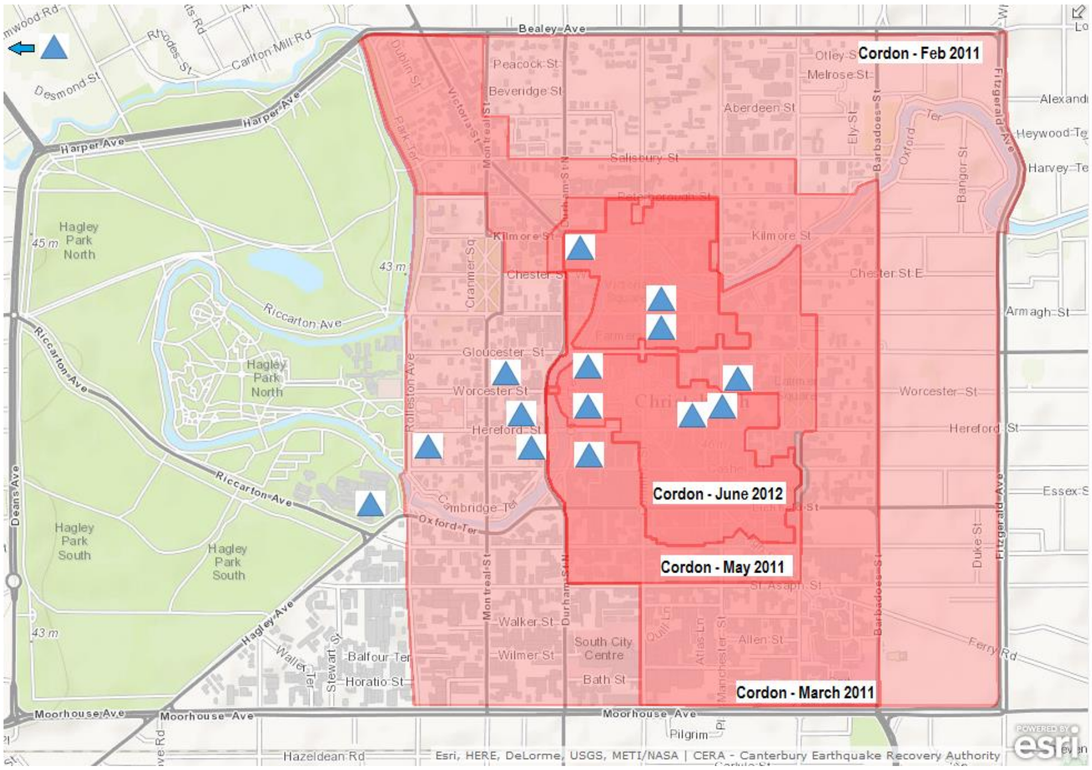


Figure 17: Map of Christchurch CBD showing location of case-study buildings (Source: after Canterbury Earthquake Recovery Authority, http://cera.govt.nz/maps)

4.2 Description of cases and data

Specific details and findings for each case-study building are provided in the following subsections. A large proportion of information was retrieved from CERA (Silverfish database), which was complemented by insights from semi-structured interviews with building owners, technical reports from research organisations, reports from the Canterbury Earthquakes Royal Commission, popular media articles, and data sharing with structural engineering consultants. The review of such data enabled a better understanding of the uniqueness of the decision-making process for each building. A summary of damage (structural, non-structural, and geotechnical) is provided for each case. The findings are presented based on the framework outlined in Chapter 3 and aim to cover all of the pertinent facts and details about the building which helped to arrive at the overall observations in Chapter 5. Some details have been obscured due to confidentially agreements.

Table 9: Summary - Case-study building profiles (Data source: Canterbury Earthquake Recovery Authority – Silverfish Database, interviews with building owners, and Christchurch City Council Database)

		ID	Year of Design	Number of Storeys	Lateral System	Design Ductility	Overall NBS Pre-EQ	Regular Structural Form	Foundation System	Occupancy	Owner Type	Site Sum Insured[2]	BI[3]	Placard[4]	Overall Damage Ratio[4]
DEMOLISHED	CERA	D117	1987	17	MRF	3.00	34-66	✓	Spread Footings	Offices	International	250 %	36	R1	11-30
		D192	1986	13	Shear Wall	n/a[1]	34-66	Asym. plan	Pile Caps	Hotel	International	360 %	36	Y2	2-10
		D196	1986	8	Shear Wall	n/a[1]	34-66	High torsion	Spread Footings	Offices	Private / Small / Local	220 %	24	R1	11-30
	OWNER INITIATED	D11	1987	22	MRF	3.00	34-66	✓	Raft	Offices	Public /Large National	220 %	36	Y1	11-30
		D49	1986	10	MRF/ SW	n/a[1]	20-33	Asym. plan + High torsion	Spread Footings	Offices	Private / Small / Local	260 %	18	R1	11-30
		D73	1971	12	MRF	1.25	20-33	✓	Pile Caps	Hotel	Private /Large National	200 %	24	Y2	2-10
		D201	1968	13	MRF	2.00	34-66	✓	Raft	Government	Private / Large / Local	260 %	24	G2	2-10
		D210	1968	7	MRF/ SW	1.25	34-66	Asym. plan	Spread Footings	Hospital	CDHB	DHB Insurance		G2	2-10
REPAIRED		R74	1910 (Retrofit.)	3	Shear Wall	1.00	67-80	✓	Pile Caps	Hotel / Residential	Body Corporate	600 %	24	Y2	2-10
		R86	1988	6	Shear Wall	2.00	80-100	✓	Spread Footings	Hotel	Non-Profit / Small / Local	150 %	12	G1	0-1
		R113	1988	19	MRF	4.00	67-80	High torsion	Raft	Offices	Private / Small / Local	360 %	36	Y2	2-10
		R163	2002	8	MRF/ SW	1.25	34-66	Asym. plan	Pile Caps	Multi-Unit Residential	Body Corporate	130 %	24	Y1	2-10
		R202	1972	6	MRF	3.00	80-100	✓	Raft	Government	Private / Large / Local	275 %	24	G2	0-1
		R901	1972	6	MRF	2.00	67-80	✓	Pile Caps	University	University of Canterbury	University Collective		G2	-
		R902	2000	3	MRF/ SW	1.25	67-80	✓	Raft	Public Assembly	Christchurch City Council	LAPP Civic Assurance		G2	0-1

Notes: All buildings are located on Site Class D soil conditions

1) Data not available (Detailed Engineering Evaluation not on file)
2) Insurance: Sum Insured for material damage, expressed as a ratio (%) of the building value (pre-earthquake valuation, excluding land value, from CCC database)
3) Insurance: Business Interruption cover (in months)
4) From the latest Level 2 rapid assessment forms (NZSEE 2009)

Table 10: Level 2 rapid assessments - Case-study buildings (Data source: Canterbury Earthquake Recovery Authority – Silverfish Database and Christchurch City Council Database)

	DEMOLISHED								REPAIRED						
	CERA			OWNER INITIATED											
BULIDING ID	D117	D192	D196	D11	D49	D73	D201	D210	R74	R86	R113	R163	R202	R901	R902
Overall Hazards / Damage															
Collapse, partial collapse, off foundation	○	△	△	○	○	○	○	○	○	○	○	○	○	○	○
Building or storey leaning	○	○	○	○	△	○	○	○	○	○	○	○	○	○	○
Wall or other structural damage	■	○	■	△	△	△	△	○	△	○	○	△	○	○	○
Overhead falling hazard	△	■	■	△	■	○	○	○	○	○	■	○	○	△	○
Ground movement, settlement, slips	○	■	○	○	○	○	○	○	○	○	△	○	○	○	○
Neighboring building hazard	○	△	○	△	△	○	○	○	△	○	○	△	△	○	○
Electrical, gas, sewerage, water, hazmats	-[1]	△	○	○	○	○	○	-	○	○	-	○	○	○	○
Structural Hazards/Damage															
Foundations	○	■	○	○	○	-	○	○	○	○	○	○	○	○	○
Roof, floor (vertical load)	■	○	△	○	○	-	○	○	○	○	○	○	○	○	○
Columns, pilasters, corbels	○	○	△	△	△	-	○	○	○	○	△	○	○	○	○
Diaphragms, horizontal bracing	■	○	○	△	○	-	○	○	○	○	-	△	○	○	△
Precast connections	○	○	△	○	○	-	○	○	△	○	○	△	○	○	○
Beam	△	○	○	○	■	-	○	○	○	○	△	○	○	○	○
Non-structural Hazards/Damage															
Parapets, ornamentation	△	○	△	○	○	-	○	○	○	○	○	△	○	○	○
Claddings, glazing	△	■	△	○	■	-	○	○	○	○	△	△	○	○	○
Ceilings, light fixtures	△	△	△	△	○	-	△	○	○	○	△	△	△	△	○
Interior walls, partitions	-	○	○	○	○	-	△	○	○	○	○	△	○	○	○
Elevators	-	○	○	○	-	-	○	○	○	○	-	△	○	○	△
Stairs/Exits	■	○	△	○	△	-	○	○	○	○	■	○	○	○	△
Utilities (e.g. gas, electricity, water)	-	○	○	○	○	-	○	○	○	○	-	△	○	○	-
Other	-	-	○	○	-	-	-	-	-	○	-	○	-	-	-
Geotechnical Hazards/Damage															
Slope failure, debris	○	-	○	○	-	-	○	○	○	○	○	○	○	○	○
Ground movement, fissures	○	■	○	○	-	-	○	○	○	○	○	○	○	○	○
Soil bulging, liquefaction	△	-	○	○	-	-	○	-	○	○	○	○	○	○	○

Legend: ○ (Minor/None) △ (Moderate) ■ (Severe)

Notes: All buildings had on file a Level 2 rapid assessment form. The available Level 2 rapid assessment form for D73 was not completed entirely (as show in the table). No entry (-)

4.2.1 D117 - 17-storey RC frame office building

Building Characteristics

Building D117 comprised 17 floors levels above one basement level. The ground floor and the floor above formed a podium (about 40.4 m by 50.5 m in plan) that provided parking from the basement up to the roof of the podium. The tower (about 24 m by 37 m in plan) was symmetrical and rectangular, and was offset to the north-west of the podium. The building was designed in 1987 and detailed to behave in a ductile manner, with design based on the capacity design philosophy as encompassed by previous New Zealand Standards (Concrete Structures - NZS 3101 1982; Loadings - NZS 4203 1984). The seismic force resistance was provided predominately by perimeter moment resisting frames. In the perimeter frames on the eastern and western faces of the tower, there were six bays: four that spanned 5800 mm and two that spanned 6500 mm. In the corresponding moment resisting frames on the northern and southern faces, there were eight bays in the frames each having a span of 2900 mm. Therefore, the rigidity of the building for lateral deflection in the E–W direction was higher than in the N–S direction. The columns in the perimeter frame were cast-in-place and were 800 mm by 800 mm, except in the corners, where they were 1500 mm by 800 mm, and the beams were precast. The floors were 250 mm precast double-tee units with 65 mm minimum of seating and comprised a 60 mm cast-in-place topping acting as a diaphragm. The building was founded on reinforced concrete spread footings.

Ground Conditions

The building was located on site class D and was about 40 m from the banks of the Avon River at its closest point. A geotechnical report was not available for review.

Ownership Details and Tenancy

This property was a premium-grade office building in the CBD. The majority of the levels were used as offices, with some retail activities on the ground floor, accounting for approximately 20 businesses (the majority were professional services). The building was owned by a family from overseas having other property investments in Christchurch, New Zealand. The owner was also a tenant of the building. The pre-earthquake valuation, excluding land value, was set at $31.6m.

Insurance Policy

The building was insured for reinstatement cover for about 250% of its pre-earthquake valuation and had a business interruption cover of 36 months. The building was insured overseas. Interestingly, the material damage policy renewed in October 2010, between the two main loss events, with an increased reinstatement sum insured.

Damage States, Neighborhood Conditions, and Access Conditions

The building damage states (Level 2 rapid assessment) are presented in Table 10. Approximately 60% of the buildings that are located within a 100 m radius have been demolished. The building has been given a red (R1) placard and the property site remained inside the cordon for ~28 months.

Table 11: Decision-making variables - D117 - 17-storey RC frame office building

Insurance	The owner representative (interviewee) reported that divergent engineering recommendations caused substantial complications and delays in the claiming process, forcing the owner to take legal actions against their insurer. The owner's engineers argued that the building was damaged beyond repair, while the insurer's engineers argued it could have been repaired for about 60% of the sum insured. In between the September 2010 and February 2011 events, we note that repairs to the value of $NZD 2.5 million had been partially completed.
Damage and residual capacity	The 2011 February earthquake caused extensive cracking in the floor diaphragm with wide cracks developing between the northern and southern frame perimeter beams and the precast double-tee units. Although the building had only minor irregularities in the structural system, the sustained damage indicated that the structure was subjected to a high torsional response. An engineering report concluded that the high torsional response was largely due to the loss of stiffness in the northern frame, which greatly increased the eccentricity of the seismic forces to the effective centre of stiffness of the building. It was also found that some torsion was induced in the building owing to the heavy façade (present on the south and west sides) and the offset podium. A computer modelling of the building indicated that the capacity of the primary structural system was well below 100% of current code in its pre-earthquake condition (the report indicated that the structure could achieve 67% NBS with 'moderate' strengthening, in addition to the repairs required). No formal evaluation of the residual capacity has been completed. The key aspects of the damage can be summarized as: Structural Damage: • Moderate-severe damage to the seismic force resisting system, being most significant at the mid-levels and at the north end of the structure • Light damage to the east and west moment resisting frames • Extensive cracking in the beams and floor diaphragm • Frame elongation causing a reduction of the precast beam seating Non-Structural Damage: • Collapsed stairs between level 7 and level 10, due to displacement incompatibility Geotechnical Damage: • Separation on the ground slab, liquefaction in carpark
Decision-making strategies	The owner had no preference whether to repair or demolish until CERA issued a Section 38 notice for the building. The access to the interior of the building was restricted and controlled by Civil Defence, therefore the owner had limited time to assess the damage and come up with a repair methodology. The interviewee reported that the owner had limited powers in terms of decision-making, having to comply with the insurer's requirements, but also with CERA and building regulations.
Legislation	The building was declared dangerous by CERA on 10 June 2011 (Section 38 notice) because of its risk of collapse posing a threat to dozens of surrounding buildings. Two demolition plans were proposed by the owner and subsequently rejected by CERA.

Implementation of Decision

The demolition of the building, managed by CERA, started in June 2012 and was finished by February 2013. A cash settlement with the insurer was reached through legal mediation in early 2013.

4.2.2 D192 - 13-storey RC shear wall hotel building

Building Characteristics

Building D192 comprised 13 floor levels above two basement levels. The building's general arrangement was two decks of car parking over the whole site, a podium floor of public hotel spaces, a mezzanine floor, and nine floors of bedrooms distributed in two symmetrical wings. The structure was designed in 1986 to support loadings required by the NZS 4203 1976. The foundation system consisted of 16 m precast piles and cast-in-place bulb piles underneath a 300 mm slab on grade with thickenings at columns and pile caps. At the lower levels, the building was square in plan with cast-in-place reinforced concrete shear walls around the carpark perimeter. Above the foundation, the primary lateral system consisted of the central precast stair and lift core, in addition to longitudinal shear walls at the outer stairs and transverse walls in the wings. The transverse walls were, on the lower storeys, spaced at 7.8 m and 15.6 m along the north and west sides of the building, respectively. The shear walls were cast-in-place reinforced concrete, and were generally 4 m long and 400 mm thick in levels 1-6 and approximately 6 m long and 200-250 mm thick in the bedroom floors. The stair tower walls at each end of the hotel wings were 400 mm thick and the lift shaft shear walls were 200 mm thick. The gravity system throughout the building consisted of a mix of cast-in-place/precast columns and beams, with the floor system comprising 250 mm precast double-tee units and a 65 mm cast-in-place concrete topping acting as the diaphragm. In the bedroom floors, columns were 1200 mm x 200 mm internally, and 500 mm x 250 mm externally. Above the level 6, the longitudinal walls at the ends of the building were replaced by structural steel trusses transferring the lateral load to the top of the shear walls. The trusses were supported at each floor level by concrete beams. At the roof, the central lift cores provided the structure for the lift machine rooms. The building was seismically separated through its central axis above level 6. The structure was considered as an Importance Level 3 building.

Ground Conditions

The building was located on site class D. A geotechnical report was not available for review.

Ownership Details and Tenancy

This property was a major five-star 300-room hotel in the CBD, employing close to 240 staffs. The building was owned by a large private investment company based overseas (Australia) which had other property investments (hotel, retail, and office buildings) in New Zealand and Australia. The company owned the building since 2008 and the property was worth 10% of the total owner's portfolio. The pre-earthquake valuation, excluding land value, was set at $47.6m.

Insurance Policy

The building was insured for reinstatement cover for about 360% of its pre-earthquake valuation and had a business interruption cover of 36 months, including a special cover for employees (wages) for 12 months. Furthermore, the policy included an option for cash settlement, which is typically unusual for insurance policies for commercial buildings. The building was insured in Australia (Affiliated FM).

Damage States, Neighborhood Conditions, and Access Conditions

The building damage states (Level 2 rapid assessment) are presented in Table 10. Approximately 55% of the buildings that are located within a 100 m radius have been demolished. The building has been given a red (R1) placard in March 2011 and subsequently a yellow (Y2) placard in April 2011. The property site remained inside the cordon for ~ 21 months.

Table 12: Decision-making variables - D192 - 13-storey RC shear wall hotel building

Insurance	The building was built in two wings over the podium floor and one of the wings had a differential settlement. The owner (interviewee) reported that it was very clear from the first damage assessments that the wing with differential settlement would need to be demolished. The insurers argued the other hotel wing was salvageable. According to the owner, this argument was more from a negotiation perspective, based on divergent technical recommendations. After several iterations and arguments, both wings were found to be not repairable because of the extent of the differential settlement, giving clarity in terms of the decision to demolish the whole building. However, this argument has delayed and complicated the claiming process. Reportedly, the amount of insurance (sum insured) available for this building versus the market value shaped the decision quite substantially in terms of the demolition (high sum insured, opportunity for a capital gain). Also, the owner mentioned that both parties wanted to get it off the books and do a quick deal, which had a very big impact in terms of the process and the decision.
Damage and residual capacity	A report (memo) from CERA's engineers dated on 24 August 2011 indicated that the lateral resisting system was found to be more flexible than concrete columns elements designed to resist gravity loads only. As a result, the horizontal earthquake loads were resisted by concrete columns elements which were not designed to resist this type of loading. Some gravity columns were found to be unable to resist further lateral earthquake loads. A relatively small horizontal floor displacement was likely to result in the failure of these columns and the collapse of a substantial section of the building. The behavior of the connection between the steel trusses and the concrete beams at each floor level was also found inadequate, and the capacity of the beams supporting the trusses was insufficient to resist vertical reactions from the truss without significant vertical deflections. The key aspects of the damage can be summarized as: Structural Damage: • Moderate-severe damage in shear walls, spalling of cover concrete • Severe damage in exterior beam-column joints

Table 12: Decision-making variables - D192 - 13-storey RC shear wall hotel building (cont'd)

Damage and residual capacity (cont'd)	• Extensive cracking of floors at levels 6, 7, and 8 • Shear cracking in columns Non-Structural Damage: • Extensive damage to lobby glazing, loss of ceilings throughout the building • Sewerage in the basement Geotechnical Damage: • Moderate liquefaction • Maximum overall out-of-plumb: 110 mm • Differential settlement (approx. 220 mm) and moderate cracking of the basement slab, with severe cracking in localized areas around columns (one wing only). No formal evaluation of the residual capacity has been completed.
Decision-making strategies	From a commercial perspective, the owner preferences and decision-making strategies were very significant in terms of the decision. The owner preferred the building to be demolished because of the risks on the repair methodologies for earthquake-damaged buildings, in addition to the negative perception of high rise buildings from the public, reducing the ability to attract clients or sell the building in the future. The owner also reported that a repair scenario would be a massive disadvantage to the rest of the market (now mostly new hotel buildings in Christchurch CBD) and would not make sense from a commercial perspective. A cash settlement with no condition to rebuild was the preferred option because of several reasons. First, the owner mentioned that there was a significant financial gap due to the impossibility to rebuild the hotel in time before the business interruption cover run out. Also, the reconstruction cost was an issue because of the deductible (excess) and underinsurance (the cost of rebuild was estimated to approximately $NZD 190m), leaving the owner out of pocket. Third, the key driver was the fact that the owner could have been a year or two out of pocket in terms of loss of income by the time the hotel was actually rebuilt. Finally, the business strategy did not encompass a situation where this asset was held regardless of the earthquakes, since the building was going to be on the market for sale at some stage. Therefore, a cash settlement with their insurers provided the opportunity to cash-in their equity and walk away.
Legislation	The owner reported that the changes in the building regulations (67% NBS from 33% NBS) created uncertainties around the repair scope and methodology, in addition to further financial issues in relation to the extra costs associated with the strengthening works. The additional costs resulting from the changes to the building code, combined to the increase in costs due to demand surges, made the scenario of re-establishing the hotel in Christchurch less financially attractive for the owner. A Section 38 notice was issued by CERA on 26 August 2011 due to high life-safety issues within and near to the building, based on the observed structural damage and the likely behavior of the structure under future earthquake loading. CERA indicated that temporary strengthening work was required, however it was not be possible to do so in a safe manner without an unacceptable risk of at least part of the building collapsing.

<u>Implementation of Decision</u>

An amount equivalent to 85% of the sum insured has been paid as a cash settlement in August 2011. The demolition of the building started in March 2012 and was finished in June 2012. The demolition was managed by CERA. The land was a leasehold land owned by the Christchurch City Council. The site was handed back to the Council after demolition.

4.2.3 D196 - 8-storey RC shear wall office building

Building Characteristics

Building D196 had eight floors plus a plant room above ground level and one level of basement. The building was a reinforced concrete shear wall structure with concrete gravity columns supporting steel floor beams. In the north-south direction, the building relied on the east elevation shear wall only. Therefore, most of the strength of the building was on the east side (inducing a high torsional response). In the east-west direction, the seismic forces were resisted by the lift core shear walls and the south shear wall. The south shear wall was adjacent to a precast slab ramp down to the basement level. Floors were precast slab units with a 70 mm concrete topping reinforced with wire mesh that formed the diaphragm. The building was generally cladded with precast concrete cladding panels and the north and west elevations were clad with a full high window assembly. The building had shallow strip and pad foundations under the basement walls and interior columns. The structure was designed and constructed in 1986-1987 to support the design loadings required by the NZS 4203 1984.

Ground Conditions

The building was located on site class D. A geotechnical report was not available for review.

Ownership Details and Tenancy

The building use was carpark in the basement, retail on the ground floor and commercial office space in the floors above (primarily government departments). The building was owned since 2000 by a local family having other property investments in Christchurch (the family owned a total of four commercial buildings in the CBD at the time of the earthquakes). The pre-earthquake valuation, excluding land value, was set at $6.3m.

Insurance Policy

The building was insured for reinstatement cover for about 220% of its pre-earthquake valuation and had a business interruption cover of 24 months. The building was insured in New Zealand and the insurance company was Zurich New Zealand.

Damage States, Neighborhood Conditions, and Access Conditions

The building damage states (Level 2 rapid assessment) are presented in Table 10. Approximately 80% of the buildings that are located within a 100 m radius have been demolished. The building has been given a red (R1) placard and the property site remained inside the cordon for ~8 months.

Table 13: Decision-making variables - D196 - 8-storey RC shear wall office building

Insurance	The owner (interviewee) had no specific comment on this topic for this building.
Damage and residual capacity	The building suffered significant damage to the south elevation shear wall at ground level, which consequently seriously compromised the lateral stability of the building. The south shear wall failed in compression, causing the fracture of all reinforcing steel in the wall, which dropped by about 150 mm. Temporary emergency securing work, involving pouring mass concrete around the damaged proportion of the wall, has been carried out to stabilize the building and to allow further inspection work to be undertaken. No formal evaluation of the residual capacity has been completed. The key aspects of the damage can be summarized as: Structural Damage: • Severe damage to the structural system (south elevation shear wall lost its capacity since all reinforcing steel has fractured) • Significant cracking in the basement slab • Beam/column joint splitting/spalling at steel beam support • Slab support failure (level 5 south side) Non-Structural Damage: • Spalling of precast cladding panel. The panels were not well tied into the building and were a significant fall hazard. • Glazing damage Geotechnical Damage: • None reported
Decision-making strategies	The owner indicated he had no preference whether to repair or demolish until CERA issued a Section 38 notice for the building. After the building was demolished, the owner sold the land and reinvested in existing commercial properties in Auckland. The owner mentioned that the decision to demolish was out of his hands, but the strategy was to do a quick deal with their insurer and invest somewhere else in New Zealand. The owner indicated that he was not interested to assume a greater role in property development, therefore the option of a cash settlement was preferred instead of rebuilding. We also note that the leases were due to terminate in December 2011, which may have influence the decision to demolish rather than rebuild or repair.
Legislation	Based on previous damage assessments from private consulting engineers, the building was declared dangerous by CERA (Section 38 notice) in June 2011. Furthermore, the owner indicated that he initially planned to rebuild in Christchurch, but the lower height limits imposed by the recovery plan (CCDU), in addition to several other factors and commercial uncertainties, have influence the decision to move his equity to Auckland.

Implementation of Decision

The demolition of the building, managed by the owner, started in July 2011 and was finished by October 2011. The insurance claim was settled in December 2011.

4.2.4 D11 - 22-storey RC frame office building

Building Characteristics

Building D11 comprised 22 floors above a single storey basement. The structure was designed and constructed in 1987-1990 to support design loadings required by the NZS 4203 1984. The building was founded on a raft foundation, typically 1.8 m thick at the main building columns and 0.9 m thick elsewhere. The podium structure formed a U-shape to the west, north, and east sides of the tower that was seismically separated from the tower itself. Podium foundations were simple pads and strip footings. The tower was symmetrical and rectangular (36 m x 26 m). The seismic force resisting system was a conventional ductile reinforced concrete moment resisting frame (MRF) around the perimeter, with cast-in-place concrete columns (1100 mm x 1100 mm to the 4 corners, and 1100 mm x 800 mm elsewhere), and 1100 mm deep x 575 mm wide precast beams. The E-W frames had a return in the middle bay meaning that the MRF consisted of two frames of two bays. Potential plastic hinges were assumed to form at the column faces in the event of a significant earthquake (as per capacity design principles). The floors typically comprised 200 mm precast double-tee units with a 65 mm thick cast-in-place concrete topping, spanning E-W between the perimeter frames and the internal gravity structural steel beams, which were in turn supported on insitu concrete columns. The tower had a centrally located lightweight service core with 2 sets of precast concrete scissors stairs. The tower was cladded with a glazed curtain wall.

Ground Conditions

The building was located on site class D. The subsurface soil profile beneath the basement raft is provided in the geotechnical report. Groundwater levels were high (between 1 m and 2 m below ground level) across the site. The report notes that some layers are likely to have liquefied during the February 2011 earthquake and there is a high risk of liquefaction during a future Ultimate Limit State (ULS) earthquake.

Ownership Details and Tenancy

Building D11 was a premium-grade office tower in Christchurch CBD comprising 18 floors of office space, three levels of car parking, and retail areas on the ground and first floor levels. The building owner is a large public investment company based in Auckland. The company owns and manages a $NZD 2.3 billion portfolio of real estate, comprising shopping centers (two-thirds) and office buildings (one-third). Approximately 60% of the portfolio is located in Auckland. Building D11 was worth 1.6% of the overall owner's portfolio and the company owned the building since 1997. The company is also active in the real estate development, although they are primarily conservative, low-risk investors. The pre-earthquake valuation, excluding land value, was set at $43.8m.

Insurance Policy

The building was insured for reinstatement cover for about 220% of its pre-earthquake valuation and had a business interruption cover of 36 months. The building was insured in New Zealand (the insurers were Vero - 45%, Zurich - 25%, AIG - 20%, and QBE - 10%). The policy did not have a follow the leader clause which means an agreement (e.g. cash settlement) must be executed/agreed by all four insurance companies. Also, the policy included a constructive total loss clause which covers for total loss where a property is repairable but cannot be occupied for its original purpose.

Damage States, Neighborhood Conditions, and Access Conditions

The building damage states (Level 2 rapid assessment) are presented in Table 10. Approximately 45% of the buildings that are located within a 100 m radius have been demolished. The building was placarded yellow (Y1) and the property site remained inside the cordon for ~25 months.

Table 14: Decision-making variables - D11 - 22-storey RC frame office building

Insurance	Based on evaluations from independent valuers, the estimated repair costs represented at least 50% of the building value (or ~25% of the sum insured). The owner indicated that the insurance coverage did not really influence the decision. The preference was to demolish, regardless of the claim outcome, because the building was a constructive total loss.
Damage and residual capacity	The 4 September earthquake caused limited structural damage to the structure: the building was suitable for continued occupation and the building continued to be occupied. However, as a result of the February 2011 earthquake, the structure has undergone a high degree of inelastic action with noticeable frame elongation to north and south seismic frames, and the building tilted towards the SW by 230 mm, causing a loss of serviceability of the structure. A computer modelling of the building indicated that the capacity of the primary structural system (pre-earthquake, undamaged) was well below 100% current code. No formal evaluation of the residual capacity has been completed, although a detailed engineering evaluation report states that the reinforcing bars have lost capacity and hence the structural elements have greatly diminished capacity to resist seismic loads. The key aspects of the damage can be summarized as: Structural Damage: • Cracking of floor slabs to east and west perimeter beams. Cracks widths are maximum (approximately 10 mm) at the corner columns at north and south ends. Evidence of significant frame elongation. • Extensive damage to all beams to the north and south elevations where framing into corner columns. Internal beams typically have parallel cracks through the floor slab topping on each side of the top flange. • Plastic hinges have formed at the column faces (worst damage at levels 7 and 8). Non-Structural Damage: • Basement flooded. Main power supply submerged. Geotechnical Damage: • Significant liquefaction was observed around the site, differential settlement. The northern section of the podium area appears to have rotated upward by approximately 400 mm.

Table 14: Decision-making variables - D11 - 22-storey RC frame office building (cont'd)

Decision-making strategies	Initially, the decision (either to repair or demolish) was not clear to both parties (owner and insurers). The owner reported to have no specific agenda between demolition and repair in the early days, but the building's out-of-plumbness and the uncertainties in the repair methodologies were major issues in the decision. The owner indicated that the decision to demolish was based on engineering findings, but then tempered by a commercial pragmatism (the building was deemed uneconomic to repair). The owner's engineers put the case to the insurer's engineers as a constructive total loss and the insurer's engineer came to the same conclusion. It is important to note that, in 2009, the building was on the market for sale because the business strategy was to re-weight the office portfolio more to the Auckland and Wellington market. We also highlight that it took more than 10 years to fully lease the building since its completion in 1990. Therefore, the full replacement insurance payout has potentially provided the owner a better result than a repaired building which could take a long time to lease and could also be difficult to sell.
Legislation	The owner indicated that the change in the building code (increase in the seismic design loads – z factor) would have been an important factor in considering the repair and how would the building have measured up against the new standard of repair. Furthermore, because of the conditions imposed by the recovery plan (CCDU), the site was not ideally placed for the sort of asset suited to the owner investment strategy (more suited to an entertainment or hotel building, which was not a business the owner was interested in), therefore the option of a cash settlement was preferred instead of rebuilding.

Implementation of Decision

The insurers and owner agreed that the building was a constructive total-loss (the building was deemed not repairable) and approximately 70% of the sum insured has been paid out as a cash settlement. The owner asked CERA to manage the demolition in February 2012. The demolition of the building started in March 2012 and was finished by December 2012. The insurance claim was settled in May 2012. After the building was demolished, the owner sold the land and used the cash recovered from the insurance proceeds and the land for the repayment of bank debt.

4.2.5 D49 - 10-storey RC shear wall/frame office building

Building Characteristics

Building D49 was a 10 storey building designed and built in 1986-1987 (design loadings - NZS 4203 1984). The building was an asymmetrical pentagon shaped structure with a rooftop plant room and elevators lift rooms. There was also a circular ramp structure at the rear of the building providing access to two levels of carpark deck located on levels one and two. The floor system consisted of pre-stressed ribs and timber infill, spanning perpendicular to the moment frames and parallel to the shear walls, with a 100 mm concrete topping acting as the diaphragm. The lateral system consisted of cast-in-place shear walls (thickness of 300 mm from foundation to level 2 and 200 mm from level 3 to level 10) in the NW-SE direction and concrete moment frames in the NE-SW direction that also supported the majority of the gravity loads. The boundary shear walls were not parallel meaning that the frames at the front of the building were longer than the frames at the rear of the building. The perimeter moment frames had closely spaced column lines (typ. 3.5

m) and 800 mm typical beam depths. The front moment frames were discontinuous because of the exterior elevator shaft. The gravity frames were cast-in-place reinforced concrete beams and columns, at greater span than the moment frames. The building was founded on spread footings.

Ground Conditions

The building was located on site class D. A geotechnical report was not available for review.

Ownership Details and Tenancy

The ground floor comprised hospitality spaces, while the remaining levels comprised office spaces (mainly professional services). The building was owned by a local family since its completion in 1987. The family had other real estate investments in the Canterbury region, accounting for a portfolio value of approximately $NZD 250 million (10% office buildings and 90% industrial/commercial buildings). The pre-earthquake valuation, excluding land value, was set at $10.7m.

Insurance Policy

The building was insured for reinstatement cover for about 260% of its pre-earthquake valuation and had a business interruption cover of 18 months. The building was insured in New Zealand and the insurance company was NZI, a business division of IAG.

Damage States, Neighborhood Conditions, and Access Conditions

The building damage states (Level 2 rapid assessment) are presented in Table 10. Approximately 70% of the buildings that are located within a 100 m radius have been demolished. The building has been given a red (R1) placard and the property site remained inside the cordon for ~25 months.

Table 15: Decision-making variables - D49 - 10-storey RC shear wall/frame office building

Insurance	The interviewee (owner) had no specific comments on this topic for this building. The insurer has determined that the building was a total loss.
Damage and residual capacity	The asymmetric seismic force resisting system of the building has caused the building to undergo torsion displacements. This has resulted in greater displacement and consequently greater damage to the frames located further away from the center of rigidity of the building. The building has been identified as being earthquake-prone. However, the shear walls remained relatively undamaged and the moment frames were expected to perform in a ductile manner. The most significant damage noted on the shear walls was a horizontal crack at the construction joint on carpark level two. The moment frames at the rear of the building have suffered minor damage only. The building was expected to deform further without collapse in future, less than moderate earthquake, and aftershock.

Table 15: Decision-making variables - D49 - 10-storey RC shear wall/frame office building (cont'd)

Damage and residual capacity (cont'd)	The key aspects of the damage can be summarized as: Structural Damage: • Severe cracking in the front moment frames (building street elevation) at lower levels, cracking in west shear wall at floor levels • Diagonal cracking in transfer beams (rear moment frames) indicating the onset of shear failure • Horizontal cracking of shear wall at level 2 (construction joint) • Cracking in floor slab topping at rib connections • Flexural cracking at column face (approximately 5 mm wide) • Severe cracking through cast-in-place concrete beams connections at mid-span (cruciform precast units) Non-Structural Damage: • Floors consistently out of level to an extent outside acceptable levels of construction tolerance • Cracking of precast stair flights at the stair landing junction • Loose glass above main entrance • Loose precast panels and loose panes of glass at level 7 • Much severe damage to non-structure with height • Extensive cosmetic damage in stairways, and generally to walls, ceilings, and partition throughout the building Geotechnical Damage: • Differential settlement - Approximately 130 mm lean to SE No formal detailed damage investigation and evaluation of the residual capacity have been completed.
Decision-making strategies	The owner indicated that the building was clearly uneconomic to repair and the decision to demolish was made soon after the February earthquake. The decision was entirely financially driven (the building was deemed uneconomic to repair) and the strategy was to achieve a settlement with the insurance company as fast as possible. The owner indicated having no intention of rebuilding in Christchurch.
Legislation	Based on the extent and severity of observed structural damage, the building was not declared dangerous by CERA (CERA Memo – 13 September 2011). However, the land was designated for compulsory acquisition under the CCDU recovery plan (after the decision to demolish was made). The owner mentioned he would have demolished the building and sold the land regardless of the CCDU plan. Furthermore, the owner's engineer mentioned in the damage assessment report that the changes in the building code (the increase in the seismic design loads and the requirements for earthquake-prone buildings - 67% NBS from 33% NBS) were important factors in the decision to demolish.

Implementation of Decision

In April 2011, the full sum insured was paid out with no condition to rebuild. The demolition of the building, managed by the owner, started in October 2011 and finished in March 2012. After the building was demolished, the owner sold the land (February 2013) and reinvested in existing commercial properties in Auckland.

4.2.6 D73- 12-storey RC frame hotel building

Building Characteristics

Building D73 was designed and constructed in the early 1970's before the release of NZS 3101 1982, the first code of practice in New Zealand requiring specific seismic design details for concrete structures. The building comprised twelve floors above ground level, with a part level services basement. The building was constructed on a pile foundation. The main building was approximately 35 m long by 16 m wide, with a main core located off the south-west corner of the building. A secondary fire escape stair well was located on the south-east corner. Seismically, the building was a two-way moment resisting concrete frame structure. The building has been constructed using cast-in-place reinforced concrete for the main structural frames, including the floor slab (thickness of 5", or 125 mm) and secondary floor beams. The 8 columns were 36" square (910 mm x 910 mm) at ground level and reduced in 6" (150 mm) intervals to 18" square (450 mm x 450 mm) above level 10. The primary beams were 24" wide by 48" deep (600 mm x 1200 mm) at ground level and reduced progressively to 18" wide by 39" deep (450 mm x 990 mm) at level 9 and above. Perimeter concrete beams supported external precast concrete cladding panels along the north, east and western elevations.

Ground Conditions

The building was located on site class D. The piles were driven to approximately 8 m below the original ground level into a dense sand and silt-sand layer. Piles caps were tied together by reinforced concrete foundation beams. The groundwater level is high, at 1.0 m below ground level. The geotechnical report notes that the site has a high risk of liquefaction during an Ultimate Limit State (ULS) earthquake.

Ownership Details and Tenancy

The building was originally designed as a commercial office building, but later modified into a hotel (135 rooms) in the mid-1990s. Lightweight penthouse units have been constructed over the roof slab following the conversion into hotel rooms. The building was owned and operated by a large hotel management company since its conversion in the mid-1990s. The ownership was a mixed-model, however the hotel management company was the majority owner for this specific building. The owner was also a tenant of the building. The pre-earthquake valuation, excluding land value, was set at $18.1m.

Insurance Policy

The building was insured for reinstatement cover for about 200% of its pre-earthquake valuation and had a business interruption cover of 24 months. The building was insured in New Zealand and the insurance company was Zurich New Zealand.

Damage States, Neighborhood Conditions, and Access Conditions

The building damage states (Level 2 rapid assessment) are presented in Table 10. Approximately 50% of the buildings that are located within a 100 m radius have been demolished. The building has been given a yellow (Y2) placard and the property site remained inside the cordon for ~28 months.

Table 16: Decision-making variables - D73- 12-storey RC frame hotel building

Insurance	According to the owner, the estimated repair costs ranged from 90% to 140% of the building value (or 45% to 70% of the sum insured). We highlight that divergent recommendations between the owner's engineers and the insurer's engineers created uncertainties in the repair methodology, influencing the owner's strategy in terms of the decision (as explain below).
Damage and residual capacity	The building performed well considering the loading intensity imposed by the February 2011 earthquake and the lack of ductility of the structure. Flexure cracking and minor spalling of the concrete columns was observed throughout but occurred much more frequently on levels 4 to 7 and 11. Cracks ranged in thickness from mostly less than 0.2 mm to up to 0.8 mm. Flexural cracking of the main floor beams was observed throughout and particularly more frequently in the lower levels. Critical structural weaknesses were identified in the detailing of the concrete moment frames and the beam-column joints. According to the owner's engineer report, the anchorage of the bottom reinforcement in the joint was not sufficient to develop the strength of the bars, or had not sufficient flexural capacity under repeated cyclic loading to resist the duration of a design level earthquake. The building has been identified as being earthquake-prone and the columns were identified to be the weakest link in the structure, having around 25-30% of current code strength. The key aspects of the damage can be summarized as: Structural Damage: • Flexural cracking of the lower level columns and floor beams • Cracking of columns at upper levels where changes in column size occur • Damage to beam-column joints at lower level floors • Diaphragm cracking adjacent to eastern stair well and the main core • Cracking of the floor slabs adjacent to beam hinges/flexural cracking Non-Structural Damage: • Precast concrete stair sections have partially collapsed • Cracking and spalling of stair flights (significant damage) • Significant cracking to lower cladding panels Geotechnical Damage: • The basement had 130 mm depth of water over the floor • No evidence of liquefaction induced settlement or differential movement A Detailed Engineering Evaluation spreadsheet is available in Appendix E. No formal evaluation of the residual capacity has been completed, although the report indicates that potential damage to beam column joints could result in a reduction of the lateral load resisting capacity in the order of 20%.

Table 16: Decision-making variables - D73- 12-storey RC frame hotel building (cont'd)

Decision-making strategies	The owner preferred demolition over repair because of several reasons. First, the repair/strengthening scenario proposed by the owner's engineers would involve a significant increase in the size of the columns. The proposed solution was to encase the existing columns with a circular reinforced concrete encasement. The columns were located in the middle of the hotel rooms, so there was already an issue in terms of functionality of space. The owner mentioned that wider columns would make the rooms not tenantable in terms of actually being able to use it as an accommodation room. The solution proposed by the insurer's engineers included glass FRP wrapping (quake wrap) to provide lateral confinement to the existing columns. The owner indicated that their engineers (and the Christchurch City Council's engineers) were not convinced of the solution proposed by the insurer's engineers (noting that the owner's engineers have identified the structure as weak column, strong beam), which created uncertainties in the repair methodology. Second, the cost escalation (due to post-disaster demand surges) and the uncertainties around the repair costs have contributed to the decision to demolish. Third, the perception of risks for tall buildings was another important factor, in terms of uncertainties in the ability to sell the building after remediation works and uncertainties in the ability to attract clients to stay in a tall building.
Legislation	Based on the extent and severity of observed structural damage, the building was not declared dangerous by CERA (CERA memo – 1 March 2012). However, the legislation and the changes to the building regulations were important variables in the decision. The owner mentioned that the issue at the time was around having the building to be strengthen up to 67% NBS because it was deemed earthquake-prone (< 33% NBS). There was a lot of difficulties in understanding whether the insurer would cover a strengthening up to 67% NBS or not, representing a substantial risk for the owner in terms of costs. There were also many unknowns in estimating what that gap would look like either between a 34% NBS and 67% NBS retrofit. The 67% NBS target was the owner's desired preference level because of the new commercial reality in New Zealand following the earthquakes. The company indicated that guests were asking about the seismic rating of their buildings (%NBS), particularly corporates and government organisations. However, the owner emphasized that the understanding at that stage was that the strengthening target of 67% NBS was also a requirement by the Council (CCC). Finally, according to the interviewee, CCC pointed out during the damage investigation process that the repair methodology proposed by the insurer's engineers (glass FRP wrapping around the columns) would probably not be approved in order to obtain a building consent for earthquake repairs.

<u>Implementation of Decision</u>

The insurance claim was settled in November 2012 and approximately 70% of the sum insured has been paid out as a cash settlement. The demolition of the building, managed by the owner, started in May 2013 and finished in December 2013. After the building was demolished, there was no plan to rebuild and the owner sold the land (September 2014).

4.2.7 D201 - 13-storey RC frame office building

Building Characteristics

Building D201 comprised 13 floor levels over a one level basement. The building also included a three storey podium that was about twice the plan area of the tower above. The tower was approximately central to the major portion of the podium, with a seismically separated portion of the podium to the west. The foundation system was a deep reinforced concrete cellular raft system (raft depth was about 2.5 m). The main lateral and gravity load capacity in both directions was provided by cast-in-place ductile moment frames. There was a central stair and lift core with precast concrete wall panels, but was not designed to contribute to the lateral resistance of the building. In the tower, there were 20 columns arranged in a grid to give four bays of 6400 mm in the east–west direction and three bays of 6400 mm in the north–south direction. The columns in the lower levels of the tower were 762 mm by 762 mm and in the upper levels they were 686 mm by 686 mm. The beams were 762 mm deep with a web width of 686 mm in the lower levels of the tower, and 686 mm deep with a web width of 610 mm in the upper levels of the tower. Beams were made continuous with the columns. The floor system consisted of a 152 mm thick cast-in-place reinforced concrete slab. Precast concrete panels were used as non-structural elements for cladding and also for walls in the vicinity of the lift/stair core. The building was regular in plan and verticality. The building was designed in 1968 and built in the early 1970s. Despite the year of design, the detailing of the structure was relatively similar to modern standards and incorporated many of the concepts of capacity design (e.g. the columns were designed to be considerably stronger than the beams). The structure was considered as an Importance Level 4 building.

Ground Conditions

The building was located on site class D. A geotechnical report was not available for review.

Ownership Details and Tenancy

Since 2000, the owner of the building was a large property investment and development company based in Christchurch. The company has other real estate investments on the South Island (mostly in Christchurch), accounting for a portfolio value of approximately $NZD 600 million. The pre-earthquake valuation of the building, excluding land value, was set at $12.8m.

Insurance Policy

The building was insured for reinstatement cover for about 260% of its pre-earthquake valuation and had a business interruption cover of 24 months. The name of the insurer is confidential.

Damage States, Neighborhood Conditions, and Access Conditions

The building damage states (Level 2 rapid assessment) are presented in Table 10. Approximately 65% of the buildings that are located within a 100 m radius have been demolished. The building has been given a green (G2) placard and the property site remained inside the cordon for ~1 month.

Table 17: Decision-making variables - D201 - 13-storey RC frame office building

<table>
<tr><td>Insurance</td><td>The owner (interviewee) had no specific comments on this topic for this building. According to the owner, the estimated repair costs ranged from 30% to 40% of the building value (or 12% to 16% of the sum insured).</td></tr>
<tr><td>Damage and residual capacity</td><td>No significant structural damage was recorded following the September 2010 earthquake, though there was some non-structural damage. In the February 2011 earthquake, the performance of the building was satisfactory in terms of the structural damage, but there was appreciable non-structural damage in the building (damage to secondary infill panels and lightweight internal partition walls). The building tilted 90 mm to the east and 150 mm to the north.
The very robust nature of the building, which was due to its high level of redundancy and its symmetrical, regular form, contributed to its good performance.
The key aspects of the damage can be summarized as:
Structural Damage:
• Hairline cracks in some of the primary beams and columns, internal stairways, and walls. Some cracks up to 2 mm wide in the beams at the column faces.
• Minor differential floor levels
• No structural damage observed beyond the central core
Non-Structural Damage:
• Significant non-structural damage in the building
• Damage to secondary elements, mainly wall panels and stairway landings, in the general core area
Geotechnical Damage:
• Differential settlement - Approximately 175 mm lean to north-east
• Minor liquefaction occurred at the north-eastern corner of the building

A Detailed Engineering Evaluation spreadsheet is available in Appendix E.</td></tr>
<tr><td>Decision-making strategies</td><td>The building was deemed uneconomic to repair. The owner preferred to demolish because of the nature of the building use and the incapacity to economically achieve the desired performance level in relation to the high importance level (IL) of the building. There were concerns over the building's ability to remain fully functioning after another major earthquake and tenants had ongoing concerns over the stability of the building. There were also uncertainties in the repair (re-levelling) methodologies. Furthermore, the owner reported that there was a plan for a new building prior to the earthquakes (the existing building was old and not attractive) and therefore a cash settlement with their insurers provided the opportunity for a new building.

The building has been continually occupied until late 2012 (apart from short duration evacuations until cleared as safe to occupy by engineers).</td></tr>
<tr><td>Legislation</td><td>Based on limited structural damaged observed, the quantitative assessment, and the repairs made to damaged secondary elements, the building was not declared dangerous by CERA (CERA Memo - 15 December 2011).
The owner had no specific comments on this topic.</td></tr>
</table>

Implementation of Decision

The insurance claim was settled in July 2014 (confidential cash settlement). The demolition of the building, managed by the owner, started in September 2014 and was not finished at the time of writing.

4.2.8 D210 - 7-storey RC shear wall/frame hospital building

Building Characteristics

Building D210 was designed and constructed in the late 1960s and comprises three structures (central, west and east) that are seismically separated. The west and east buildings are essentially identical buildings, constructed as mirror images of each other, and comprise seven levels with a partial basement containing service tunnels. The gravity system consists of cast-in-place reinforced concrete waffle slabs, spanning between internal columns and the perimeter walls and frames. The lateral forces are resisted by cast-in-place concrete walls on the exterior elevations. In the transverse (N-S) direction, the shear walls at either end of the building are of reasonable length, however, in the longitudinal (E-W) direction, the concrete walls are heavily punctured, forming frames with deep spandrel beams. The concrete floors act as structural diaphragms to distribute lateral forces to the walls. The walls and columns are founded at basement level on a combination of strip footings and isolated pad foundations. The central building links the west and east buildings and consists of seven levels, with a two storey rooftop plant room plus a partial basement containing service tunnels. Similarly, the gravity system consists of cast-in-place reinforced concrete waffle slabs, spanning between internal columns and the perimeter walls and frames. The seismic force resisting system consists of reinforced concrete walls, primarily located around the perimeter of the building. Significant lengths of wall are provided on the west and east elevations, with a concentration of walls surrounding the service shafts at the southern end of the building. In contrast, the northern elevation is heavily punctured to reflect the piers and spandrels of the west and east buildings. The building was originally designed to predecessor standards of the current NZ Building Code (NZS 1900 1965 for loadings).

Ground Conditions

The building is located on site class D. A geotechnical report was not available for review. According to the summary provided in the structural engineer's report, the building bear on a gravel layer at the basement level that is approximately 4 m thick. There is a medium dense sand layer below the gravel that is approximately 4.5 m thick. The same report (structural engineer's summary) indicated that this sand layer has liquefied during the 22 February 2011 earthquake.

Ownership Details and Tenancy

The building is considered as healthcare facilities with a capacity of 380 beds (Importance Level 3). The building is owned and operated by the Canterbury District Health Board (CDHB).

Insurance Policy

The building is insured for reinstatement cover as part of the District Health Boards national insurance policy. The pre-earthquake valuation of the building, excluding land value, is not available.

Damage States, Neighborhood Conditions, and Access Conditions

The building damage states (Level 2 rapid assessment) are presented in Table 10. The percentage of demolished buildings that are located within a 100 m radius is negligible. The building has been given a green (G2) placard and the property site was located outside the cordon.

Table 18: Decision-making variables - D210 - 7-storey RC shear wall/frame hospital building

Insurance	The interviewee had no specific comments on this topic for this specific building.
Damage and residual capacity	Following the February 2011 earthquake, the top two floors of the building, including five adult medical wards, were evacuated immediately and closed due to water damage from leaking roof tanks, making 106 adult medical beds unusable. The third floor was evacuated in a subsequent phase. These evacuations were triggered by failures of suspended ceilings, the lack of functionality of fire sprinkler system, and the lack of sufficient pressure in the back up water system. The key aspects of the damage can be summarized as: Structural Damage: • Flexural cracking of piers (up to 0.5 mm in width) • Shear cracking of shear walls, particularly at the lower ground level • Minor cracking to the stairwell walls (crack widths observed up to 0.3 mm) • Cracking of the spandrel beams in some locations Non-Structural Damage: • Severe damage to internal and external roof coverings and roof top water tanks (flooding of upper floors) • Finishes damage around seismic joints • Moderate amount of cracking observed in the cladding • Flooded basement Geotechnical Damage: • Earthquake-induced land damage observed • Minor differential settlement of the building (central and west buildings are leaning to the north, between 1mm/m and 2 mm/m lean). A Detailed Engineering Evaluation spreadsheet is available in Appendix E. Interestingly, the %NBS pre- and post-earthquake in the spreadsheet are equal, however the report indicates that strain hardening has occurred (30% lost capacity).
Decision-making strategies	In accordance with their decision-making framework (see Chapter 5 of this thesis for further details), the CDHB has decided to demolish the building because of the extent of repair and strengthening work required to achieve desired performance. The building is currently designated as an Importance Level 3 building, however, the CDHB may require the building to be considered as an Essential Post-Disaster Facility (Importance Level 4) in the future.

Table 18: Decision-making variables - D210 - 7-storey RC shear wall/frame hospital building (cont'd)

Decision-making strategies (cont'd)	This building is located on the Christchurch Hospital Campus adjacent to other IL3 and IL4 buildings. The building is also adjacent to the road entrance from the CBD. The owner's engineers indicated that if the building was significantly damaged in the event of a severe earthquake, the impact on the operation of the hospital facilities would be significant and the ability of the hospital to perform its post disaster function would be reduced. This factor may have significantly influenced the decision to demolish the building in the near future. Furthermore, the owner reported that there was a plan for a new building prior to the earthquakes (the existing building is old and would not be able to cope with the needs of Canterbury's growing population) and therefore a cash settlement with their insurers provided the opportunity for a new building.
Legislation	Because of the nature of the services provided (healthcare) and complexity of decisions, CERA managed CDHB's buildings differently than other commercial buildings in the CBD. The Board was allowed to manage their own portfolio and simply notify CERA of subsequent actions/decisions based on their recovery plan and decision framework (e.g. no notice was given by CERA on CDHB buildings). The implications of the recent amendments in the building code (increase in the basic seismic design loads for Canterbury) for this building are discussed in the Detailed Seismic Assessment Report (July 2013).

Implementation of Decision

CDHB will continue to occupy the building until 2020 because of the unavailability of other space. Consequently, the Board has changed the nature of patients (the top floors are no longer used as acute in-patient beds) and has depopulated parts of the building to help reduce the risks in the evacuation components in a scenario of a partial collapse of the building.

4.2.9 R74 - 3-storey RC shear wall hotel building

Building Characteristics

Building R74 is a heritage building (Group 1 listing in the Christchurch City Plan) and was designed and constructed in the period of 1910 through 1913. The building comprises two floors above ground level, with a single level basement with multi-use rooms. Seismically, the building is a refurbished and strengthened unreinforced masonry wall (URM) building. Strengthening has been achieved using partial demolition and re-construction of two main concrete shear cores incorporating hollow core concrete floors. The retrofit and strengthening work was carried out in 1995-1996 and designed to predecessor standards of the current NZ Building Code (NZS 4203 1992 for loadings). Existing perimeter masonry walls have been secured with concrete skin wall overlays and floor tie details incorporated into timber floor joists and plywood diaphragms at ground, level 1 and level 2. At the roof level, concrete beams and floor slabs have been constructed over the original slabs and steel beams. The new roof slab has been designed as a diaphragm to secure the top of the original walls. Lightweight penthouse apartments have been constructed over the new roof slab and the parapets have been reconstructed using lightweight materials supported by steel supports cantilevered from the new concrete slab. The building is founded on piled foundations beneath the original masonry walls, and new reinforced concrete piles beneath the new concrete shear wall cores.

Ground Conditions

The building is located on site class D. The groundwater level is high, at 1.0 m below ground level. The site has a high risk of liquefaction during an Ultimate Limit State (ULS) earthquake.

Ownership Details and Tenancy

The building use is a mix of residential apartments and hotel rooms (54 hotel rooms). The building is owned by a body corporate (building strata) since its conversion in the mid-1990s from what was previously an office building. The hotel portion is owned and operated by a large hotel management company based in New Zealand. The pre-earthquake valuation, excluding land value, was set at $10.4m.

Insurance Policy

The building was insured for reinstatement cover for about 600% of its pre-earthquake valuation and had a business interruption cover of 24 months. The building is insured in New Zealand and the insurer is Zurich New Zealand.

Damage States, Neighborhood Conditions, and Access Conditions

The building damage states (Level 2 rapid assessment) are presented in Table 10. Approximately 60% of the buildings that are located within a 100 m radius have been demolished. The building has been given a yellow (Y2) placard and the property site remained inside the cordon for ~28 months.

Table 19: Decision-making variables - R74 - 3-storey RC shear wall hotel building

Insurance	According to the owner, the final repair costs represented about 95% of the building value (or 15% of the sum insured) (note: initial estimate of repair costs was much smaller, about 15% of the building value, or 3% of the sum insured). Reportedly, the amount of insurance (sum insured) available for this building facilitated the decision in terms of the repair (enough to cover the repairs, but not enough to rebuild).
Damage and residual capacity	The building performed well during the earthquakes, with the majority of structural damage observed in localized areas of unreinforced masonry. Localized cracking around the external building envelope suggests that movement has occurred, but the stiffness of the building has resulted in only a limited amount of consequential damage to the stonework features and historic masonry. The key aspects of the damage can be summarized as: Structural Damage: • Structural damage relatively minor • Shear cracking to URM in several locations adjacent to the main stair • Significant cracking of the basement slab • Cracking of concrete walls including around openings • Significant cracking of the basement slab Non-Structural Damage: • Cracking to the main stair landings • Minor cracking of plaster ceilings • Movement and cracking of some external stonework • Spalling and cracking damage to the masonry arches Geotechnical Damage: • No evidence of liquefaction induced settlement or differential movement A Detailed Engineering Evaluation spreadsheet is available in Appendix E.
Decision-making strategies	The owner (body corporate) made the decision quite early that the building was a priority as part of their recovery strategy, because of the limited amount of damage (and associated repair costs). The owner also mentioned that the heritage status of the building was a factor in the decision to repair, as they wanted the building to be restored as much as possible. Furthermore, the owner had a lot of confidence that a three-storey building would be more popular than a high rise hotel building in terms of clientele preference and perception of seismic risks.
Legislation	Based on limited structural damaged observed, the building was not declared dangerous by CERA (CERA Memo - 7 March 2012). The owner had no specific comments on this topic for this building.

Implementation of Decision

Repair works were carried out and the building reopened for public use in September 2013. As of December 2014, the insurance claim was not settled.

4.2.10 R86 - 6-storey RC shear wall hotel building

Building Characteristics

Building R86 is a symmetrical and rectangular structure (40 m x 15 m footprint) designed in 1988. The structure has five concrete floor levels above ground floor level, and a timber mezzanine floor within the roof space. Gravity loads are carried by the floor beams to either cast-in-place columns or walls. Concrete floors consist of a precast rib and timber infill floor system with a 75 mm thick cast-in-place concrete topping. The lift shaft is formed from 140 mm concrete blocks and the two north/south walls of the lift shaft are split into two segments vertically to reduce their in-place stiffness. The main stair is precast, with two flights per floor. Two egress structural steel stairs exist, one at each end of the building. The seismic force resisting system consists of four cast-in-place concrete walls in each direction. In the north/south direction, walls are located adjacent to the four corners of the building. In the east/west direction, the walls are located close to the center of the floor plan. The walls are symmetrical about the center of mass, and have similar stiffness. The walls are doubly reinforced, and have been detailed with confinement in their end zones. In the north/south direction, walls are 300 mm thick from the ground floor up to 2.4 m in height and 250 mm thick thereafter. In the east/west direction, wall thickness is 250 mm at ground floor and 200 mm above first floor. At the foundation level, the shear walls are linked by shallow foundation beams, 1500 mm deep by either 1000 mm or 1300 mm wide. Internal columns sit on square pads, with slab thickening tie beams in each direction.

Ground Conditions

The building is located on site class D. A geotechnical report was not available for review

Ownership Details and Tenancy

The building use is primarily accommodation, in addition to dining and meeting room facilities on the ground floor. The building is owned and operated by a local non-profit organization (charitable trust). The pre-earthquake valuation, excluding land value, was set at $7.6m.

Insurance Policy

The building was insured for reinstatement cover for about 150% of its pre-earthquake valuation and had a business interruption cover of 12 months. The building was insured in New Zealand and the insurance company was NZI, a business division of IAG.

Damage States, Neighborhood Conditions, and Access Conditions

The building damage states (Level 2 rapid assessment) are presented in Table 10. Approximately 10% of the buildings that are located within a 100 m radius have been demolished. The building has been given a green (G1) placard and the property site remained inside the cordon for ~1 month.

Table 20: Decision-making variables - R86 - 6-storey RC shear wall hotel building

Insurance	The hotel manager (interviewee) confirmed that the final repair costs represented about 15% of the building value (or 10% of the sum insured). Going forward, the affordability and availability of earthquake insurance is a significant concern for this building, potentially leading to underinsurance issues. Interestingly, the organization was not allowed by their insurers to increase the sum insured despite that the current amount would not be sufficient to rebuild. Also, their premiums have increased by more than 400% following the earthquakes. Nevertheless, such issues were not significant at the time the decision to repair the building was made.
Damage and residual capacity	The structural damage observed was minor and unlikely to have significantly reduced the overall strength of the building. Several structural inspections have been carried out on the building. The reports noted minor cracking damage within precast panel elements, minor spalling of balcony slabs, and minor settlement of the ground floor slab. Repairs for the observed damage were detailed and the subsequent remedial work was carried out. The key aspects of the damage can be summarized as: Structural Damage: • Minor diagonal cracking of shear walls (0.5 mm crack width) • Minor cracking of diaphragm Non-Structural Damage: • Minor cracking of stair landings • Minor cracking to external precast panels. Cracks wider than 0.2 mm had been repaired with epoxy • Flooding damage throughout (plumbing leakage) Geotechnical Damage: • No liquefaction observed and no evidence of foundation damage A Detailed Engineering Evaluation spreadsheet is available in Appendix E.
Decision-making strategies	The owner made the decision quite early to repair the building, because of the limited amount of damage (and associated repair costs). The owner reported that they never had a conversation about whether or not the building should be demolished because there was never a question of structural integrity. The building use was also very critical in terms of business operations, therefore a repair scenario was preferred. Furthermore, the owner was very motivated to reopen the building as quickly as possible to give the staff their jobs back.
Legislation	Based on limited structural damaged observed, the building was not declared dangerous by CERA (CERA Memo – 26 October 2011). The owner had no specific comments on this topic for this building.

Implementation of Decision

Repair works were carried out and the building reopened for public use in August 2011.

4.2.11 R113 - 19-storey RC frame office building

Building Characteristics

Building R113 is a 19 storey reinforced concrete building with a three storey podium carpark extending on the east and south sides of the tower. The building was designed and constructed in 1988 as a retail and office development, using predecessor standards of the current New Zealand Building Code (principally NZS 4203 1984 for loadings). The structural system consists of a reinforced concrete moment frame on a 1600 mm concrete raft foundation at a depth of 2.5 m below the ground floor level, with thickenings under the columns and walls. The seismic force resisting system is somewhat unusual, comprising two “L” shaped seismic resisting frames in the north-east and south-west sides of the building, having similar strength and stiffness in both directions. Diagonal gravity frames run from the north-west to the south-east of the building. The floors typically consist of a precast beam and timber infill floor system with a 75 mm thick cast-in-place concrete topping acting as the diaphragm. The lift and stair core is located in the south-east corner with a pair of steel beams tying the building together at this location. Steel channels support the stairs and cantilever out the rear of the building to support the restroom area. The stairs (precast units) are orientated diagonally within the tower (north-east to south-west direction) and are seated on a steel channel with a horizontal gap (30 mm) at their lower landings. The carpark relies on the main structure for the seismic resistance, inducing a torsional response in the main structure.

Ground Conditions

The building is located on site class D. A geotechnical report was not available for review.

Ownership Details and Tenancy

Building R113 was a premium-grade office building in the CBD. The majority of the levels were used as office spaces, with some retail activities on the ground floor. The building was owned by group of 17 passive shareholders and investors, and 2 directors. One of the director was also a tenant of the building. The pre-earthquake valuation, excluding land value, was set at $20.0m.

Insurance Policy

The building was insured for reinstatement cover for about 360% of its pre-earthquake valuation and had a business interruption cover of 36 months. The building was insured in New Zealand and the insurance company was Vero. Interestingly, within a year prior to the September 2010 earthquake, the company had been offered an extension of the BI policy from two years to three years, with a very minimal premium increase.

Damage States, Neighborhood Conditions, and Access Conditions

The building damage states (Level 2 rapid assessment) are presented in Table 10. Approximately 80% of the buildings that are located within a 100 m radius have been demolished. The building has been given a yellow (Y2) placard and the property site remained inside the cordon for ~25 months.

Table 21: Decision-making variables - R113 - 19-storey RC frame office building

Insurance	The director (interviewee) reported that the prime issue in the decision process was to deal with the insurance claim which was described as an extremely complicated, complex, long and arduous exercise. The investigation of the damage started more than a year after the February 2011 earthquake because of the falling hazard associated with the collapsed stairs. Once both parties (owner's and insurer's engineers) accessed the interior of the building, then the negotiation started on the nature of the damage (damage caused by the earthquake or not) and the repair methodologies. The insurer argued that the building was repairable, however the directors (owners) were not satisfied with the proposed standard (quality) of repair. Reportedly, the amount of insurance (sum insured) available for this building versus the market value shaped the decision quite substantially in terms of the decision (low indemnity value and high replacement value). However, the cost estimates to repair the building were well within the sum insured, so the building couldn't be written off; it was a cash settlement offer within the sum insured. The owners were happy with the cash settlement offer, indicating that it was a win-win financial arrangement for both parties, since the insurer was also satisfied with the cash settlement and not having to go through complex repairs.
Damage and residual capacity	Excluding the damage to the stairs and the podium structure, the building performed relatively well during the February 2011 earthquake. The main structural damage observed was the inelastic displacement of the main frame structure, cracking of the floor around columns, collapse of the stairs, and possible damage to the connections between the podium and the main structure. The inelastic displacement has been most extensive on levels 4 to 7, causing cracks up to 0.5 mm in the beams and up to 4.0 mm in the floors. A vertical study has been conducted indicating an overall displacement from ground to top of about 80-120 mm north. The key aspects of the damage can be summarized as: Structural Damage: • Flexural cracking of the lower level beams and columns (below level 9) • Cracking of the floor slabs adjacent to exterior beams and internal columns (up to 4.0 mm around corner columns) • Damage to cantilever steel beams due to collapsing stairs • Failure of two columns in the carpark area • Spalling of concrete to the base of corner columns Non-Structural Damage: • Collapsed stairs below level 14 in one stairwell and below level 15 in the other • Glazing broken to allow USAR access Geotechnical Damage: • Liquefaction damage to the ground floor slab

Table 21: Decision-making variables - R113 - 19-storey RC frame office building (cont'd)

Decision-making strategies	From a commercial perspective, the owner preferences and decision-making strategies were very significant in the decision. The director reported to have no specific agenda between demolition and repair in the early days. The strategy was to get the best financial outcome for the shareholders. However, the company was not satisfied with the repair scheme proposed by the insurer, given the high quality of the building prior to the earthquake and the impossibility to reinstate "when new" conditions. The company who owned the building was a group of passive shareholders/investors. The director indicated that they were not interested to assume a greater role in property development, therefore the option of a cash settlement was preferred. The strategy with the insurer was also to demonstrate the difficulty to convince former tenants that they should come back into the building (in part because tenants/employees were trapped in the floors after the stairs collapsed in the February 2011 earthquake and some were traumatized to return in a high rise building), which was going to be a significant argument with regards to the business interruption policy. After the cash settlement, the decision was either to sell the site with the damaged building or just the land after demolishing the building. One group of building developers approached the company to purchase the building as-is-where-is.
Legislation	The director mentioned that CERA was keen to acquire the land as part of the CCDU recovery plan. However, after negotiation, CERA became convinced that the new developers had sufficient expertise to carry out the repairs and redeveloping the building. CERA finally did not play a role in the decision.

<u>Implementation of Decision</u>

The insurance claim was settled in August 2013 (confidential cash settlement with no requirement to rebuild). The building has been sold and will be refurbished into a hotel (reopening in 2016). Furthermore, the interviewee (director of the company) is holding off before reinvesting in Christchurch due to many uncertainties in the recovery pace and the high construction costs.

4.2.12 R163 - 8-storey RC shear wall/frame residential building

Building Characteristics

Building R163 comprises two distinct structures (east tower and west tower) designed and constructed in 2002-2004. The east tower has eight storeys and includes a three storey high carpark building to the south eastern corner of the tower. A basement connects the east and west tower blocks. The basement is used as a carpark with small areas of storage and plant rooms. In the east tower, the gravity load resisting system consists of reinforced concrete columns in the basement and on the ground floor (typically rectangular - 700 mm x 350 mm or circular - 550 mm diameter), precast concrete wall panels on the first six storeys (typically 180 mm thick), and steel frames on the top two lightweight storeys. The lightweight level 8 floor is supported on timber walls and steel floor beams that bear on the exterior concrete panels and the concrete floor at level 7. The level 7 concrete floor is also supported by two deep steel trusses spanning east-west that are connected to the exterior wall panels. The seismic force resisting system consists of 250 mm thick concrete shear walls in the basement, precast shear wall panels in the first six storeys, and steel frames consisting of steel hollow sections for the top storeys. The floor system is precast spaced hollow core units with 90 mm mesh reinforced topping. The floor at level 8 and the roof is constructed from timber. There is steel cross bracing at the roof and level 8 floor level to transfer the lateral loads to the steel frames. The west tower block is seven storeys high over the basement and has a similar structural configuration to the east tower. The buildings are founded on steel screw piles.

Ground Conditions

The building is located on site class D. A detailed geotechnical investigation was completed in December 2011 and a copy of the report is available. No liquefaction or liquefaction related damage was noted on the site following the February or June earthquakes. The results of the liquefaction analyses indicate that there is a low to moderate likelihood of future liquefaction under ULS seismic load conditions.

Ownership Details and Tenancy

The towers are managed by a serviced apartment brand operating in Australia, New Zealand and Fiji. The building provides accommodation for a total of 150 units and comprises a range of studios, one and two and three bedroom self-contained apartments. The building owner is a body corporate (building strata). The pre-earthquake valuation, excluding land value, was set at $30.0m for the two buildings.

Insurance Policy

The buildings were insured for reinstatement cover for about 130% of the pre-earthquake valuation and had a business interruption cover of 24 months. The buildings were insured in New Zealand (Vero).

Damage States, Neighborhood Conditions, and Access Conditions

The building damage states (Level 2 rapid assessment) are presented in Table 10. Approximately 50% of the buildings that are located within a 100 m radius have been demolished. The building has been given a green placard in February 2011 and subsequently a yellow (Y1) placard in July 2011. The property site remained inside the cordon for ~18 months.

Table 22: Decision-making variables - R163 - 8-storey RC shear wall/frame residential building

Insurance	The repair costs were initially perceived to be well below the full replacement amount and the superstructure was sufficiently intact to justify repairing without any detailed analysis. The owner (interviewee) confirmed that the final repair costs (including strengthening works to achieve 34% NBS) represented about 90% of the building value (or 65% of the sum insured). The initial repair costs were much lower (about 55% of the building value) however, one part of the structure had to be demolished and completely rebuilt resulting in substantial additional costs. The owner indicated that the body corporate may have decided to take a different approach knowing the final repair costs would be so high at that time, as they would have possibly argued the building was not economic to repair in order to maximize the insurance payout. However, it would have been a difficult negotiation because the scope of work was about $NZD 16.5m initially (i.e. only 40% of the sum insured). Reportedly, the amount of insurance (sum insured) available for this building versus the costs to rebuild shaped the decision quite substantially in terms of the decision (the sum insured was not enough to rebuild therefore a repair scenario was preferred in a commercial sense).
Damage and residual capacity	The cracks and minor spalling in the wall panels were generally fine hairline cracks, indicating that the steel reinforcing has not likely yielded. An Initial Evaluation Procedure (IEP) has revealed that both buildings had a likely strength of 75 % NBS pre-earthquake, however a quantitative assessment including the effect of damage resulted in a strength of 34% NBS. The inspection report also notes that, although very little damaged and constructed as per the drawings, some connections in the steel frames were not designed adequately (column flanges and web panel shear capacity are closer to 50% NBS). There were also deficiencies noted in the transfer diaphragm and the diagonal bracing, possibly reducing the %NBS further (not discussed in the engineering report). The key aspects of the damage can be summarized as: Structural Damage: • Damage to the seismic gaps • Spalling of concrete and hairline cracking at various locations (panels, floor slabs, hollow core precast floor units) • Compressions failure to end regions of shear walls at ground floor level on south-western side of west building Non-Structural Damage: • Plasterboard linings damage • Damage to the exterior fiber cement linings on the upper storeys • Water leaks on inside face of east tower carpark panels and lift shaft Geotechnical Damage: • Minor differential settlement (floor level survey) • No liquefaction or liquefaction related damage noted A Detailed Engineering Evaluation spreadsheet is available in Appendix E.

Table 22: Decision-making variables - R163 - 8-storey RC shear wall/frame residential building

Decision-making strategies	The owner preferences in terms of the outcome on the building were not really a significant factor. Many of the owners were absentee owners. However, an important factor in the decision to repair was the building's unique features (mix of retail, restaurants and cafes and other facilities) in addition to the quality of surrounding buildings making the area attractive, and the functionality of the building (built in 2004). Also, the tenants collectively put pressures to get the building fixed and reopened. Many hotels were being demolished in the CBD and therefore, owners/tenants believed that remaining hotels would benefit from reopening sooner.
Legislation	The implications of the recent amendments in the building code (increase in the basic seismic design loads) for this building are discussed in the Post-Earthquake Assessment Report (May 2012). The report notes that the primary reason for the building achieving less than 100% NBS is the increase in the basic seismic coefficient in the Christchurch area (the Z factor has increased 36% from 0.22 to 0.30) and the structural performance factor has increased for low ductility structures.

Implementation of Decision

Repair works were carried out and the building reopened for public use in August 2013.

4.2.13 R202 - 6-storey RC frame office building

Building Characteristics

Building R202 comprises six storeys of office floors over a two-storey basement (78 m by 37.6 m in plan). The building was designed and completed in 1972-1974 and completely refurbished in 2008-2010. The main structural features of the refurbishment included the addition of an 8.7 m wide extension to the north side of the building and the construction of mezzanines on five levels. The foundations for the building consist of a reinforced concrete cellular raft system with a total depth of about 3.5 m. The structural system for both the gravity loads and lateral forces consists of moment resisting frames. Reinforced concrete columns are constructed on a grid pattern to give bays of 9.75 m in each direction. There are eight bays in the east–west direction and three bays in the north–south direction. Primary beams are supported by the columns to give four moment resisting frames in the east–west direction and nine in the north–south direction. Two secondary beams are added in the bays between moment resisting frames in the east–west direction to provide support for the 127 mm reinforced concrete floor slab. The inter-storey heights are very large, close to 5.82 m in the upper storeys and 6.9 m in the first storey. The support for the floors in the extension area is provided by 400 mm concrete-filled tubular steel columns, and the floors are supported by steel beams that span from the moment resisting frames over the columns. The lateral seismic forces arising from the extension are carried back into the original part of the building. Despite the year of design, the detailing of the structure was relatively similar to modern standards, incorporating many of the concepts of capacity design (similarly to building D201) and appropriate detailing. Furthermore, all of the original construction is of cast-in-place, as opposed to precast concrete elements which are typically used in conventional construction in New Zealand.

Ground Conditions

The building is located on site class D. A detailed geotechnical investigation was completed in June 2011 and a copy of the report is available. The site data shows that the building is constructed over a soil profile consisting of a sandy surface layer over a sandy gravel witch is typically 6-8 m thick. The underlying sand is potentially liquefiable. The water table is at about 2-2.5 m depth.

Ownership Details and Tenancy

The building was originally designed as an industrial facility, but later modified into an office building in 2008-2010. Since its conversion, the building is owned and managed by a large property investment and development company based in Christchurch (50% ownership). The company has other real estate investments on the South Island (mostly in Christchurch). The pre-earthquake valuation of the building, excluding land value, was set at $61.7m. The owner is also a tenant of the building.

Insurance Policy

The building was insured for reinstatement cover for about 275% of its pre-earthquake valuation and had a business interruption cover of 24 months. The building was insured in New Zealand (80% - Vero (lead insurer) and 20% - QBE).

Damage States, Neighborhood Conditions, and Access Conditions

The building damage states (Level 2 rapid assessment) are presented in Table 10. Approximately 30% of the buildings that are located within a 100 m radius have been demolished. The building has been given a green (G2) placard and the property site remained inside the cordon for ~1 month.

Table 23: Decision-making variables - R202 - 6-storey RC frame office building

Insurance	According to the owner, the final repair costs represented about 25% of the building value (or 10% of the sum insured). Reportedly, the amount of insurance (sum insured) available for this building versus the relatively low cost to repair facilitated the decision in terms of outcome.
Damage and residual capacity	The building has a regular structure with multiple lateral force resisting elements, minimal eccentricity between the centre of mass and the centre of rigidity of the seismic force resisting system, and robust cast-in-place concrete floors to act as diaphragms. There was no failure of any primary structural system. The damage is relatively minor, although there was some limited strain hardening (less than 10% of the ultimate strain). As a result, the stability of the structure and its ability to resist aftershocks and subsequent earthquakes has not been compromised. Furthermore, we note that a minimum of 100% structural compliance with the Building Standard for an Importance Level 2 was achieved during the building refurbishment in 2008, as appropriate for a modern office building. We also note that the structure was originally designed for industrial loadings rather than the lighter office loadings that it now carries. The key aspects of the damage can be summarized as: Structural Damage: • Shear cracking to primary beams (numerous small cracks of less than 0.5 mm, maximum crack of around 2 mm in one location) • Cracking in columns and infill slab at the connection at the interface between the old and new structure • Spalling of concrete in columns adjacent joints Non-Structural Damage: • Extensive damage to non-structural fixtures, linings and claddings • Damage incurred by the stairs was generally minor (adequate support and isolation of the stairs during the building refurbishment in 2008) • Significant damage to stairwell wall linings Geotechnical Damage: • Moderate liquefaction at east end of structure during the Feb. 2011 earthquake A Detailed Engineering Evaluation spreadsheet is available in Appendix E.
Decision-making strategies	The owner preferences in terms of the outcome on the building were not really a significant factor. However, an important factor in the decision to repair was the building's unique features (sustainability features of the building, landmark building, location, size, importance for the city's operations, etc.) and the current functionality of spaces (completely refurbished in 2008). The owner also indicated that the tenants wanted to move in as soon as possible since there was no major damage.
Legislation	The implications of the recent amendments in the building code (increase in the basic seismic design loads) are discussed in the Post-Earthquake Assessment Report (10 August 2011). However, the report notes that the proposed change is only for structures with a 1.5 second time period or less, and that for buildings with a time period over 1.5 seconds, there is no proposed change to the standards. The period of the building has been assessed at approximately 2.2 seconds, putting it outside of the code change proposal. Nevertheless, it was anticipated, as indicated in the report, that there would be subsequent changes to standards which will amend the design loads for these longer time period structures. Code changes for longer time period structures were still at the discussion stage at the time of the decision.

Implementation of Decision

Repair works were carried out and the building reopened for public use in November 2011. The building closed again after the 23 December 2011 aftershock. Minor repairs have been carried out to the building and finally reopened to the public in mid-January 2012.

4.2.14 R901 - 6-storey RC frame university building

Building Characteristics

Building R901 was originally designed in 1972 as a four storey building, with two additional storeys added in the mid 1980s. The building is rectangular in plan and has a footprint of 48 m by 12 m with the long direction running north to south. In both the north-south and east-west directions, the seismic force resisting system consists of reinforced concrete frames. There are eight bays in the north–south direction and one bay in the east–west direction. Gravity load are carried to the columns primarily by relatively deep concrete beams in the short (transverse) direction. All columns land directly onto pile caps which typically sit on five 432 mm x 432 mm reinforced concrete piles running 6 m into the ground. The floor diaphragms consist of 165 mm thick cast-in-place concrete slabs up to level four with the additional two levels consisting of precast slab flooring with cast-in-place concrete topping. The roof is lightweight steel supported on concrete columns. The building is clad with decorative precast concrete panels. The structure is considered as an Importance Level 3 building.

Ground Conditions

The building is located on site class D. A detailed geotechnical investigation was completed in November 2012 and a copy of the report is available. The Avon River is located approximately 140 m to the south west of the site. The water table is at about 2.1-2.8 m depth.

Ownership Details and Tenancy

The building is part of the University of Canterbury main campus and the building use is primarily classrooms. We note that the structure has been replicated for four other buildings on campus.

Insurance Policy

The building is insured for reinstatement cover as part of a collective arrangement with other universities in New Zealand. The same policy applies for each of the buildings (each building has a different cap value). The pre-earthquake valuation, excluding land value, is not available.

Damage States, Neighborhood Conditions, and Access Conditions

The building damage states (Level 2 rapid assessment) are presented in Table 10. The percentage of demolished buildings that are located within a 100 m radius is negligible. The building has been given a green (G2) placard and the property site was located outside the cordon.

Table 24: Decision-making variables - R901 - 6-storey RC frame university building

Insurance	Insurance coverage is a major factor in terms of post-earthquake decisions for UC's buildings, however there was no specific comment on this topic for this structure. The final repair costs for this building are not available.
Damage and residual capacity	The building did not suffer major structural damage as a result of the earthquakes. Consequently, the building's gravity and lateral load resistance are unlikely to have been significantly reduced. The building was analysed for its likely behaviour under a current code design level earthquake using ETABS. The building is expected to have a lateral capacity of at least 67% of current code requirements. Therefore, the building is not categorized as an earthquake-prone building. The key aspects of the damage can be summarized as: Structural Damage: • Spalling of concrete due to pounding and superficial damage at seismic gaps • Minor cracking to beams around the stairwell • Minor cracking to columns in some locations within the stairwell Non-Structural Damage: • Minor damage to non-structural elements throughout the building • Partial damage (cracking and spalling) to stairway due to inter-storey drift movements • Dislodgement of a cladding panel at the top level of the northern lift tower Geotechnical Damage: • No significant land damage observed A Detailed Engineering Evaluation spreadsheet is available in Appendix E.
Decision-making strategies	The owner preferences and decision-making strategies were very significant in terms of the decision. All of the decisions that are made on UC buildings go through the University Council. The outcome is based on a decision-making framework (see Chapter 5 for details) and the suitability of the building in the long term based on the strategic master plan (Capital Prioritisation Framework). The strategic master plan outlines principles and a high level planning vision to guide the development of the University's built infrastructure over the next 20-30 years.
Legislation	The rules around the strengthening of earthquake-prone buildings on campus were a significant financial issue for the University of Canterbury, since the differential between insurance cover to 34% NBS and 67% NBS was estimated at $NZD 140 million. Furthermore, UC generally aims for 100% NBS (strengthening target) and requires all buildings on campus to be at least 67% NBS. Finally, the implications of the recent increase in the basic seismic design loads for Canterbury are discussed in the Structural Assessment Report (August 2011).

Implementation of Decision

Structural remediation work commenced in February 2013 and was carried out to a number of structural aspects including the internal stairs, the link bridges, and the damaged cladding panel connections. Staff progressively relocated back into the building in December 2013. Level 2-6 were completed and occupied by February 2014. The ground floor of the building re-opened in April 2014.

4.2.15 R902 - 3-storey RC shear wall/frame public assembly building

Building Characteristics

Building R902 is a three storey building with a partial lightweight top storey forming the roof top plant room. The building also includes a basement carpark that extends nearly to the full site. The basement is formed of reinforced concrete walls over a raft slab on ground of either 400 mm or 500 mm thick. The superstructure is constructed of a combination of precast and cast-in-place concrete elements forming rigid "boxes" containing the primary accommodation (north box and south box). The two boxes are supported by columns at the basement level. The seismic force resisting system consists of rigid concrete floor diaphragms at roof and floor levels, which transfer lateral loads into the reinforced concrete walls. These walls transfer the seismic loads into the transfer diaphragm that forms the roof of the basement carpark, and through this raft foundation into the ground. Steel moment frames at a high level over the foyer link these boxes and form the roof and façade support. Precast concrete panels form the cladding to most of the external walls and the internal walls in the main atrium space. The building was constructed during 2001-2002 and was officially opened in May 2003. The structure was designed to support loadings required by the NZS 4203 1992.

Ground Conditions

The building is located on site class D. A detailed geotechnical investigation was completed in July 2011 and a copy of the report is available. In a future design level earthquake to building code demands, potential for up to 150 mm liquefaction induced subsidence and up to 100 mm differential settlement is expected to occur. The water table is at about 1.5-2.2 m depth.

Ownership Profile and Tenancy

The interior includes offices, an educational area, a theatre and four principal areas all finished to a very high architectural standard. There are workshops, storage rooms and facilities maintenance areas all finished to a basic standard. The structure is considered as an Importance Level 3 building. The building is owned and operated by the Christchurch City Council and employed 50 people before the earthquakes.

Insurance Policy

The building is insured for reinstatement cover as part of a collective arrangement with other Councils in New Zealand. The same policy applies for each of the buildings (each building has a different cap value). This building was insured for reinstatement cover for approximately $85.0m. The pre-earthquake valuation, excluding land value, is not available.

Damage States, Neighborhood Conditions, and Access Conditions

The building damage states (Level 2 rapid assessment) are presented in Table 10. Approximately 20% of the buildings that are located within a 100 m radius have been demolished. The building has been given a Green (G2) placard and the property site remained inside the cordon for ~1 month.

Table 25: Decision-making variables - R902 - 3-storey RC shear wall/frame public assembly building

Insurance	The investigation of the damage started more than a year after the February 2011 earthquake. The scope and the cost of strengthening and repair work were still not fully defined at the time of the interview and the required budget remained unclear as a result of uncertainty relating to the Council's insurance claim. We highlight that divergent recommendations between the owner's engineers and the insurer's engineers created uncertainties in the repair methodology (the type of repair option was in dispute). The total repair and strengthening costs is expected to be about \$NZD 54m (of which ~\$NZD 14m are insurance repairs).
Damage and residual capacity	The building is of robust construction and has generally performed well during the Canterbury earthquakes. A detailed finite element analysis computer model has been constructed and indicates that the global building performance is above 67% NBS. No critical structural weaknesses have been identified in the building. The key aspects of the damage can be summarized as: Structural Damage: • General cracking to the structural concrete elements • Basement: Large cracks (up to 5 mm) are present in concrete block wall that make up the carpark lift and stair cores at the western side of the basement. • Ground Floor: Several cracks up to 1.2 mm wide in the slab Non-Structural Damage: • Cracking to precast cladding panels (columns, walls, slabs) • Damage observed to non-structural items such as suspended ceiling grids/panels, flashings, cold water chiller, fan units, pipe, duct, and cable distribution • Cracking in the precast concrete panels forming the stair core. Geotechnical Damage: • Differential settlement and ground subsidence (minor) A Detailed Engineering Evaluation spreadsheet is available in Appendix E.
Decision-making strategies	The building wasn't heavily damaged and therefore it was believed it could be repaired right from an early time. The discussion around the appropriate repair methodologies for the building was, however, very complex due to the differential settlement of the foundations. Also, the building and its content are one of the city's most important and valuable cultural assets. It was believe that the re-opening of the building would significantly help the education and tourism sectors to recover from the earthquakes. External pressures (from the public) were significant in the decision to repair. Another important factor in the decision to repair was the building's unique features (high value of the contents, architecture, landmark building, location, size, etc.) and the current functionality of spaces.
Legislation	Reportedly, the legislation was not really significant in the decision to repair since the building is fairly modern and the structural damage was not extensive. However, we note that the lateral design forces used in the original design are calculated to be equivalent to 57% of the current loading code (2012) by direct comparison between loading codes.

<u>Implementation of Decision</u>

The owner (Christchurch City Council) decided to repair and upgrade the building to 100% NBS. The repair program include the construction of a base-isolation system for the foundations, in addition to the installation of a secondary electrical system for the lighting and climate-control backup. The reopening of the building is schedule for December 2015.

4.3 Conclusions

Findings from this study suggest several key conclusions and areas of further investigation. First, there is no evident correlation between the type (and design ductility) of the lateral system and the decision (either repair or demolish). Structural damage is typically assumed to be associated with the ductility demand, however, this correlation is not observed with the small sample size considered in this study. Second, the %NBS (pre-earthquake) appears to be a strong indicator of the decision. Buildings at less than 67% NBS have been demolished, while buildings above 67% NBS have been repaired (with one exception). Two earthquake-prone buildings (less than 33% NBS pre-EQ) were included in the study (D49, D73) and both have been demolished. Third, the level of insurance coverage varies greatly between the case studies (for both repaired and demolished buildings), with some well-insured and others under-insured (as discussed in section 5.2). All demolished buildings have cash-settled. Finally, placarding does not appear to be a good measure of the likelihood of demolition. Two buildings with low damage ratios that were considered safe to occupy (i.e. green placard) have been demolished, in addition to the demolition of all red placard buildings.

Chapter 5: Findings and discussion of results

This chapter describes the results from the interviews in relation to the decision-making themes identified in the framework (insurance, damage and residual capacity, decision-making strategies, and legislation) (Figure 15 – Chapter 3). As the framework suggests, the four themes address the major considerations for building owners and property managers in the process of determining the fate of earthquake-damaged structures. The following sections discuss the conditions in Christchurch and how the factors are interrelated in arriving at the final decision. The first section (recovery progress) does not explicitly relate to the decision-making framework variables, but provides the necessary background to examine how the government and the community response to the earthquakes may have influenced the whole context of decision-making for earthquake-damage structures in the central city.

5.1 Recovery progress

Interviewees were asked to rank how well they considered Christchurch's recovery to be proceeding, on a scale of 1 to 7, with 1 being "extremely poorly" and 7 being "extremely well." Interviewees were asked to rate recovery and then elaborate on their reasons. The average score was 4.3. The average response from building owners (categories A and B from Appendix C) was 4.0, while the interviewees speaking on the topic of insurance (category C) gave an average response of 4.7, and government authorities (category D) reported an average score of 5.0 (Figure 18). Several respondents reported that the recovery progress was uneven geographically, where specific areas, including the CBD, were described to be going extremely well compared to largely residential eastern suburbs. The 'central city' has temporarily shifted to other western suburbs (e.g. Addington, Riccarton), resulting from a decentralisation of economic activities and movement of businesses. Some participants highlighted the government had too much control in the CBD and argued the recovery could have been managed more effectively with a better engagement of the private sector and the community in the early days.

Interestingly, a similar question was asked to a different subset of interviewees in 2012 and an average score of 4.2 was reported (Figure 19) (Chang et al. 2014). From the 2012 study, interviewees speaking on the topic of insurance ranked the recovery progress much lower, with a score of approximately 2.4. The results are not fully comparable given the different scope of the research projects, but provide an indication of how the insurance industry perceived the recovery progress at two points in time. We also highlight that a much greater percentage of commercial claims were settled by the time of the 2014 study (ICNZ estimated that 83% of all commercial claims were settled by February 2015) which has allowed businesses and property investors to recover and rebuild.

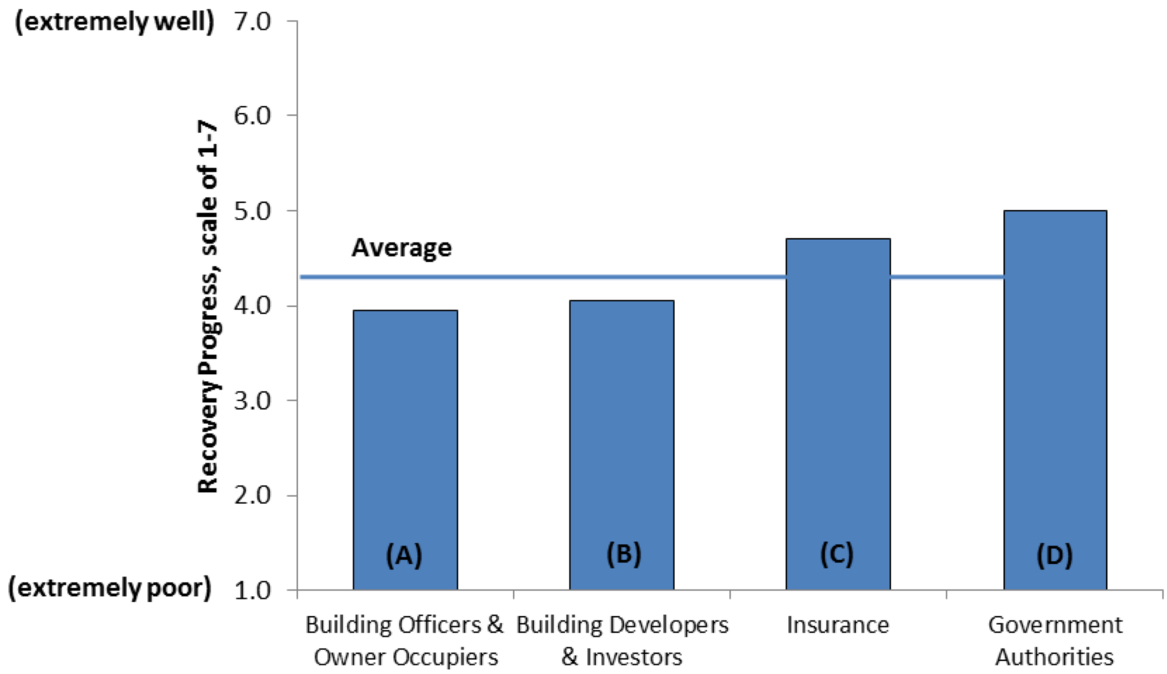


Figure 18: Recovery progress by interviewee group (2014 interviews)

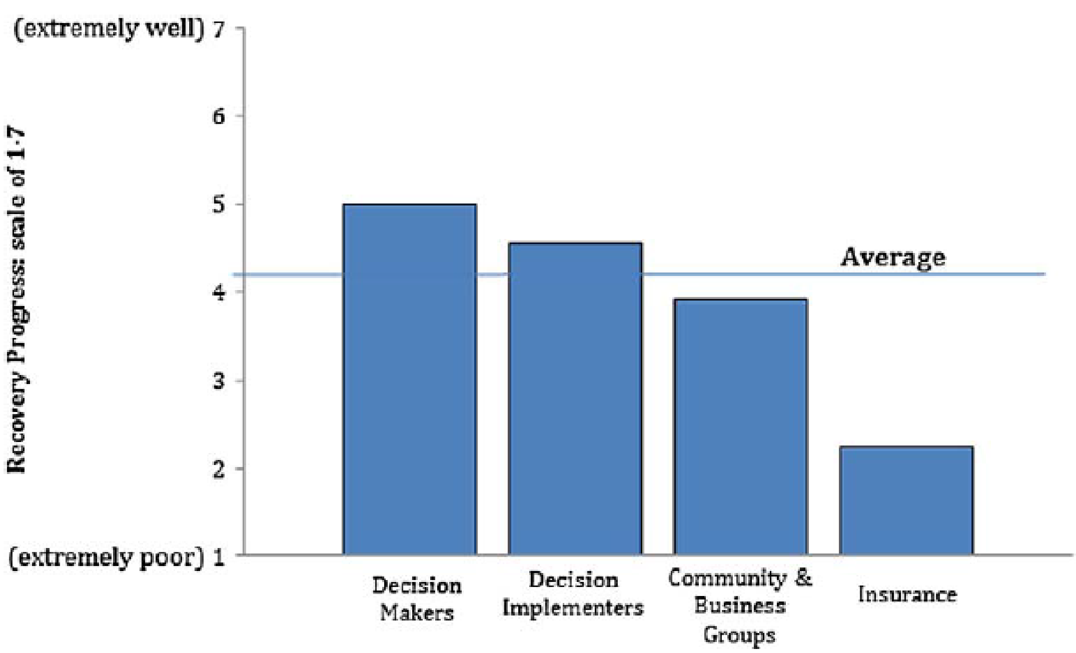


Figure 19: Recovery progress by interviewee group (2012 interviews - Chang et al. 2014)

In 2014, the city has seen the initiation of a number of major construction projects including the new $NZD 325 million Justice Precinct, the redevelopment of the $NZD 250 million Burwood Hospital, and the new $NZD 50 million Bus Interchange (CCDU 2012). A number of multi-storey commercial buildings have begun construction or have been completed to the west and north of the CBD along Victoria and Colombo Street, and plans are underway for other medium and large new build commercial projects within the CBD.

However, the opinions were divided as to whether the CCDU recovery plan will be beneficial for the recovery of the city and the community. There are fears that the redevelopment of the CBD will result in a surplus of new office buildings for premium tenants (lawyers, accountants, governments) and unaffordable commercial rents for small businesses, which may slow down the economic growth of the property market in Christchurch in the near future. One interviewee reported that many new developments in the CBD were initiated without a full pre-commitment of tenants (as low as 50% space commitment) because of the availability of insurance payouts to reduce the amount of mortgage financing required to rebuild. Also, there are concerns with regard to public funding, cost escalation, resource availability, and the viability of new development in the CBD in consideration of the lower height limits imposed by the recovery plan (generally 7 storey buildings in the Core and 4 storey buildings elsewhere). Lastly, as discussed below, interviewees revealed that the disaster has created benefits to certain stakeholders, such as building owners and the construction industry, in part because of the insurance structure.

5.2 Insurance

The aftermath of the earthquake sequence revealed that the sum insured was unintentionally less than the actual rebuild cost for most commercial properties, and therefore the policy was not adequate to provide cover for replacement of the building. This situation was explained in part because of inadequate valuations, including not accounting for demand surge and high demolition costs in a post-earthquake environment. One interviewee from the insurance industry estimated that only two buildings out of 1000 commercial buildings were more than adequately insured.

Rider Levett Bucknall (RLB) publishes hard construction cost estimates for office, retail, hotel, car parking, industrial warehouse, and residential multi-storey buildings in Christchurch. These costs are expressed per m^2 of gross floor area and typically include the base building costs (structure) and fit-out. We have used RLB's values to estimate the replacement cost of specific case-study buildings and compare against the sum insured for material damage in the insurance policy to evaluate the degree of underinsurance. We have selected the median values for office and hotel buildings for each year between 2009 and 2015 from the RLB reports. As shown in Figure 20, there was a significant increase (approximately 25% to 30% increase) in the construction costs after February 2011 due to post-disaster demand surges in the construction industry and resources shortages (excluding 5-star hotels for which pre-earthquake construction rates were relatively higher in comparison to other types of building occupancy). These cost estimates do not include the costs of demolition, contingency, FF&E, professional fees, and taxes (GST).

Based on observations from the interviews, experience of local engineers, and actual construction cost for new buildings in Christchurch (RLB 2015), we estimate that 1980s-1990s office and hotel buildings with less than approximately 320% sum insured (expressed as a ratio of the building value, including depreciation) were not fully covered for replacement (demolition and rebuild) (Table 26). This threshold is greater for older or heritage buildings (e.g. the rebuilding cost for building R74 was about 850% of the building value according to the 2014 insurer's valuation) and lower for more recent buildings (between 150% - 200%). Therefore, only two case-study buildings are estimated to have had sufficient coverage to rebuild (D192, R113) when accounting for demolition costs, contingency (10%), furniture, fixture and equipment (FF&E - $NZD 100 per m²), professional fees, permits (12.5%), and taxes (GST – 15%). The actual cost of demolition for each building was considered when available and a cost of $NZD 200 per m² of gross floor area (excluding taxes) was used otherwise (when demolition costs were not available or for repaired buildings). These costs are consistent with the local practice based on recommendations from two industry professionals.

A sufficient sum insured is also critical to achieve appropriate repairs, including strengthening for earthquake-prone buildings, and as a result, underinsurance has influenced the prevalence of building demolitions in Christchurch. Repairing and possibly strengthening was usually not economic from an investment perspective if the sum insured was inadequate to cover both repair and building code compliance costs. Unique aspects of the NZ insurance market, such as policy wordings (e.g. replacement as "when new" policy) and local practices (e.g. absence of condition of average, where the claim is paid in proportion to the underinsurance), rendered repairs uneconomic and facilitated demolitions in terms of cost (Drayton and Verdon 2013). As already reported in the literature, most commercial demolitions were not because the buildings were dangerous and damaged beyond repair, but because they were uneconomic to repair to a condition as when new, as was the entitlement of the policyholder (Brown et al. 2013; Miles et al. 2014).

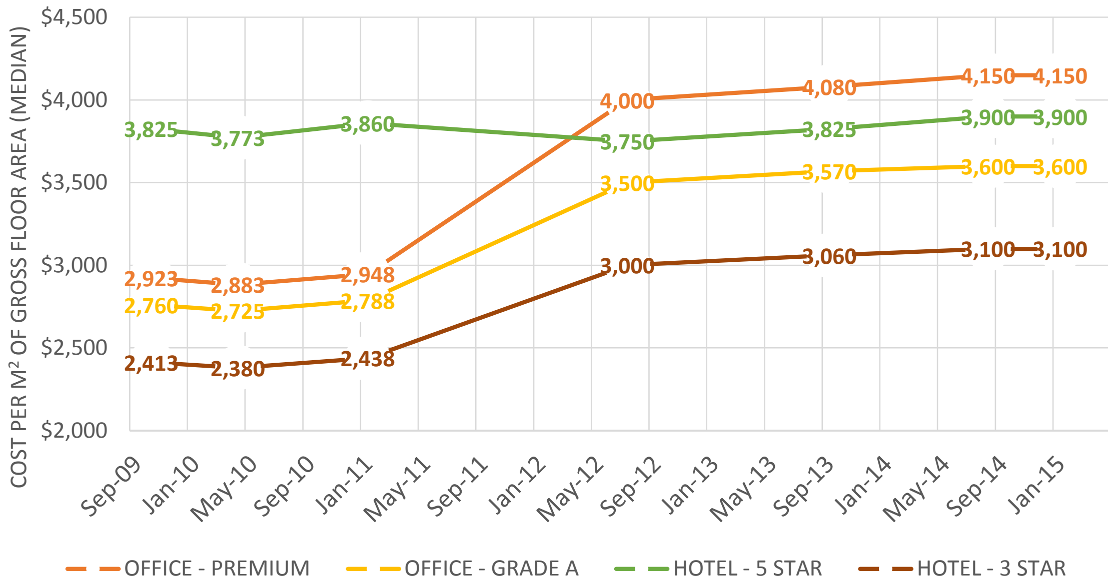


Figure 20: Median construction rates (in $NZD) between 2009 and 2015 in Christchurch (Data source: Rider Levett Bucknall 2015)

Table 26: Estimated replacement costs for 1970s-1990s case-study buildings (office and hotel)

Building ID			Demo. Cost	Base Cost (Struct. + Fit-Out)[3]	Contin-gency[3]	FF&E[3]	Profess. Fees and Permits[3]	Taxes (GST)[3]	Grand Total	Site Sum Insured
OFFICE	Premium (4,100$/m²)	D11	0.11[1]	2.10	0.25	0.05	0.27	0.42	**3.20**	**2.20**
		D117	0.15[2]	2.00	0.23	0.05	0.27	0.40	**3.10**	**2.50**
		R113	0.12[2]	2.35	0.27	0.06	0.29	0.46	**3.55**	**3.60**
	Grade A (3,600$/m²)	D49	0.10[1]	1.94	0.22	0.05	0.24	0.40	**2.95**	**2.60**
		D196	0.13[1]	2.40	0.27	0.06	0.28	0.46	**3.60**	**2.20**
HOTEL	5-Star (3,800$/m²)	D73	0.11[1]	1.90	0.22	0.05	0.24	0.38	**2.90**	**2.00**
		D192	0.08[1]	1.95	0.22	0.05	0.24	0.38	**2.92**	**3.60**
	3-Star (3,000$/m²)	R86	0.13[2]	2.00	0.23	0.06	0.25	0.40	**3.07**	**1.50**
								Average	**3.2**	**2.5**

Notes: All values are expressed as a ratio of the building value (pre-earthquake). Bold values indicate numbers to be compared to determine if the building was underinsured (red values) or had sufficient coverage to rebuild (green values).

1) Actual Demolition Cost (confirmed by the building owner)
2) Estimated Demolition Cost (200$ per square meter + GST)
3) Source: RLB 2015, interviews and experience of local engineers

Despite widespread underinsurance, some commercial owners have financially benefited from the insurance structure, some doubling or tripling their equity. Reportedly, if the estimated repair costs were beyond 80-85% of the sum insured (in some cases as low as 60% of the sum insured), building owners and insurers favored cash settlements without reinstatement of the property. Cash settlement provided maximum flexibility for building owners and was typically less financially risky than repairs and rebuilds for insurers. Although cash settlement was not an entitlement under most policies, this outcome was by far the most common because of the reasons above and the incapacity for insurers to actually do reinstatement on thousands of claims. In case of repair, building owners usually did not want to cash settle because the risks of escalating costs during repairs were typically carried by the insurer. Even though cash settlement was usually reached by negotiation, one interviewee reported that insurers in the early days would not make a cash settlement over 85% of the sum insured, but by 2014 the majority of cases were cash settled at 100% of the sum insured. Many policyholders made claims for successive earthquakes which in aggregate exceeded the fixed sum insured and even the full replacement cost of the building; however, a Supreme Court decision (Ridgecrest v IAG New Zealand) ruled that building owners cannot recover more than the replacement cost of their building through insurance claims (NZSC 2013). Sometimes final settlements exceeded 100% of the sum insured if there was a policy renewal between two damaging events. Some owners sold their properties after cash settlement, sometimes with the building in place, thus avoiding the uncertainties of the Christchurch CBD rebuild. Therefore, this pragmatism around doing cash settlements generally provided a good financial outcome for the policyholder (observed to varying degrees among the case-study buildings), however, the details were usually confidential.

Reportedly, material damage insurance for commercial buildings is now harder to secure than prior to the earthquakes, especially for earthquake-prone buildings. Initially after the February earthquake, insurance companies shifted the financial risks from themselves to property owners by increasing the cost of insurance premiums (up to 500% in some cases) and changing the deductibles (excess) from a percentage of damage to a percentage of the sum insured (as high as 10%). In some cases, insurance premiums became unaffordable for businesses and different responses have been observed (e.g., switching insurance companies, obtaining insurance on the international market, reducing cover to indemnity value, buying down insurance on deductibles, etc.). We believe that such changes in the insurance contracts may have incentivized investors already financially suffering from a low-rent market to demolish rather than repair. Insurers have also modified their policy wordings and introduced coverage restrictions. For instance, the extra cost of bringing a damaged building into compliance with current earthquake construction standards or any cost in connection with the seismic performance of the building is now typically explicitly excluded. Automatic reinstatement of loss cover is no longer available and policies are subject to annual aggregate loss limits (Axco 2014, Vero 2013). Insurance premiums follow, however, the dynamics of international reinsurance markets (Middleton 2012). Reportedly, international insurers with no losses to recover from the Canterbury earthquakes are now coming to New Zealand offering lower premiums. Interestingly, an interviewee from the insurance industry reported that the price of insurance had actually come down even to levels lower than before the earthquake, and deductibles are also back down in some instances. Nevertheless, the self-retention of risks in the case of an event is much greater than it has been in the past, and as a consequence, a combination of risk mitigation strategies is now being used by property owners and developers (e.g., seeking increased seismic performance, damage-resistant technologies, diversification of the risk portfolio, etc.) instead of relying on insurance to fully cover losses in the case of future disasters.

5.3 Damage and residual capacity

The first challenge for city officials, building owners, insurers, and structural engineers was to ensure appropriate investigation of damage in order to define the relative safety of buildings for public access and to initiate insurance claims. The investigation process generally includes a review of the existing documentation for the building, damage assessments, scope of repair or reinstatement, quantification of the expected seismic performance (pre and post-earthquake), and estimation of costs to determine if it is economic to repair. There were many technical challenges around the investigation phase; examples include the assessment of damage to reinforcement in reinforced concrete structural elements, quantification of residual capacity and loss of fatigue life. Logistical challenges have been reported in relation to the impacts of the cordon around the CBD, availability of appropriate resources, slow turnaround time for detailed evaluations of seismic damage, and international assessors not familiar with New Zealand standards and policies. As expected, most interviewees stressed that the level of damage was a fundamental variable in the decision to either repair or demolish. Building owners sought technical advice from structural engineers to benchmark possible options and provide their insurers with detailed damage assessments and repair cost estimates reflecting their strategy, sometimes higher than typical costs because it was to a condition as when new.

Although less damage was generally found in repaired buildings, a wide range of damage was observed among the demolished buildings. As shown in Table 10, among the case-study buildings, the overall damage ratio ranged from 2% to 30% for the demolished cases compared to less than 10% for the repaired cases. For heavily damaged buildings, demolition was typically the preferred option due to uncertainties in the assessment of the residual capacity, repair methodologies and costs. Differential movement of foundation systems was observed across a significant proportion of multi-storey buildings in the CBD. According to Muir-Wood (2012), approximately 25% of all buildings in the CBD were found to be no longer vertical, with tilts of 25 mm or greater. In most cases, out-of-plumb buildings (with varying degrees) were declared “uneconomic to repair” and demolished. Four case-study buildings (D11, D49, D201, and R902) had substantial foundation differential settlement and as a result three have been demolished. The differential settlement on building R902 was remediated by re-levelling the building’s foundations using a cementitious grouting technique.

5.4 Decision-making strategies

Building owners generally took a simplistic and pragmatic approach to decide on the future of their buildings. As illustrated in the framework (Figure 15), there are a number of possible scenarios: a building is repaired to the same performance level; a building is repaired to a higher standard; a building is demolished and replaced with an equivalent building (same site or different location); or a building is demolished and not replaced (cash settlement). Although there are some variations, decisions were usually based purely on economics. Interviewees also reported other decision-making variables, such as business strategies, perception of risks (by owners, tenants and insurers) and uncertainty, technical advice, building regulations (e.g. changes in building code, compliance issues), and government decisions (e.g. cordon, mandatory demolitions, compulsory acquisitions). Access and neighborhood conditions (expressed as demolition percentage of buildings that are located within a 100 m radius) appeared not to be very significant in the decision to repair or demolish, but very significant in terms of business interruption and speed of the recovery. The majority of commercial property owners in Christchurch were passive investors, but some interviewees reported they had to assume a greater role in property development and day-to-day affairs after the earthquake due to all the complexities of complying with both the insurer's and government's requirements. Most investors interviewed considered it a good outcome if their building was declared a total loss and demolished, because of the financial benefits, flexibility, and speed of cash settlements (as explained above). They preferred to demolish their buildings, in part because of uncertainties in the recovery of Christchurch, and move forward more quickly with cash. Building investors and tenants reportedly preferred new buildings over repaired old buildings. One building owner involved in the accommodation sector reported that a repair scenario would be a massive disadvantage to the rest of the market in terms of new build hotels or low-rise hotels moving forward. Furthermore, one interviewee reported some issues around the taxation system that may have financially favored demolition scenarios rather than repair, although this research did not assessed the influence of this factor in the decision process. In New Zealand, demolition costs are generally not deductible for tax purposes, however the Central Government made changes in December 2010 that allow demolition costs to be included as a tax deduction under certain circumstances. This provided some tax relief in a situation where a demolition of a building is required. Moreover, a cash settlement (including the scenario where the insurance proceeds are more than the depreciated value of the building) is generally tax free. On the other hand, any repair works which improve a damaged building beyond its earlier condition is generally considered as a capital improvement rather than a tax deductible repair. Therefore, there were some tax benefits to demolish rather than repair, especially for earthquake-prone buildings or structures needing strengthening to higher %NBS.

Different strategies were observed for heritage buildings and non-investor owners / owner-occupiers. Despite a high degree of damage and costs, some heritage building owners preferred to refurbish an old building in order to preserve unique architectural features or simply because of their emotional attachment to the building. Owner-occupiers have generally considered economics in their decision, however this factor was balanced with the operational importance of the building (continued occupancy) or long-term strategies.

The findings from the case-study buildings suggest that the vast majority of local investors appear to have kept their money in Christchurch while a few walked away with insurance money to other cities or countries. This situation was also evidenced by interviewees familiar with buildings owners in Canterbury, although one interviewee indicated that local investors would now prefer using a diversification strategy for future investments. For instance, rather than having a 100% of their investment in Christchurch, some investors would split a third of their investments in Christchurch, a third elsewhere in New Zealand, and then a third offshore. Some investors are also holding off before reinvesting in Christchurch due to many uncertainties in the recovery, the difficulty of attracting tenants in the CBD, and the escalation in the construction costs.

Various organisations in Christchurch with large portfolios of buildings have created a structured decision framework as part of their recovery process to guide the decision-making process and balance the impacts and costs of possible options. We highlight here the Canterbury District Health Board (CDHB), University of Canterbury (UC), and Christchurch City Council (CCC). CDHB is responsible for the health services for over 550,000 people, and is also the single largest employer in the South Island, employing close to 10,000 staff and approximately 9,500 health sector contract workers. Following the earthquakes, over 700 staff have been displaced, 14,000 rooms had earthquake damage, and the main regional hospital, the Christchurch Hospital which includes the base-isolated Christchurch Women's Hospital, sustained damage that severely restricted the hospital's ability to function at regular capacity (Jacques et al. 2014). CDHB owns near 200 buildings across the Canterbury region and had to prioritise capital expenditure, both for earthquake repairs and retrofit or replacement of earthquake-prone buildings. As a result, the Board used a holistic approach and created a decision-making framework to prioritise repairs and/or seismic upgrades in the context of the earthquake damage (Figure 21). The framework is applied to each building owned by CDHB and considers various factors such as the continued and future role of the building (if the building forms part of the CDHB Facilities Master Plan and will be utilised for the next 10 years), availability of alternative spaces, costs of repair (net of any insurance payouts that can be applied to the repairs on the particular building), and the level of disruptions to clinical services delivered (high, medium, and low) (CDHB 2012). Although not explicitly captured in the decision making framework, the decision outcome is based on reconciling the trade-off between potential harm to patients and staff in future earthquakes (based on engineering assessments and advice) against immediate harm to patients if services are withdrawn with closure of buildings and relocation of patients and staff. Therefore, a level of pragmatism and assessment of tolerable risk also needs to be overlaid as part of the assessment of priorities and progression of the decision. As of September 2014, CDHB occupies eight earthquake-prone buildings (less than 33% NBS) and a total of 44 buildings (47,000 m² of space) have been identified to be demolished in a ten-year timeframe from the 2011 February earthquake. CDHB's earthquake insurance is part of a national policy with 19 other DHBs. The policy for earthquake-damaged buildings had an annual cap of $NZD 320 million with no discounting and was not tagged to any building which provided flexibility for the repair works. The Board identified more than $NZD 700 million of earthquake-related repairs to its buildings and infrastructure, in addition to the new builds of Burwood and Christchurch Hospital, leaving a substantial gap between the insurance payout and actual repair costs.

The necessity of continued functionality of critical infrastructure, such as healthcare facilities, makes it challenging to compare and contrast approaches with other decision-making strategies for large portfolios. However, some factors included in the CDHB's decision-making framework are relevant for other organizations' models, although the priority level for each factor may change reflecting different business strategies and recovery issues. The University of Canterbury (UC) campus, located 2 km west of the CBD, has a range of building types built since the late 1950s, predominantly 3-12 storey concrete buildings. UC developed a framework to help inform building repair, retrofit, or replacement decisions, and prioritizing work across the portfolio of buildings. The framework specifically relates to buildings that were unoccupied and were not expected to be ready to occupy in the medium term (e.g. 4 months or more) following the 2011 February earthquake.

Variables are grouped into four categories and are listed in order of importance to the decision making:

1. repair and retrofit feasibility: damage sustained, expected future performance, ease of repair, ease of retrofit, staff and student perceptions of safety, compliance with mini-mum performance requirements;
2. financials: age and value, costs, ability to fund;
3. long-term suitability (campus master plan): current functionally of space, future heritage / character, fit with longer term campus vision;
4. operational importance: nature of pre-existing use, availability of alternate space, importance of use to overall recovery and operations.

The decision outcome is based on a portfolio approach, where the decision for an individual building is highly dependent on concurrent decisions made on other buildings on campus. UC's earthquake insurance was part of a collective arrangement with other universities in New Zealand, with a cover of $NZD 550M across all the universities per event.

Similarly, CCC adopted a program which describes the factors involved in the decision making for earthquake-damage facilities such as the level of damage (including safety hazard), compliance to the current building code and CCC's occupancy policy (revised in 2014), financials, strategic needs, and public and political actions (including the CCDU's blueprint). The program also prioritized facilities for further investigations, funding, and where possible, repairs. Council's above-ground assets were all insured with Civic Assurance (a self-insurance program owned by New Zealand councils) on a full re-instatement basis for close to $NZD 1.9 billion, capped to a fixed amount per asset. CCC owns approximately 1600 facilities (residential and non-residential buildings) across greater Christchurch.

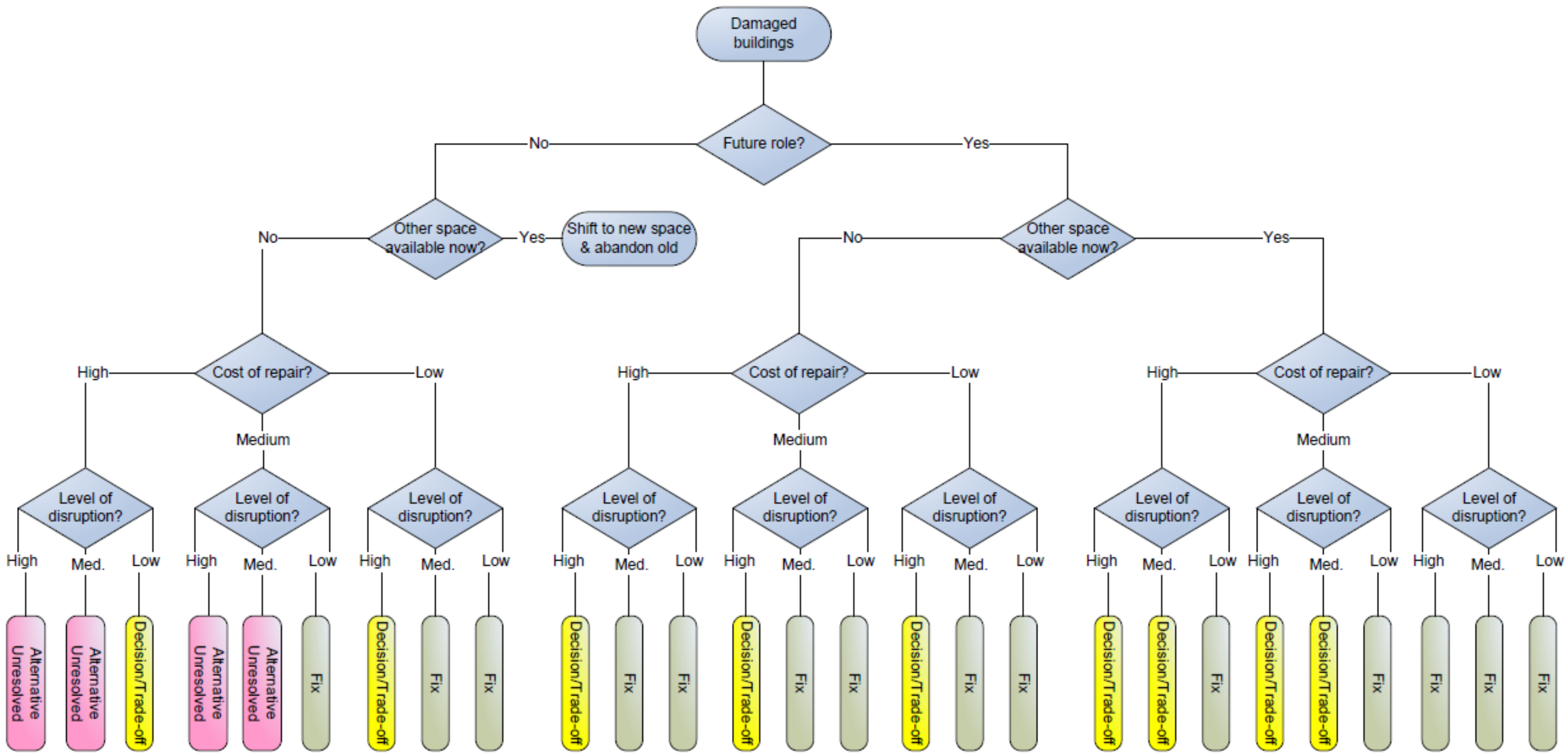


Figure 21: CDHB decision-making framework (Source: CDHB 2012)

5.5 Legislation

As previously discussed, there were two main changes to the building regulations following the earthquakes, and both influenced decisions on earthquake-prone buildings. First, the Christchurch City Council changed its earthquake-prone building policy recommending that building owners must aim to strengthen the buildings to 67% NBS, as opposed to 33% pre-earthquake. However, a High Court decision in 2013 (and a Supreme Court decision released in December 2014) ruled that property owners and insurers are only obliged to strengthen the buildings to 33% NBS, causing confusion as to whether or not insurers were required to pay for the additional remediation (NZSC 2014). Building owners were also confused if they were required or not to upgrade to at least 67% in order to receive a building consent (permit) for earthquake repairs. Second, the Z factor (i.e. the seismic hazard factor that is applied to a location to determine the design seismic actions for a building) was increased from 0.22 to 0.3 to take account of greater seismicity in the region, forcing down the NBS seismic rating of many buildings in Canterbury. Both these changes have had a significant effect on post-earthquake decisions and the cost of the repair (and strengthening), which may have led to more building demolitions than would have occurred without the legislation changes. Interviewees reported that the changes in the building regulations created uncertainties around the repair scope and methodology, and that additional costs resulting from these changes made a repair scenario sometimes less financially attractive. Furthermore, a study published by the Royal Commission (2011) has demonstrated that the overall construction costs for a new build do not appear to significantly rise as a result of increases in the seismic hazard factor, however, it does not account for the costs to strip out an earthquake-damaged building to effect the structural repairs and upgrades, which may involve significant restoration costs with regard to the non-structural components (cladding, building systems, etc.).

Because of the absence of any specific legislation or guidance for the repair of damaged buildings, compliance to the building code (including triggering fire protection and disability access) has increased the costs covered by insurance and complexity of claims. Interviewees also stressed that many tenants, banks (mortgage) and insurers are demanding premises to be at least 67%NBS (in some cases even requiring 100%NBS), but additional rental income will not necessarily be generated from the expenditure, rendering the repair of older buildings less economic, especially in a market generating a surplus of new office buildings at 100%NBS (PCNZ 2014). Informed occupants, including large multinational tenants and government tenants, have changed their perception of earthquake risks, which resulted in pressures on building owners to meet higher earthquake strengthening standards than required by the law, which also had repercussions on the property market in other cities in New Zealand. Another factor, although less significant than other factors in this study, is that parcels of land in the central city have been designated for the Anchor Projects under the Central City Recovery Plan, which affected the course of action for a small number of repairable buildings (Figure 9, Figure 16).

Chapter 6: Conclusion

This research addressed the issues and complexities when making decisions regarding the possible courses of action on earthquake-damaged buildings. Because of the specific context of Christchurch (physical, regulatory, and economic environment), the nature of the earthquake sequence, the scale and severity of damage, and the conditions of insurance policies, buildings owners had to deal with uncertainty and complex decision-making. Different variables and alternatives need to be considered to fully understand the definition of a satisfactory outcome from the building owner's perspective. As outlined in the introduction of this thesis, decisions on buildings may follow one of three simple scenarios. The first scenario (scenario "A" in Figure 1) referred to buildings that have insignificant damage, and where the remediation costs expressed a ratio of the insured value of the building are significantly low to justify a repair decision, without any detailed analysis. Most case-study buildings that were repaired fall under this category; the level of damage being minimal and the decision process being relatively short, simple and straightforward. Another scenario (scenario "B" in Figure 1) referred to heavily damaged buildings where the demolition is the only course of action available both from a technical and economical perspective. Case-study buildings that were deemed dangerous by CERA (section 38 notice) may be associated to this category. In contrast, buildings categorized as "intermediate scenario" were theoretically faced with two possible outcomes: repair or demolish. This research evidenced that such buildings (falling under the "intermediate scenario") were most often demolished in post-earthquake Christchurch, because of the factors discussed in this thesis. The decision-making process was complex and unique, not solely driven by structural damage. This chapter presents a general summary and conclusion of the research investigations, a review of the research questions and scientific contributions, and recommendations arising from the research findings including future research opportunities.

6.1 Summary

This thesis presents a study to investigate the factors influencing the courses of action on buildings in a post-earthquake environment, with a specific focus on the 2010-2011 Canterbury earthquakes. Although the level of damage was a fundamental variable, the aftermath of the earthquake sequence exposed several complicating issues in the decision to either repair or demolish. This study suggests that the insurance structure in New Zealand and the lack of clarity in building regulations, including the legislation changes following the earthquakes, have influenced the predominance of building demolitions in Christchurch. The complexities of complying with both the insurer's and government's requirements, in addition to the uncertainties in the recovery, had a significant effect on post-earthquake decision-making strategies for building owners. Most owners held reinstatement cover entitling the owner to a building in a "condition when new". However, very few policies included an adequate sum insured; we estimate that only two case-study buildings (out of 15) had sufficient coverage to rebuild. Because of inadequate insurance cover and the difficulty of satisfying the policy wordings, repairing, and possibly strengthening to satisfy the earthquake prone-building policy, was also not typically economically feasible. As a result, many investors preferred to move forward quickly with a cash settlement and demolish their buildings. Interestingly, interviews revealed that insurance, and the pragmatism around doing cash settlements, has created substantial financial benefits for certain building owners.

Important observations during this study suggest several key conclusions. First, insurance coverage and policy wording are critical variables in the repair or demolition outcome for buildings. While insurance plays an important role in disaster mitigation and provides funding for post-disaster reconstruction, a code-compliant building may end up being demolished because of uncertainties in repair costs and insufficient insurance cover, even if technically repairable. Second, improved knowledge in the assessment of residual capacity for reinforced concrete structures will help define clear, consistent, and acceptable performance objectives for individual buildings in line with owners' expectations. Despite the availability and recent development of seismic assessment and rehabilitation guidelines in New Zealand, they provide very little information and assistance for assessing the capacity of earthquake-damaged buildings. Third, clear regulations and repairability guidelines may potentially reduce the likelihood of demolition by providing confidence in repair methodologies, and facilitate the recovery of a major urban centre. Finally, a better understanding of the economic impacts of urban earthquakes will ultimately enhance community resilience.

6.2 Review of research questions

Section 1.2 listed two research questions that were defined to address the research problem specified in this study. The questions are revisited here:

- *How did building owners, insurers and structural engineers make (or influence) decisions on earthquake-damaged buildings, and what are the factors driving such decisions?*
- *Based on the lessons that can be drawn from these decisions, how should the earthquake engineering field take action to significantly reduce post-earthquake impacts for building stakeholders and communities?*

This thesis provided numerous insights into these questions. The conceptual framework described in Chapter 3 (Figure 15) captures key variables influencing post-earthquake decisions in the 2010-2011 Canterbury earthquakes. An improved understanding of the rationales behind building owner's decision-making strategies and engineering recommendations has been achieved through the investigation of case-study buildings in Christchurch and semi-structured interviews with various building stakeholders in New Zealand. Moreover, correlations of post-earthquake decisions with structural building characteristics, observed damage, insurance, business strategies, and building regulations were established in Chapters 4 and 5. Although there is a need for further research, the second question was addressed in Chapter 5 by discussing how the regulatory environment and the substantial lack of standards directed towards the repair of earthquake-damage buildings played a role in the demolition and repair decisions. Recommendations arising from the research findings are presented in this chapter (section 6.4).

6.3 Contributions

This thesis has made significant contributions to the body of knowledge in the fields of post-earthquake assessments and decisions on reinforced concrete structure, including the impacts of earthquake insurance and building regulations. This is something that has previously received little attention in the literature. This thesis originally used the literature on seismic mitigation decisions to understand how individuals and organizations analyse complex information and make decisions in relation to extreme events such as earthquakes. From this perspective, a comprehensive framework was developed to adopt a holistic perspective for studying the factors influencing post-earthquake decisions on building structures. The development of the framework is the result of an iterative process using information gathered from the review of literature and interviews, and has proven to be successful to scope and organize the data collection process, illustrate the relation among the variables influencing post-earthquake decisions, and identify the organizations and players involved in the decision process. This framework may certainly be applied to other communities after the next damaging earthquake, with few definitions having to be reworded to reflect different perspectives. The context of Christchurch, however, is characterized by some factors unique to New Zealand and therefore, site-specific conditions need to be considered when using the framework. For instance, the influence of insurance in terms of post-earthquake decisions is likely to be less significant for other countries in comparison with the Christchurch experience. Furthermore, because of the high insurance penetration in New Zealand and the high coverage of losses following the Canterbury earthquake sequence, the topic of insurance and its role in decision-making regarding damaged buildings was thoroughly addressed in this research. Simple calculations were used to estimate the replacement cost for specific case-study buildings and evaluate the degree of underinsurance in relation to the sum insured from the insurance policy. The thesis also examined the mandate of the Canterbury Earthquake Recovery Authority (CERA), explicitly in relation to its power to commission building demolitions. Three significantly damaged case-study buildings have been demolished under a Section 38 of the Canterbury Earthquake Recovery Act and the rationales behind such decisions were presented in this thesis.

6.4 Lessons and future research needs

Findings from this study suggest that research is needed to better understand the reparability and post-earthquake residual capacity of buildings. Extensive review and analysis beyond rapid visual inspection is required to understand damage and structural engineers are not well-equipped to assess residual capacity. The existing guidelines are mainly focused in mitigating the seismic risk of existing buildings designed prior to capacity design principles, and significant issues need to be addressed to enable a more accurate analysis of the residual capacity of reinforced concrete buildings. A structural engineer (interviewee) reported that uncertainty in residual capacity of buildings has generally led to more conservative assessments because engineers are not comfortable to sign off on the repair of damaged buildings. Research is also needed to understand the adequacy of repair technologies. Specifically for damaged concrete buildings, an improved understanding of damage to reinforcement and fatigue life is required. This thesis suggests that this lack of understanding exacerbated differences in engineering assessments and technical advice among engineers, particularly in the environment of trying to settle substantial insurance claims. Several respondents highlighted the divergent approaches and views between the owner's and insurer's engineers. For instance, one interviewee reported a typical case where company A provided a $NZD 24m repair methodology and company B provided a cost estimate of $NZD 2m for a building insured at $NZD 15m (sum insured for material damage).

The issues associated with the absence of repairability guidelines (compliant repairs to a condition substantially the same as its condition when new) and the lack of clarity in the definition of damage (and degrees of damage) in relation to insurance policies suggest that some adjustments are required, especially in the well-insured New Zealand building market. Such issues created situations where building owners had to fight for their entitlement and use different strategies to assess damage for insurance claim purposes and maximise their insurance payout. Repairability guidelines should provide a pragmatic basis for structural and geotechnical engineers, including local authorities, to undertake a more detailed assessment of earthquake-damaged buildings and evaluate potential repair strategies. This guidance also needs to align with the terms and conditions of insurance policies in order to establish compatible and reasonable assessment criteria, balancing safety and financial considerations. Insurance had a positive short-term effect in Christchurch, with the creation of new jobs, insurance payouts flowing into the economy and high coverage of losses. However, the lack of clarity in policy wordings and the absence of guidelines has resulted in arguments between building stakeholders, causing substantial delays to the claiming and recovery process.

From an investment perspective, a demolition scenario generally provided a favourable financial outcome for building owners in Christchurch, because of the ambiguous wording of insurance policies and the availability of cash settlements between the market value and the reinstatement value of the building. There is evidence, however, that Christchurch communities and businesses have been significantly disrupted by the high number of building demolitions in the CBD. According to CERA, approximately 65% of the 230 buildings in the CBD over five storeys high have been or will be demolished. From an engineering and societal perspective, this thesis argues that the absence of repairability guidelines resulted in demolition of potentially salvageable buildings. Although it can be argued that replacing repairable older building with new, more seismically resistant buildings may enhance resilience when considering future earthquakes, excessive demolitions counteract community resilience and sustainability objectives. First, demolition of concrete buildings has a particularly high environmental impact due to additional CO_2 emissions in the production of cement if the replacement is a concrete building. From a life-cycle perspective, the stored embodied energy (i.e. the energy used to acquire, process, manufacture, and transport building materials, and construct the building) of a demolished building goes to waste. Furthermore, the amount of demolition waste going to landfill is a significant issue. Environment Canterbury (2013) reported that new landfill sites had to be created to accommodate demolition waste and that in total, around 9 million tonnes of construction and demolition waste will be produced due to the earthquakes, equivalent to 40 years' worth of waste. Other impacts related to excessive demolition include environmental quality issues in the CBD due to concrete dust, noise, vibrations, and emissions from construction vehicles. Some of these impacts may be potentially hazardous for the human health and the ecosystems in the region. From a community resilience perspective, the traditional approach of design (life-safety) and current building regulations also fail at considering the aggregated societal impacts due to earthquake-induced damage and subsequent demolitions. A substantial loss of the built environment may have negative consequences on social networks and communities in many complex and interrelated ways: reduced quality of life of the population due to extensive construction activities, increased costs to residents to travel to new venues, movement of families to other suburbs or cities trying to relocate in a better environment, outmigration of businesses, etc. The numerous demolitions may also have delay the recovery of the city due to the limited number of contractors and resources available in the workforce, which then hindered the pace of the rebuild. Current building codes protect life-safety and minimise the risk of damage to adjacent properties, but they do not mitigate business interruption and economic impacts, or ensure reparability of buildings after design level ground motions. The Christchurch experience suggests that building owners and tenants may now be opting for damage-resistant technologies to reduce disruption, economic impacts, and dependency on insurance.

Bibliography

Air Worldwide (2013) Study of Impact and the Insurance and Economic Cost of a Major Earthquake in British Columbia and Ontario/Quebec. Report commissioned by the Insurance Bureau of Canada. October 2013. Boston, Massachusetts, United States.

Applied Technology Council (ATC) (1995) Addendum to the ATC-20 Post earthquake Building Safety Evaluation Procedures. Redwood City, California, 1995.

Axco (2014) Insurance Market Report – Lines of Business: Non-Life (P&C). Canada and New Zealand.

Bradley, B. A., Quigley, M. C., Van Dissen, R. J., & Litchfield, N. J. (2014) Ground motion and seismic source aspects of the Canterbury earthquake sequence. Earthquake Spectra: Feb. 2014, 30(1):1-15.

Brown, C., Seville, E., & Vargo, J. (2013) The role of insurance in organizational recovery following the 2010 and 2011 Canterbury earthquakes. Resilient Organisations Research Report 2013/4.

Canterbury District Health Board (CDHB) (2012) Built Infrastructure Policy and Decision-Making Framework. Version 2. January 2012.

Canterbury Earthquake Recovery Authority (CERA) (2012). Amendments to Christchurch City Council's District Plan. Updated in July 2013. Christchurch: Canterbury Earthquake Recovery Authority.

Canterbury Earthquakes Royal Commission (2011) Volume 2: The Performance of Christchurch CBD Buildings, available at http://canterbury.royalcommission.govt.nz/Final-Report-Volume-Two-Contents (accessed February 2015).

Chang, S. E., Taylor, J. E., Elwood, K. J., Seville, E., Brunsdon, D., & Gartner, M. (2014) Urban Disaster Recovery in Christchurch: The Central Business District Cordon and Other Critical Decisions. Earthquake Spectra: February 2014, 30(1):513-532.

Christchurch Central Development Unit (CCDU) (2012) The Recovery Plan, available at: http://ccdu.govt.nz/the-plan (accessed January 2015).

Christchurch City Council (CCC) (2010) Christchurch City Council Earthquake-prone, dangerous and insanitary buildings policy, 2010. Christchurch City Council, 10 September 2010.

Department of Building and Housing (DBH) (2004) Building Act (version as of March 2012). New Zealand Government, Wellington, New Zealand.

Department of Building and Housing (DBH) (2005) Earthquake-Prone Building Provisions of the Building Act 2004: Policy Guidance for Territorial Authorities. New Zealand Government, Wellington, New Zealand.

Department of Building and Housing (DBH) (2011) Compliance Document for New Zealand Building Code. Clause B1. Structure. Amendment 10 (Canterbury), New Zealand Government, Wellington, New Zealand.

Drayton, M. J. & Verdon, C. L. (2013) Consequences of the Canterbury earthquake sequence for insurance loss modelling, in Proceedings of the 2013 New Zealand Society of Earthquake Engineering, 26-28 April 2013.

Earthquake Commission (EQC) (2015) Official website, available at: http://www.eqc.govt.nz/ (accessed March 2015).

Egbelakin, T. K., Wilkinson, S., Potangaroa, R., & Ingham, J. (2011) Enhancing Seismic Risk Mitigation Decisions: A Motivational Approach. Constr. Manage. Econ., 29(10):1003-1016.

Engineering Advisory Group (EAG) (2012) Guidance on Detailed Engineering Evaluation of earthquake affected non-residential buildings in Canterbury. Part 2 - Evaluation Procedure. Revision 7, 2012, Structural Engineering Society New Zealand (SESOC), Christchurch.

Environment Canterbury (2013) Natural Environment Recovery Programme for Greater Christchurch, Whakaara Taiao. Canterbury Regional Council, Christchurch, NZ, R13/68.

Ernst and Young (2012) CERA Christchurch Central City - Commercial Property Market Study. Released by the Minister for Canterbury Earthquake Recovery. May 2012.

Federal Emergency Management Agency (FEMA) 306 (1998) Evaluation of Earthquake Damaged Concrete and Masonry Wall Buildings. Federal Emergency Management Agency. Washington DC.

Federal Emergency Management Agency (FEMA) P-58 (2012) Seismic Performance Assessment of Building: Volume 1. Federal Emergency Management Agency. Washington DC.

Galloway, B. D. & Hare H. J. (2012) A review of post-earthquake building control policies with respect to the recovery of the Christchurch CBD, in Proceedings of the New Zealand Society for Earthquake Engineering Conference, Paper 036, 13–15 April 2012.

Insurance Bureau of Canada (IBC) (2010) Earthquake Shock Endorsement. Advisory Model Wording. IBC 4039.

Insurance Council of New Zealand (ICNZ) (2015) Official website, available at: http://www.icnz.org.nz/natural-disaster/canterbury/ (accessed March 2015).

Jacques, C. C., McIntosh, J., Giovinazzi S., Kirsch, T. D., Wilson, T., & Mitrani-Reiser, J. (2014) Resilience of the Canterbury Hospital System to the 2011 Christchurch Earthquake. Earthquake Spectra: February 2014, 30(1):533–554.

Kam, W. Y. & Pampanin, S. (2011) General Performance of Buildings in Christchurch CDB after the 22 Feb 2011 Earthquake: a Contextual Report, (prepared for the Department of Building and Housing) Department of Civil and Natural Resources Engineering, University of Canterbury.

Kim, J. H. (2015) Quantitative analysis of factors influencing post-earthquake decisions on concrete buildings in Christchurch. Master's Thesis, University of British Columbia, Vancouver, Canada. (In Preparation)

King, A., Middleton, D., Brown, C., Johnston, D., & Johal, S. (2014) Insurance: Its Role in Recovery from the 2010–2011 Canterbury Earthquake Sequence. Earthquake Spectra: February 2014, 30(1):475-491.

May, P. J. (2004) Making Choices about Earthquake Performance. Nat. Hazards Rev., 5(2):64-70.

Meszaros, J. (1999) Preventive choices: Organizations' heuristics, decision processes and catastrophic risks. J. Manage. Stud. (Oxford), 36(7):977–998.

Middleton, D. (2012) Insurance Shocks: Market Behaviour and Government Responses: International Case Studies with Relevance to New Zealand, Kestrel Group, June 2012.

Miles, S., Brechwald, D., Davidson, R., Demeter, K., Johnston, D., Pampanin, S., & Wilkinson, S. (2014) Building Back Better. Case Study of the 2010-2011 Canterbury, New Zealand Earthquake Sequence. EERI Report with the NZSEE and the Natural Hazards Platform for the Global Facility for Disaster Reduction and Recovery of the World Bank. Oakland CA: EERI. February

Muir-Wood, R. (2012) The Christchurch earthquakes of 2010 and 2011. The Geneva Risk Reports. Risk and Insurance Research. Extreme events and insurance: 2011 annus horribilis. C. Courbage and W. R. Stahel. Geneva, available at: http://www.genevaassociation.org (accessed January 2015).

National Research Council of Canada (NRCC) (2010) National Building of Canada and Commentaries. 13th edition - 2010. Ottawa, Ontario, Canada.

New Zealand Society for Earthquake Engineering (NZSEE) (2006) Assessment and Improvement of the Structural Performance of Buildings in Earthquakes. New Zealand Society for Earthquake Engineering, June 2006.

New Zealand Society for Earthquake Engineering (NZSEE) (2009) Building safety evaluation during a state of emergency: Guidelines for Territorial Authorities. New Zealand Society for Earthquake Engineering, August 2009.

New Zealand Supreme Court (NZSC) (2013) Ridgecrest NZ Limited V IAG New Zealand Limited [27 August 2014] NZSC 117.

New Zealand Supreme Court (NZSC) (2014) University of Canterbury v Insurance Council of New Zealand [22 December 2014] NZSC 193.

Pampanin, S., Kam, W. Y., Akguzel, U., Tasligedik, S., & Quintana-Gallo, P. (2012) Seismic Performance of Reinforced Concrete Buildings in the Christchurch CBD under the 22nd February Earthquake, Report prepared for Christchurch City Council and University of Canterbury, Civil and Natural Resources Engineering.

Petak, W. J. & Alesch, D. J. (2004) Organizational Decision Making with Respect to Extreme Events: Healthcare Organizations Respond to California's SB 1953. In research progress and accomplishments: 2003–2004 (MCEER-04-P01). University of Buffalo, State University of New York, Buffalo.

Property Council of New Zealand (PCNZ) (2014) Submission on the Building (earthquake-prone buildings) Amendment Bill, available at: http://www.propertynz.co.nz/index.php/news (accessed January 2015).

Rider Levett Bucknall (RLB) (2015) International Report – Construction Market Intelligence. Available at: http://www.rlb.com/publications/ (accessed January 2015).

Slovic, P., Kunreuther, H., & White, G. F. (1974) Decision processes, rationality, and adjustment to natural hazards, pp. 187-205 in G. F. White (ed.) Natural Hazards: Local, National, Global. New York: Oxford Univ. Press.

SwissRe (2012) Lessons from recent major earthquakes. January 2012.

Taylor, J. E. (2013). The Christchurch Earthquake Sequence: Government Decision-Making and Confidence in the Face of Uncertainty. Master's Thesis, University of British Columbia, Vancouver, Canada.

Taylor, J. E., Chang, S. E., Elwood, K. J., Seville, E., and Brunsdon, D., 2012. Learning from Christchurch: Technical Decisions and Societal Consequences in Post-Earthquake Recovery, Resilient Organisations Research Report 2012/08.

The Press (2012) Quake cost to Canterbury tourism $230m. Retrieved from stuff.co.nz: http://www.stuff.co.nz/the-press/news/christchurch-earthquake-2011/6892054/Quake-cost-to-Canty-tourism-230m (accessed March 2015).

Uma, S. R., Nayyerloo, M., & Dhakal, R. P. (2013) Vulnerability Assessment of Christchurch Buildings in Canterbury Earthquakes. GNS Science Report 2013/20. May 2013, 35 p.

Vero (2007) Business Plan Policy. Version 6. Policy Wording, available at: https://www.vero.co.nz/ business-insurance (accessed January 2015)

Vero (2013) Business Plan Policy Endorsement. July 2013, available at: https://www.vero.co.nz/ business-insurance (accessed January 2015).

Yang, T. Y., Moehle, J., Stojadinovic, B., & Der Kiureghian, A. (2009) Performance evaluation of structural systems: theory and implementation, ASCE Journal of Structural Engineering, vol. 135, no. 10, pp. 1146-1154.

Zurich (2009) Material Damage and Business Interruption Insurance. Policy Wording, available at: http://www.zurich.co.nz/content/zurich_nz/insurance/property-insurance/material-damage-business-interruption-insurance.html (accessed January 2015).

Appendix A : Canterbury Earthquake Recovery Authority notices (sections 38 and 51)

CERA
Canterbury Earthquake
Recovery Authority

[Date]

[Name of Owner or Owner's Representative]
[Address 1]
[Address 2]
[Address 3]

[Email]

CC: Insurer (Name)

Dear [First Name or Sir/Madam]

Demolition of your building at <No> <Street> <Type>

1. The purpose of this letter is to:

- Advise you that I have determined that your building is dangerous in terms of the Canterbury Earthquake Recovery Act 2011 (CER Act), and is subject to the provisions of section 40(1) of the CER Act (as described in Schedule 1 of this letter); and

- Give you notice under section 38(4) of the CER Act that your building needs to be demolished.

2. You have 10 calendar days from the date of receipt of this notice to advise me whether you intend to undertake the demolition of the building (including, as appropriate, removal of the foundations) and, if so, when you intend to undertake and complete the work.

3. You may elect to have CERA undertake the demolition work for you. To assist you in deciding if this is your preferred option, please find attached Schedule 3, which is a summary of the services CERA will provide. If you choose this option, the demolition works will be at your cost and you will be invoiced for the work. CERA charges a management fee not exceeding 5.25% of the demolition costs. This covers the cost of exemption from obtaining the relevant consents and ensuring the works are carried out in accordance with the approved methodology. Also enclosed with this letter is an Owner's Agreement for your consideration. You are invited to complete the Owner's Agreement if you elect to have CERA complete the work on your behalf.

[redacted]

CERA
Canterbury Earthquake
Recovery Authority

4. Schedule 2 (attached) provides an outline of the information required from you should you propose to complete the demolition work using your own contractor.

Note: For the purposes of section 38 of the CER Act, where CERA approves your demolition proposal, CERA has commissioned the work. This will enable you to rely on CERA's exception from a building consent for demolition and the permitted activity status for demolition of buildings under the appropriate district plan. You will, however, need to obtain an archaeological approval if the building is dated pre-1900 and for the disturbance of the soil if the area was occupied pre-1900 (regardless of the age of the present building).

CERA commissions all demolition related work within the CBD (the area within the four avenues). Before any work may be started CERA requires that it approves the demolition plan.

5. Should you elect to have CERA undertake the demolition work for you, CERA will arrange for the work to be carried out through CERA's Project Management Office (PMO). I encourage you to consider using the PMO as CERA will schedule the work to most efficiently use accredited contractors. Accredited contractors are engaged by CERA using competitive market rates; these are independently monitored and assessed. The PMO will ensure that the demolition and related plans (similar to those listed in Schedule 2) are prepared before the work is started, that the site is monitored during the work and that the site is left safe and clear of debris

6. Reopening the central city as quickly as possible, and working towards the recovery of Greater Christchurch are top priorities for CERA. In considering your response to this notice and the acceptability of any alternative proposals you put forward, speed of completion of the works will be key criteria for me.

7. Please note that even if you wish to undertake the work I may not accept your proposal and may decide it is more appropriate for CERA to undertake the work.

8. Your written notice to CERA of your intentions should be in the form attached to this letter entitled "Owner's Response to Demolition Notice under s38(4) of the Canterbury Earthquake Recovery Act 2011". Your notice can be either:

8.1 Emailed to us at [redacted] or

8.2 Posted to Canterbury Earthquake Recovery Authority, [redacted]

9. In making your decision you should be aware that the CER Act provides that:

9.1 if you fail to give notice to me within the 10 calendar day period; or

[redacted]

9.2 if I am not satisfied with the time specified by you for demolition of the building; or

9.3 if you do not carry out the works in the time specified.

CERA may commission the demolition work and recover CERA and third party costs of carrying out the work from you as owner of the dangerous building.

10. If you do not respond to this letter within 10 calendar days of receipt CERA will look to commence action to commission the demolition works at your cost. The timing and arrangements for demolition will then be negotiated with the demolition company and you will be informed in accordance with the process under the CER Act.

11. Please take the time to read the Frequently Asked Questions information sheet that has been provided. You can also visit www.cera.govt.nz/demolitions .

Please contact my office by email, or telephone [redacted] if you have any questions about this written notice or wish to discuss the demolition.

Yours faithfully

[redacted]
General Manager Operations
Canterbury Earthquake Recovery Authority

Schedule 1: Summary of meaning of "dangerous" building: Building Act 2004 as amended by Canterbury Earthquake (Building Act) Order 2010

A dangerous building is a building which:

(a) in the ordinary course of events (excluding the occurrence of an earthquake), is likely to cause —
  (i) injury or death (whether by collapse or otherwise) to any persons in it or to persons on other property; or
  (ii) damage to other property; or

(b) in the event of fire, injury or death to any persons in the building or to persons on other property is likely because of fire hazard or the occupancy of the building; or

(c) there is a risk that the building could collapse or otherwise cause injury or death to any person in the building as a result of an earthquake that generates shaking that is less than a moderate earthquake; or

(d) there is a risk that other property could collapse or otherwise cause injury or death to any person in the building; or

(e) a territorial authority has not been able to undertake an inspection to determine whether —
  (i) the building is dangerous under paragraph (a); and
  (ii) the territorial authority or the chief executive, as the case may be, is required to exercise powers under section 124 or 129 of the Building Act 2004 as modified by the Canterbury Earthquake (Building Act) Order 2010.

(f) if, having regard to its condition and to the ground on which it is built, and because of its construction, the building —
  (i) will have its ultimate capacity exceeded in a moderate earthquake (as defined in the regulations); and
  (ii) would be likely to collapse causing —
    (a) injury or death to persons in the building or to persons on any other property; or
    (b) damage to any other property.

Note: (f) does not apply to a building that is used wholly or mainly for residential purposes unless the building —
  (i) comprises 2 or more storeys; and
  (ii) contains 3 or more household units.

Extract from Canterbury Earthquake Recovery Act 2011
S40. Compensation for demolition of building

(1) If the chief executive demolishes a dangerous building —

  (a) the Crown is not liable to compensate the owner or any tenant or other occupier of the building; and
  (b) the chief executive may recover the cost of demolition from the owner.

CERA
Canterbury Earthquake Recovery Authority

[Date]

[Name of Owner or Owner's Representative]
[Address 1]
[Address 2]
[Address 3]

[Email]

Dear [First Name or Sir/Madam]

Notice to Carry Out a Detailed Structural Assessment

One of the purposes of the Canterbury Earthquake Recovery Act 2011 (CER Act) is to enable information to be gathered about structures affected by the Canterbury earthquakes. In particular, section 51 provides that the chief executive of the Canterbury Earthquake Recovery authority (CERA) may require an owner of a building that he considers has or may have experienced structural change in the Canterbury earthquakes to carry out a full structural survey of the building before it is re-occupied for business or accommodation.

The chief executive of CERA considers that the building(s) at ([redacted]) may have experienced structural change as a result of the Canterbury earthquakes. You are required to carry out a full and detailed structural assessment of the building(s) named above prior to any re-occupation.

As the owner, or owner's representative, you are required to have a Chartered Professional Engineer (Structural) complete a structural engineering assessment of the building(s). You are requested to notify CERA that you have appointed an engineer within 10 working days. This notification should be via email at [redacted] .

It is important the assessment follows the Detailed Engineering Evaluation procedure, which can be downloaded from http://cera.govt.nz/structural-assessments . Additionally, there is a Standardised Report Form in Microsoft excel format in the same location that is required to be completed and submitted.

Please send the completed report to CERA within 8 weeks of the date of this letter by:

- uploading to http://cera.govt.nz/structural-assessments, or
- emailing to [redacted]

Please note that if you fail to satisfy the requirements of this letter, CERA may issue a section 45 notice restricting access to your building(s) until such time as you have complied.

[redacted]

This report will also be forwarded to Christchurch City Council by CERA for the Council's information and consideration. The Council may use the information to assist with its responsibilities such as issuing a building warrant of fitness. Any re-occupation of the building(s) for the purposes of carrying out business activity may be subject to the appropriate permissions and certification required by Christchurch City Council. Please find enclosed the Christchurch City Council "Guide to Structural Assessments and Repair Work" for further information.

If you have any queries on the requirements for the structural engineering report please do not hesitate to contact CERA at [redacted]

Yours sincerely,

[redacted]
General Manager Operations

CC: [Names of all additional building owner]

Appendix B : Level 2 rapid assessment form (Christchurch)

Christchurch Eq RAPID Assessment Form - LEVEL 2

Inspector Initials		Date		Final Posting (e.g. UNSAFE)
Territorial Authority	Christchurch City	Time		

Building Name

Short Name

Address

GPS Co-ordinates S° E°

Contact Name

Contact Phone

Storeys at and above ground level ____ Below ground level ____

Total gross floor area (m^2) ____ Year built ____

No of residential Units ____

Photo Taken Yes No

Type of Construction

- ☐ Timber frame
- ☐ Steel frame
- ☐ Tilt-up concrete
- ☐ Concrete frame
- ☐ RC frame with masonry infill
- ☐ Concrete shear wall
- ☐ Unreinforced masonry
- ☐ Reinforced masonry
- ☐ Confined masonry
- ☐ Other:

Primary Occupancy

- ☐ Dwelling
- ☐ Other residential
- ☐ Public assembly
- ☐ School
- ☐ Religious
- ☐ Commercial/ Offices
- ☐ Industrial
- ☐ Government
- ☐ Heritage Listed
- ☐ Other

Investigate the building for the conditions listed on page 1 and 2, and check the appropriate column. A sketch may be added on page 3

Overall Hazards / Damage	Minor/None	Moderate	Severe	Comments
Collapse, partial collapse, off foundation	☐	☐	☐	
Building or storey leaning	☐	☐	☐	
Wall or other structural damage	☐	☐	☐	
Overhead falling hazard	☐	☐	☐	
Ground movement, settlement, slips	☐	☐	☐	
Neighbouring building hazard	☐	☐	☐	
Electrical, gas, sewerage, water, hazmats	☐	☐	☐	

Record any existing placard on this building: Existing Placard Type (e.g. UNSAFE)

Choose a new posting based on the new evaluation and team judgement. Severe conditions affecting the whole building are grounds for an UNSAFE posting. Localised Severe and overall Moderate conditions may require a RESTRICTED USE. Place INSPECTED placard at main entrance. Post all other placards at every significant entrance. Transfer the chosen posting to the top of this page.

INSPECTED			RESTRICTED USE			UNSAFE			
GREEN	*G1*	*G2*	*YELLOW*	*Y1*	*Y2*	*RED*	*R1*	*R2*	*R3*

Record any restriction on use or entry:

Further Action Recommended:

Tick the boxes below only if further actions are recommended

- ☐ Barricades are needed (state location):
- ☐ Detailed engineering evaluation recommended
  - ☐ Structural ☐ Geotechnical ☐ Other:
- ☐ Other recommendations:

Estimated Overall Building Damage (Exclude Contents)

None	☐		
0-1 %	☐	31-60 %	☐
2-10 %	☐	61-99 %	☐
11-30 %	☐	100 %	☐

Sign here on completion

Date & Time

ID

Inspection ID: ________ *(Office Use Only)*

Structural Hazards/ Damage	Minor/None	Moderate	Severe	Comments
Foundations	☐	☐	☐	
Roofs, floors (vertical load)	☐	☐	☐	
Columns, pilasters, corbels	☐	☐	☐	
Diaphragms, horizontal bracing	☐	☐	☐	
Pre-cast connections	☐	☐	☐	
Beam	☐	☐	☐	
Non-structural Hazards / Damage				
Parapets, ornamentation	☐	☐	☐	
Cladding, glazing	☐	☐	☐	
Ceilings, light fixtures	☐	☐	☐	
Interior walls, partitions	☐	☐	☐	
Elevators	☐	☐	☐	
Stairs/ Exits	☐	☐	☐	
Utilities (eg. gas, electricity, water)	☐	☐	☐	
Other	☐	☐	☐	
Geotechnical Hazards / Damage				
Slope failure, debris	☐	☐	☐	
Ground movement, fissures	☐	☐	☐	
Soil bulging, liquefaction	☐	☐	☐	

General Comment ______________________________

Usability Category

Damage Intensity	Posting	Usability Category	Remarks
Light damage *Low risk*	Inspected (Green)	G1. Occupiable, no immediate further investigation required	
		G2. Occupiable, repairs required	
Medium damage *Medium risk*	Restricted Use (Yellow)	Y1. Short term entry	
		Y2. No entry to parts until repaired or demolished	
Heavy damage *High risk*	Unsafe (Red)	R1. Significant damage: repairs, strengthening possible	
		R2. Severe damage: demolition likely	
		R3. At risk from adjacent premises or from ground failure	

2 *Inspection ID:__________ (Office Use Only)*

Sketch (optional)
Provide a sketch of the entire building or damage points. Indicate damage points.

Recommendations for Repair and Reconstruction or Demolition (Optional)

3 *Inspection ID:__________ (Office Use Only)*

Appendix C : List of interviewees by category

(Participants who requested anonymity are listed by general role and not named)

Category A: Building Executive Officers / Owner's Representatives

Connal Townsend, Chief Executive: Property Council of New Zealand (Auckland, 14 October 2014)
Darren Moses, Unit Manager: Christchurch City Council (Christchurch, 29 October 2014)
David Meates, Chief Executive: Canterbury District Health Board (Christchurch, 24 September 2014)
Gary Jarvis, Group Operations Manager: Heritage Hotel Management (Auckland, 13 October 2014)
Jeff Field, University Registrar: University of Canterbury (Christchurch, 26 September 2014)
Josie Ogden-Schroeder, Chief Executive: YMCA Christchurch (Christchurch, 25 September 2014)
Mark Youthed, Senior Commercial Asset Manager: Knight Frank (Christchurch, 24 September 2014)
Miles Romanes, Project Manager: Pace Project Management (Christchurch, 24 September 2014)
Participant A1, Structural Engineer (Christchurch, 23 September 2014)

Category B: Building Developers / Property Investors

Chris Gudgeon, Chief Executive: Kiwi Income Property Trust (Auckland, 15 October 2014)
Ernest Duval, Trust Manager/CEO: ETP/Fortis Construction (Christchurch, 24 September 2014)
Glen Boultwood, Fund Manager: Eureka Funds (Auckland, 15 October 2014)
Lisle Hood, Property Investor: Business Building Systems (Christchurch, 22 October 2014)
Miles Middleton, Property Investor: Viewmount Orchards (Christchurch, 25 September 2014)
Participant B1, General Manager (Christchurch, 5 November 2014)
Peter Rae, Chairman and Managing Director: Peter Rae Industries (Christchurch, 23 September 2014)
Philip Burdon, Property Investor and Developer (Christchurch, 5 November 2014)
Shaun Stockman, Managing Director: KPI Rothschild Property (Christchurch, 22 September 2014)

Category C: Insurance

Jimmy Higgins, Executive GM – Earthquake Programme: Vero NZ (Auckland, 15 October 2014)
John Lucas, Insurance Manager: Insurance Council of New Zealand (Wellington, 17 October 2014)
Murray Spicer, Engineer acting for insurers: MacDonald Barnett (Auckland, 14 October 2014)
Simon Foley, Distribution Manager: Zurich New Zealand (Auckland, 15 October 2014)
Storm McVay, Executive Broker: Crombie Lockwood (Christchurch, 22 September 2014)

Category D: Government Authorities

John O'Hagan, Lead Engineer – Significant Buildings Unit: CERA (Christchurch, 22 October 2014)
John Snook, Structural Engineer: CERA (Christchurch, 30 September 2014)
Participant D1, CERA (Christchurch, 26 September 2014)
Steve McCarthy, Regulatory Services Manager: CCC (Christchurch, 26 September 2014)

Appendix D : Sample interview questions

Category A and B – Building Executive Officers, Owner's Representatives and Building Developers / Property Investors

Part 1: Introduction

1. Please briefly describe the responsibilities of your position. Following the earthquakes, in what ways were you involved with the recovery of the Christchurch CBD, and more specifically, post-earthquake decisions for multi-storey buildings? Which buildings were you specifically involved?

2. In your view, on a scale of 1-7 (where 1="extremely poorly" and 7="extremely well"), how well is Christchurch's recovery proceeding?

Part 2: Understanding Post-Earthquake Decisions on Buildings

3. Please explain the process by which your organisation responded to the earthquakes, specifically with regard to [building name].

4. Please tell us about how your organisation came to the decision to demolish or repair [building name]. Please describe all key events surrounding the decision.

5. Please characterise the insurance coverage with regard to [building name]. How has insurance shaped the decision (either repair or demolition)? What percentage of the overall losses (including loss of rent/profit) associated with this particular building was recovered by insurance?

6. To what degree did the tenant's decisions and preferences affect the decision to repair or demolish [building name]?

7. Please consider the following variables as drivers influencing post-earthquake decisions (either repair or demolition) for buildings in the Christchurch CBD. With regard to the decision that was made on [building name], how would you rank these factors in significance? Please elaborate on the most significant items.

	Not At All	Not Very	Somewhat	Very
a. Building Characteristics (pre-EQ cond., functionality, location, etc.)	☐	☐	☐	☐
b. Insurance Coverage (inclusions, exclusions, % sum insured, etc.)	☐	☐	☐	☐
c. Extent of Damage / Cost to repair	☐	☐	☐	☐
d. Access Conditions (placard, cordon, etc.)	☐	☐	☐	☐
e. Neighborhood Conditions	☐	☐	☐	☐
f. Impacts on Business Operations (disruptions, high op. costs, etc.)	☐	☐	☐	☐
g. External Pressures (lenders, tenants, shareholders, etc.)	☐	☐	☐	☐
h. Legislation (CERA; CCDU; CCC; Building Code)	☐	☐	☐	☐
i. Owner Preferences (business strategy, uncertainty about future, etc.)	☐	☐	☐	☐
j. Technical Advice (structural engineers)	☐	☐	☐	☐
k. Compensation / Claim Process (speed, adjustments, etc.)	☐	☐	☐	☐
l. Other (please specify)	☐	☐	☐	☐
m. Other (please specify)	☐	☐	☐	☐

8. Going forward, how has this event affected your organisation in regard to the selection of earthquake risk mitigation strategies for existing and new buildings (insurance, diversification of portfolio, seismic retrofit, increased seismic performance, etc.)?

9. How have the access and affordability of insurance changed since the earthquake (variation of premiums, coverage, conditions, etc.)?

Part 3: Sharing the Christchurch Experience

10. In your view, what are the impacts of numerous demolitions on the recovery of the city? How has the property market sector in Christchurch changed since the earthquakes?

11. Given your experience of the Canterbury earthquakes, what advice do you want to share with other businesses or building owners/investors in earthquake-prone areas around the world (e.g. Vancouver)?

Category C – Insurance

Part 1: Introduction

1. Please briefly explain the process by which [name of organisation] responded to the earthquakes.

2. Please briefly describe the responsibilities of your position. Following the earthquakes, in what ways were you involved with the recovery of the Christchurch CBD, and more specifically, post-earthquake decisions for multi-storey buildings?

3. In your view, on a scale of 1-7 (where 1="extremely poorly" and 7="extremely well"), how well is Christchurch's recovery proceeding?

Part 2: Post-Earthquake Decisions and Insurance

4. Given your experience of the Canterbury earthquakes, please tell us about the steps and associated issues involved in the decision making process as to whether a building should be demolished or repaired. What role does the building owner play in this decision? What role do insurers play in this decision?

5. Please explain the main features of a typical earthquake insurance policy for commercial buildings, and for multi-storey apartment buildings in New Zealand. What policy features and market practices may have facilitated demolition decisions for buildings in Christchurch?

6. For the Christchurch earthquake, it is estimated that 80% of global losses are covered by insurance. How has this high level of insurance penetration influenced the repair or demolition decisions in Christchurch CBD?

7. Please consider the following variables as drivers influencing post-earthquake decisions (either repair or demolition) for buildings in the Christchurch CBD. Given your experience of the Canterbury earthquakes, how would you rank these factors in significance? Please elaborate on the most significant items. *[List of items]*

8. How have the access and affordability of insurance changed since the earthquake (variation of premiums, coverage, conditions, etc.)? What changes are expected in the earthquake insurance market in the future?

9. In your view and going forward, how has this event affected your clients (inside and outside Christchurch) in regard to the selection of earthquake risk mitigation strategies for existing and new multi-storey buildings (insurance, diversification of portfolio, seismic retrofit, increased seismic performance, etc.)?

Part 3: Sharing the Christchurch Experience

10. In your view, what are the impacts of numerous demolitions on the recovery of the city? What are the impacts of other factors (CCDU processes, insurance claims, etc.)?

11. Given your experience of the Canterbury earthquakes, what advice do you want to share with other businesses or building owners/investors in earthquake-prone areas around the world (e.g. Vancouver)?

Category D – Government Authorities

Part 1: Introduction

1. Please briefly describe the responsibilities of your position. Following the earthquakes, in what ways were you involved with the recovery of the Christchurch CBD, and more specifically, post-earthquake decisions for multi-storey buildings?

2. In your view, on a scale of 1-7 (where 1="extremely poorly" and 7="extremely well"), how well is Christchurch's recovery proceeding?

Part 2: Post-Earthquake Decisions

3. With regard to the Canterbury Earthquake Recovery Act, please describe the implications of Section 38 (demolition) and Section 39 (urgent demolition) for building owners. Please specify major changes in the Act since 2010, if any.

4. Please tell us about the steps and associated issues involved in the decision making process as to whether a building should be demolished or not under the CER Act. What are the factors and alternatives considered in the decision? What role does the building owner play in this decision?

5. In your view, how has building regulation (and changes in regulation since 2010) affected post-earthquake decisions for buildings in the Christchurch CBD (either repair or demolition)? How has earthquake-prone building legislation affected demolition decisions? What impact has the decision to rise the required strengthening level to 67% NBS in September 2010 (and its repeal in February 2013) had on demolition decisions?

6. For the Christchurch earthquake, it is estimated that 80% of global losses are covered by insurance. How has this high level of insurance penetration influenced the repair or demolition decisions in Christchurch CBD?

7. Please consider the following variables as drivers influencing post-earthquake decisions (either repair or demolition) for buildings in the Christchurch CBD. Given your experience of the Canterbury earthquakes, how would you rank these factors in significance? Please elaborate on the most significant items. *[List of items]*

Part 3: Sharing the Christchurch Experience

8. In your view, what are the impacts of numerous demolitions on the recovery of the city? What are the impacts of other factors (CCDU processes, insurance claims, etc.)?

9. Given your experience of the Canterbury earthquakes, what advice do you want to share with other businesses or building owners/investors in earthquake-prone areas around the world (e.g. Vancouver)?

Appendix E : Additional data – Case-study buildings

Appendix E provides a summary of the engineering reports that are relevant in the analysis of the decisions for each case-study building (with some excerpts provided). The latest Detailed Engineering Evaluation (DEE) spreadsheet is included, if available.

Appendix E - Relevant documentation and notes –
D117 - 17-storey RC frame office building

Date	Type (Name)	Notes
27 Feb. 2011	Level 2 rapid assessment	The building has been given a Red R1 placard.
8 March 2011	Level 2 rapid assessment	The building has been given a Red R1 placard.
March 2011	Inspection Report (Level 2 assessment)	Conclusions about the risk posed by the building: "*While a partial collapse is possible, it is unlikely to involve large sections of the floor at multiple floors. Thus the overall stability of the building would be unlikely to be compromised and that cordoning off the surrounding building collapse zone is not warranted.*"
May 2011	Inspection Report	The damage to the floor slab was noted to be worst at Levels 7 and 8, with cracks >30 mm. A structural analysis of the building was carried out on ETABS. The most likely failure mode for the building was a local partial collapse as a result of a double-tee unit losing its seating and dropping, causing progressive collapse of floors below. The report suggests that it would be extremely difficult from both a strength and stiffness perspective to strengthen the building up to 100% NBS.
June 2011	Inspection Report	The report summarizes additional damage observed after the 6 June 2011 aftershock, but does not include any observations from the 13 June 2011 event. A temporary strengthening scheme has been developed to prevent a double-tee unit losing its seating and protect the building against more extensive damage and collapse. The report concludes that "*the building has reached a point where its capacity has been compromised to such an extent that repair is not a commercially viable option: the entire seismic needs to be removed and replaced, while the majority of the gravity system requires significant repair, which may take a number of years to complete the remediation work*."
August 2011	Inspection Report	The report summarizes additional damage observed after the 13 June 2011 aftershock and the aftershock of 22 July 2011. The report reiterates previous observations and states that the building should be considered dangerous in accordance with the CER Act because the seismic system has been compromised severely.

Note: Structural Drawings Available: Yes

Additional notes - D117 - 17-storey RC frame office building

The detailing of the east and west frames was that of a conventional moment resisting frame intended to develop plastic hinges at the column faces. However, due to the close column spacing, the north and south side frames used an unusual diagonal bar detail that was intended to position the plastic hinge in the middle portion of the beam rather than adjacent to the column faces. This special detailing of reinforcing led to inelastic deformation in regions where it was not anticipated and this has further reduced the ductility of the structure.

Appendix E - Relevant documentation and notes –
D192 - 13-storey RC shear wall hotel building

Date	Type (Name)	Notes
2 March 2011	Level 2 rapid assessment	The building has been given a Red R1 placard.
11 April 2011	Level 2 rapid assessment + Report	The building has been given a Yellow Y2 placard. Notes: severe damage to the base of secondary shear walls in main entry, severe damage to columns in north corner of building at levels 6-8, substantial settlement to south end of the building evidenced by cracking of transfer beam at level 5 and rotation of precast panels.
22 June 2011	Level 1 rapid assessment + Report	The building has been given a Yellow placard. Recommendation to undertake a L2 rapid assessment.
1 July 2011	Level 2 rapid assessment + Report	The building has been given a Yellow Y2 placard. Notes: Minor additional damage after 13 June event, including spalling at exterior ends of longitudinal shear walls, damage to main core stairs, and non-structural ceiling and balcony parapet damage.
August 2011	Structural Damage Review	A summary of the observed damage and recommendations to return the building back to its pre-earthquake conditions are provided. The report notes differential settlement and significant inter-storey offsets, severe cracking of corner columns, spalling of concrete on shear walls and failure of shear walls within the stairs. Indications on the repair methods: "*The governing damage to the building is the permanent horizontal offset and the slope of the floors at the south end in one wing. There is no practical method to restore the building to its original plumb horizontal position without complete reconstruction of all levels. The damage that has occurred to the foundations and basement and the unknown condition of the tanking means that demolition and reconstruction is required.* " The reconstruction of the entire building was recommended to return the building to its pre-earthquake condition. Furthermore, it was believed that the low resistance to partial collapse under loads generated by a low to moderate seismic event would pose a high risk to workers engaged in the repair of the building.
August 2011	Conceptual Deconstruction Methodology	The document provides a summary of the structural characteristics of the building and details a deconstruction methodology, as requested by the owner following damage and repair assessments in July 2011. The report notes that securing work inside the building is required prior to demolition.

Note: Structural Drawings Available: Yes

Appendix E - Relevant documentation and notes –
D196 - 8-storey RC shear wall office building

Date	Type (Name)	Notes
26 Feb. 2011	Level 1 rapid assessment + Report	Level 1 rapid assessment includes a report dated on 27 February 2011. The report details the damage to the south shear wall following the 22 February event which has compromised the lateral load resisting capacity of the building and put it at risk of collapse during a significant aftershock. A temporary securing scheme was outlined to stabilize the building to allow a more detailed inspection and to reduce the risk to surrounding properties. This scheme involved pouring mass concrete around the damaged portion of shear wall. The report notes that the long-term re-occupation of the building was subject to observed damage inside the building and further assessment.
2 March 2011	Level 2 rapid assessment	The building has been given a Red R1 placard.
May 2011	Preliminary Damage Review (Report)	The report includes an assessment of the damage and the possible courses of action for the owner. Although it was not considered an immediate collapse hazard, the building was not safe to enter due to the failure of the south elevation shear wall and failure of the upper floor steel beam to concrete column connections along the west elevation. Only a selection of expose structure was reviewed. Notes on the strength evaluation: *"No formal evaluation of the residual capacity has been completed, but given the level of damage and the previous securing work, the building would likely be earthquake-prone in its current condition."* The reports concludes that there are significant areas of the building that would require a full rebuild if repair was to be considered. The reports also advises that repair of the building would be not an economically viable option and recommends that demolition should be considered for this building.

Note: Structural Drawings Available: Yes

Appendix E - Relevant documentation and notes –
D11 - 22-storey RC frame office building

Date	Type (Name)	Notes
22 March 2011	Level 2 rapid assessment	The building has been given a Yellow Y1 placard.
July 2011	Geotechnical Report	The report specifies that the foundation system has generally performed well in the context of ultimate limit state design, however liquefaction induced settlements have resulted in differential settlement of the foundation. The podium structure has rotated and lifted by approximately 400 mm, and the axis of this movement appears to coincide with a crack in the podium slab. The report suggests that the northern portion of the podium would need to be demolished and rebuilt. Also, the reports notes that the cracks in the foundation may have compromised the structural integrity of the raft and recommends the exploration of several remediation options.
July 2011 (Revision 2)	Detailed Seismic Assessment	The report covers the structural damage sustained by the building as a result of the September 2010, February 2011, and June 2011 events. A linear elastic computer modeling has been conducted on ETABS. The report states that "*the only reliable way of repairing the damage to corner columns (and connected beams) and restoring the building to the pre-earthquake condition, is to break out these columns full height and rebuild them. This is also the only satisfactory way to address the issue of low cycle fatigue.*" As for the specific geotechnical issues, the report indicates that "*a potential option involves grout injection of the soils to a depth below the liquefiable layer(s), however although technically possible it is practically difficult to achieve and carries a high degree of risk and uncertainty. Repair of this type, on a building of this scale (which is also badly damaged) have never been done in New Zealand before, and there has been limited application anywhere in the world.*" Also, the report highlights that the cost of repairs would involve the replacement of the entire façade to the tower, and substantial replacement of the services and internal base build fit-out. The report concludes that "*there are significant issues relating to the capacity of the structural frame and the soils under the site which will need to be reliably and cost effectively solved if the building is going to be repaired.*"
August 2011	Façade Assessment	The report notes that replacement of the damaged portion of the curtain wall would be extremely difficult and it is recommended that a whole new curtain wall would be the only practical solution.
December 2011	Site Inspection Report	The report summarizes additional damage observed after the 23 December 2011 aftershock (floors 5-6-7-8-10 were inspected). The report notes more extensive beam hinging observed at all locations to the north and south frames, and additional damage to concrete topping adjacent to corner columns, suggesting significant frame elongation. Furthermore, the report concludes that damage is at a point where access shall be limited to short periods of time for retrieval of essential items only.

Note: Structural Drawings Available: Yes

Appendix E - Relevant documentation and notes –
D49-10-storey RC shear wall/frame office building

Date	Type (Name)	Notes
23 March 2011	Level 2 rapid assessment	The building has been given a Red R1 placard.
March 2011	Damage Assessment	Conclusions: "*The structure is stable and repairable, however the nature of the insurance being "as new" means the likely result is demolition and rebuild*" (Source: CERA 13 September 2011).
July 2011	Damage Assessment - Letter	The reports notes that the shear cracking in the carpark deck support beams is extensive and the beam/column joints in the precast exterior façade are severely damaged, with the vertical cracking wide enough to indicate that the horizontal steel has yield. The cracking in the floor slabs to the carpark decks is approximately up to 20-25 mm wide and the west side shear wall has large horizontal cracking at the third floor level. Seismic Assessment of Existing Building: "*In its damaged post-earthquake state I believe the building is earthquake-prone in accordance with Section 122 of the Building Act 2004 as the lateral load resistance is less than 33% of the current code. Based on the Earthquake-Prone, Dangerous and Insanitary Buildings Policy 2010, an earthquake prone building which has been damaged in the earthquake is now required to be strengthened to 67% of the current code. On 18 May 2011 the DBH increased the seismic hazard factor for the design of all buildings by 35% from 0.22 to 0.3. This has the effect of increasing the earthquake loads for the design of buildings by 35% of the code prior to 18 May 2011*". Conclusions: "*The degraded structure of the building is such that strengthening, repair and refurbishment is an almost impossible task and advanced geotechnical considerations will add to this position. I have taken a respected contractor through the building who has considerable experience in tackling difficult construction contracts and without prompting him, his opinion was similar to my own*". The report concludes that the replacement of the building was the only course of action available.

Note: Structural Drawings Available: Yes

Appendix E - Relevant documentation and notes –
D73- 12-storey RC frame hotel building

Date	Type (Name)	Notes
26 February 2011	Level 1 rapid assessment	The building has been given a Yellow placard. A Level 2 rapid assessment form is available (8 March 2011) but not completed in full (Placard: Yellow Y2. Damage Ratio: 2-10%).
April 2011	Geotechnical Report	Conclusions: "*There is no evidence sighted to suggest anything other than a satisfactory performance of the foundations*".
April 2011	Verticality Survey	Summary: "*In the course of observing each of the primary building corners, we saw no evidence of any significant lateral offset in any isolated sections of the walls. Observations have been made to random points up the surface of each wall corner. Any difference in the elevation of observation points at one corner to another, should not be interpreted as the building being off-level. No determination has been made of the levels on any floor".*
July 2011 (Revision 2 and Revision 3)	Damage Assessment Report	The report summarizes preliminary damage investigations, provides indicative strengthening options to comply with current regulations, and discusses the proposed changes to the seismic design load level for Christchurch and the implications for the building. A detailed analysis of the structure has been carried out using a linear analysis package (ETABS) to access its response to seismic loading. The analysis showed that the overall strength of the building (pre-earthquake) was between 25% and 30% of NBS. Executive Summary: "*In general the structural damage sustained has been relatively limited, although the building's capacity may have been reduced as a result of potential beam column joint failure. Following the repairs recommended herein, the lateral load resisting capacity of the building should be restored to its pre-earthquake capacity (noting that this could be as low as 34% of current code).*" Basis of the report: "*It should be noted that even after the detailed observations and analysis outlined above, it is difficult to accurately quantify the residual capacity remaining in the structure following this significant earthquake. As such, it is likely that we may never be able to categorically state that the building is as good as it was before the earthquake.*"
July 2012	Geotechnical Report	Comprehensive geotechnical report. Refer to document for further information.
May 2012 (Updated Aug. 2012)	Detailed Structural Assessment – Insurer Report	A quantitative analysis of the structure was performed in ETABS. The solution proposed in the report, after completion of the work required in the rehabilitation drawings, would achieve 67% NBS. The rehabilitation option includes the strengthening of concrete beams and columns utilizing Fiber Reinforced Polymer (FRP).
August 2012	Seismic Upgrade Design – Insurer Report	The report outlines the design loading, structural modelling assumptions, material properties, foundation requirements, and design standards for the proposed strengthening works.
January 2013	CERA Continuing Concerns Letter	CERA sent a letter to the building owner outlining specific issues of concern regarding the occupancy of the building after reviewing the detailed engineering evaluation (DEE) report.

Note: Structural Drawings Available: Yes

Appendix E - Relevant documentation and notes –
D201 - 13-storey RC frame office building

Date	Type (Name)	Notes
23 Feb. 2011	Level 2 rapid assessment	The building has been given a Green G2 placard. The assessment noted minor cosmetic damage and moderate damage to internal secondary walls, and recommended "thorough inspection" as soon as practicable.
May 2011	Detailed damage assessment	Most damage was reported to the secondary infill panels (cracking due to the poor detailing of connections to the main frames) and cosmetic damage to lightweight internal partition walls. The report concludes that the primary structural elements, including the foundations, have not suffered any significant damage.
July 2011	Structural inspection	A brief damage evaluation assessment was carried out following the June 2011 aftershock concluding that no further damage was evident compared with the 4 September 2010 and 22 February 2011 events. The report closes with: "*Some of the previously reported damage to the secondary infill panels, and cosmetic damage to lightweight walls has been exacerbated but again we reiterate that this is not affecting the primary structure. We have not yet noticed any significant damage to primary building structure and the building continues to perform very well. […] The building is fit for normal occupancy on all levels.*"
October 2011	Structural inspection	A further report summaries the results of a detailed structural analysis to assess the seismic capacity of the building (ETABS model). This report includes discussion on building verticality survey results and geotechnical performance. The tower was found to lean approximately 90 mm to the east and 150 mm to the north. The surveyors also estimated that the building has experienced a global settlement in the order of 200 mm following the earthquakes. However, the report notes that "*it is not conclusive how much of this differential settlement is earthquake-related to possible deeper layer liquefaction, shaking consolidation of the gravels and deeper sand layers; or in fact original construction tolerances or long term consolidation and creep of the soils*". Furthermore, the report concludes that "*in summary, we do not believe this building is earthquake prone, but is should certainly be classed as earthquake risk i.e. between 33% NBS and 67% NBS. The assessment, which effectively limits the theoretical capacity to 60% current IL2 code levels, is dictated by the current detailing in the main beams and beam column joints which will generate a bean hinging mechanism*".

Note: Structural Drawings Available: Yes

Appendix E - Relevant documentation and notes –
D210 - 7-storey RC shear wall/frame hospital building

Date	Type (Name)	Notes
25 Feb. 2011	Level 2 rapid assessment + Report	The building has been given a Green G2 placard. The assessment noted minor cracking in walls, repair to cracked walls required, and central lift shafts viewed – no cracks in walls.
December 2011	Inspection Report	Summary: "*In general, the structural damage appears to be limited to isolated locations. The majority of the damage observed is to the wall partitions, ceilings, and seismic joints. The seismic joints should be repaired and cleared of any loose debris. At this time there is no reason to believe the overall capacity of the building has been significantly decreased due to the events of December 23rd, although a more detailed investigation of the damage should be undertaken.*"
July 2013 (Revision 10)	Detailed Seismic Assessment Report	The report summarizes the general form of the building and its pre-earthquake capacity. It discusses findings from detailed observations and provides recommendations regarding the repair work required. Strengthening solutions have been investigated for three levels of upgrade (67%NBS – IL3, 100%NBS – IL3, 100% - IL4). Executive Summary*: "The capacity of the west building prior to the earthquake has been assessed using a non-linear time-history (NLTH) analysis. The results of the analysis indicate that the west building has the capacity to resist 55-60% of the new Ultimate Limit State (ULS) Design Basis Earthquake (DBE) for an IL3 building. (Note that this is equivalent to a building strength of 65-70% DBE for an IL2 building and 35-40% DBE for an IL4 building). The results of the NLTH analysis for west building indicate that the onset of collapse or partial collapse is likely to occur at approximately 80% of the new IL3 DBE.* *[…]* *The capacity of central building prior to the earthquake has been assessed in a similar manner to west building. The results of the non-linear time history analyses indicate that central building reaches the Collapse Limit State at 54% of the new DBE for an IL3 building. With an allowance for a ULS to CLS margin of 1.5 the effective capacity is 54/1.5 ~ 35-40% of new code strength.* *[…]* *Some testing has been carried out on the reinforcing in the Lower Ground Floor walls to determine if any strain hardening of the reinforcing bars has occurred. The lost strain capacity varied between 15-25% and 30-50%, on average being 30%.* *[…]* *A discussion is included on the buildings' likely performance under the Maximum Considered Event (MCE). It is recommended that the identified CSWs are retrofitted to remove potential collapse hazards. Provided that this work is done, it is considered that the buildings are acceptably unlikely to collapse in such an event, although they are likely to require demolition.*

Note: Structural Drawings Available: No

Appendix E - Relevant documentation and notes –
R74 - 3-storey RC shear wall hotel building

Date	Type (Name)	Notes
7 March 2011	Level 2 rapid assessment	The building has been given a Yellow Y2 placard.
April 2011	Geotechnical Report	Satisfactory performance of the foundations.
April 2011	Verticality Survey	No evidence of any significant lateral offset.
May 2012 (Revision 3)	Detailed Seismic Assessment Report	This report summarizes the findings of detailed observations of the damage sustained as a result of the earthquakes and provides recommendations regarding further observations and repair works required. Executive Summary*: "The lateral load resisting capacity of the building prior to the earthquakes is estimated to be approximately 67% of current code, due to strengthening and retrofit carried out in 1995.[…] In general the structural damage sustained has been relatively minor, with the building's capacity immediately following the earthquake not considered to have been significantly reduced. As such, the damage resulting from the earthquake is not considered to pose a significant structural hazard in relation to reoccupation of the building. Following the repairs recommended herein, the lateral load resisting performance of the building should be restored to approximately 67% of current code."*

Note: Structural Drawings Available: No

Appendix E - Relevant documentation and notes –
R86 - 6-storey RC shear wall hotel building

Date	Type (Name)	Notes
5 March 2011	Level 2 rapid assessment	The building has been given a Green G1 placard.
March 2011	Brief Visual Structural Inspection	The report recommends further removal of interior linings to checks for cracking to both west side shear walls and to central corridor shear walls. The report also notes that the ultimate strength of the shear wall should be unaffected by cracking of this nature.
April 2011	Site Inspection Report	Earthquake damage: "*Damage to the property is minimal and has not affected the structural elements of the building*"
July 2011	Site Inspection Report	Scope of report: "*The building is not significantly different in terms of structural strength than before the earthquakes."*
December 2011	Detailed Engineering Evaluation Report	A DEE summary spreadsheet has been completed for the building and was issued with this report. Conclusions*: "We believe the damage observed to this building indicates a satisfactory performance in recent earthquakes. In one direction the primary earthquake resisting elements have suffered from some concrete cracking. The crack widths were unlikely to have yielding any reinforcing. The cracks have been repaired such that the overall stiffness of the structure has been restored to as close as the original as is practically possible. The ultimate strength of the structure remains as it was pre-earthquake*."

Note: Structural Drawings Available: Yes

Appendix E - Relevant documentation and notes –
R113 - 19-storey RC frame office building

Date	Type (Name)	Notes
30 March 2011	Level 2 rapid assessment	The building has been given a Yellow Y2 placard. General Comments: The building appears to have performed well apart from stair failure. Cracks in beam indicate yielding began during earthquake.
March 2011	Site Report	Tower - General: *“There is minor damage to the seismic frame beams and gravity frame beams cracks typically less than 0.5 mm. The cracks were most prolific on levels 4 to 7. There are up to 4 mm cracks in the floor slabs, these were localized around the corner columns. Very little diaphragm damage was evident generally.”* Tower - Stairs: *“The stairs have collapsed up to level 15”.*
April 2011 (Revision 1)	Preliminary Structural Review	Seismic Assessment: “*The building has sustained minor to moderate damage from the strong shaking experienced from the Darfield and Lyttleton earthquakes. From our limited investigations, the building could be considered to still have the majority of its strength. The seismic resisting system has undergone minor inelastic displacement, which have likely resulted in a minor reduction of stiffness. […] The podium structure could be insufficiently tied into the main structure. This would result in the podium structure having minimal seismic resistance. Further investigation is required to verify this.”*
August 2012 (Revision 2)	Assessment and Repair Scope Report	A non-linear time history analysis was carried out on the building to identify specific areas of potential damage form future earthquakes. Executive Summary: *“Cracking to the concrete frames and floors was observed. Two columns in the carpark area failed and have been propped. The ground floor slab suffered liquefaction damage. Testing of reinforcement indicates that there is up to a 10% reduction in the tested bars strain capacity. Verticality surveys indicate that there has been no significant change since the first survey following the February 22 earthquake. In general, the structural damage sustained is considered moderate and substantial repairs will be required. As a result of the earthquakes the building’s capacity has not been reduced.”* Post-Earthquake Building Capacity: *“In its damaged state following the earthquakes, we do not consider the building to have any reduction in gravity load resistance. The overall lateral load resisting capacity of the building has not been significantly affected, although repairs are required as outlined above. Following the recommended repair of the structural damage, the lateral load resisting performance of the structure should be restored. The capacity of the primary structural system remains in excess of 70 to 90% current code depending on the results of the site specific spectra.”*

Note: Structural Drawings Available: Yes

Appendix E - Relevant documentation and notes –
R163 - 8-storey RC shear wall/frame residential building

Date	Type (Name)	Notes
25 Feb. 2011	Level 1 rapid assessment	The building has been given a Green placard.
7 July 2011	Level 2 rapid assessment	The building has been given a Yellow (Y1) placard.
December 2011	Geotechnical Report	The reports indicates that "*the site at XX Street shows no sign of the ground having liquefied. While there are minor variations at the ground floor level (likely due in part to the various fit-outs) the first floor levels surveys indicate the floors remain substantially level. The foundations appear to have performed well.*"
May 2012 (Revision 1)	Post-Earthquake Assessment	The report covers the structural damage sustained by the building as a result of the 4 September 2010, 22 February 2011, 13 June 2011, 23 December 2011, and aftershocks. Most of the key structural components have been inspected and the corresponding damage locations have been indicated. The report suggests a list of further recommended inspections, investigations and repairs. Executive Summary: "*We have made recommendations for further investigations. The damage has not significantly compromised the structural integrity of the buildings, however they require repair*. […] *An Initial Evaluation Procedure (IEP) has been completed. The buildings are neither earthquake-prone or earthquake risk. There is no requirement to strengthen the buildings*."
August 2013	Earthquake Repairs	Structural drawings for the repairs and site inspection notes. (337 pp. document)

Note: Structural Drawings Available: No

Appendix E - Relevant documentation and notes –
R202 - 6-storey RC frame office building

Date	Type (Name)	Notes
December 2010	Report – Structural Performance and Repairs	The report covers the structural damage sustained by the building as a result of the 4 September 2010 only. Conclusion: "*The building performed well under the earthquake with no failure of any primary structural system. The stability of the structure and its ability to resist aftershocks and subsequent earthquakes has not been compromised*."
26 Feb. 2011	Level 1 rapid assessment	The building has been given a Green placard.
7 April 2011	Level 2 rapid assessment	The building has been given a Green (G2) placard.
May 2011	Post-February Earthquake Structural Assessment	The report includes the inspection of the glazed facades only. The façade structure appears to be structurally undamaged and is safe to use without any structural repairs.
June 2011	Geotechnical Report	Executive Summary: "*There is no evidence of any untoward movement or settlement of the building foundation. […] Observation and evidence all indicates that the building foundations have performed satisfactorily during the recent earthquakes and their aftershocks. Although there is a low probability of a different large earthquake liquefying more of the deeper underlying sands, in which case some settlement of the building could occur, it is expected that the foundations will also perform satisfactorily in any future earthquakes.*"
August 2011	Report – Structural Performance and Repairs	The report covers the structural damage sustained by the building as a result of the 4 September 2010, 22 February, and 13 June 2011. Executive Summary: "*Major structural damage that endangered the stability of the building has not been found. The building performed well under the earthquake and is considered to have had residual capacity to have resisted a longer or more energetic seismic event. Where structural repairs have been carried out they have been designed to remediate the damaged area to a strength at least as great to that which existed prior to the earthquake. The stability of the structure and its ability to resist aftershocks and subsequent earthquakes has not been compromised*."
October 2011	Structural Technical Review	The document provides a summary of the building characteristics and discusses the methodology used by the primary consultant in assessing the damage, repairs and residual seismic capacity of the building. The methodology and the responses provided to questions raised by the peer-review team were considered reasonable.
March 2012	Independent Earthquake Performance Assessment	Conclusions: "*The performance of the building during the 2010 and 2011 Canterbury earthquakes was largely satisfactory, with primarily non-structural damage occurring. The performance of the structure was considered to be commensurate with the performance that would be expected based on the design of the structure*."

Note: Structural Drawings Available: No

Appendix E - Relevant documentation and notes –
R901 - 6-storey RC frame university building

Date	Type (Name)	Notes
14 June 2011	Level 2 rapid assessment + Detailed Inspection Report	The building has been given a Green (G2) placard. Notes: Flexural cracking to transverse beams, plenty of cosmetic cracking and partition damage.
August 2011	Structural Assessment Report	The report covers the structural damage sustained by the building as a result of the 4 September 2010, 22 February, and 13 June 2011. The report concludes that the building is unlikely to collapse under a current code design level earthquake, and based on its original design, should have sufficient capacity to withstand loads of at least 67% of current design earthquake load levels. However, the building column bases are expected to yield initially at approximately 20% of current design earthquake load levels in the north-south direction and initial yielding may occur in beams at approximately 25% of current design earthquake load levels in the east-west direction. The report points out some issues that need further consideration: • The building inter-storey drifts are expected to be greater than that allowed under the code (2.5% drift limit) • The relative flexibility of the building and the large deflections than can be expected suggest that pounding could cause significant damage to the building at the joints to the two adjacent structures. • The flexibility of the building indicates that under serviceability conditions, relatively low levels of shaking are likely to cause superficial damage across seismic joints. • The extent of strain hardening that the building's steel has undergone has not been determined.
November 2012 (Version 1)	Geotechnical Report	Conclusions: "*The foundations of the buildings appear to have sufficient capacity to manage future ULS earthquake load. No settlement around the building major structural pile groups was observed during the building inspection indicating that failure of the piles has not occurred as a result of the Canterbury earthquake series*."

Note: Structural Drawings Available: Yes

Appendix E - Relevant documentation and notes –
R902 - 3-storey RC shear wall/frame public assembly building

Date Issued	Type (Name)	Notes
1 March 2011	Level 2 rapid assessment	The building has been given a Green (G1) placard.
6 March 2011	Level 2 rapid assessment	The building has been given a Green (G2) placard.
7 March 2011	Level 2 rapid assessment	The building has been given a Green (G1) placard.
May 2011	Structural Assessment Report	The report was prepared to assist the Christchurch City Council with the insurance claim associated with the building. Conclusions: "*The structural damage has not significantly reduced the overall structural capacity of the building and we consider that repair of all damage is feasible. In our opinion, the costs of these repairs will be significantly less than the cost of rebuild.*"
15 June 2011	Level 2 rapid assessment	The building has been given a Green (G2) placard. General Comments: Building has not sustained significant structural damage. Building will require repairs.
22 June 2011	Level 2 rapid assessment	The building has been given a Green (G2) placard.
July 2011	Geotechnical Report	The geotechnical report shows that some settlement has occurred in the February event, and can be expected to occur again in a design level event. The settlement is not considered to have had any significant effect on the building's seismic capacity.
July 2011	Façade Assessment Report	A repair methodology comprising investigation, testing and further analysis will be necessary to satisfactorily reinstate the facade.
July 2011	Inspection Report	Inspection report on the precast concrete panels forming the exterior cladding and other architectural elements.
October 2011	Structural Assessment Report	This report address the extent of the structural damage and outlines remedial work required. It also includes a summary of the geotechnical report and the façade assessment report.
April 2012	Structural Assessment Report	The report notes that, although the structure generally performed well during the earthquakes, significant construction works will be required to reinstate the building to its former high level of service, prior to its re-opening to the public.

Note: Structural Drawings Available: No

Summary - Detailed Engineering Evaluation (DEE) spreadsheet

		Building ID	DEE Spreadsheet Available (Y/N) (Date of submission)
DEMOLISHED	CERA	D117	N
		D192	N
		D196	N
	OWNER INITIATED	D11	N
		D49	N
		D73	Y (July 2012)
		D201	Y (October 2011)
		D210	Y (July 2012)
REPAIRED		R74	Y (May 2012)
		R86	Y (December 2011)
		R113	N
		R163	Y (August 2013)
		R202	Y (October 2011)
		R901	Y (December 2011)
		R902	Y (June 2012)

Location

Building Name:	Building ID D73			Reviewer:	
	Unit	No:	Street	CPEng No:	
Building Address:				Company:	
Legal Description:				Company project number:	
				Company phone number:	
	Degrees	Min	Sec		
GPS south:				Date of submission:	24-Jul-12
GPS east:				Inspection Date:	22-Mar-12
				Revision:	A
Building Unique Identifier (CCC):				Is there a full report with this summary?	yes

Site

Site slope:	flat	Max retaining height (m):	3
Soil type:	mixed	Soil Profile (if available):	Silty clay & interbeds of silty sands
Site Class (to NZS1170.5):	D		
Proximity to waterway (m, if <100m):		If Ground improvement on site, describe:	
Proximity to clifftop (m, if < 100m):			
Proximity to cliff base (m,if <100m):		Approx site elevation (m):	

Building

No. of storeys above ground:	12	single storey = 1	Ground floor elevation (Absolute) (m):	
Ground floor split?	no		Ground floor elevation above ground (m):	0.00
Storeys below ground	1			
Foundation type:	driven precast piles		if Foundation type is other, describe:	
Building height (m):	46.00		height from ground to level of uppermost seismic mass (for IEP only) (m):	
Floor footprint area (approx):	560			
Age of Building (years):	40		Date of design:	1965-1976
Strengthening present?	no		If so, when (year)?	
			And what load level (%g)?	
Use (ground floor):	commercial		Brief strengthening description:	
Use (upper floors):	multi-unit residential			
Use notes (if required):				
Importance level (to NZS1170.5):	IL2			

Gravity Structure

Gravity System:	frame system		
Roof:	concrete	slab thickness (mm)	127
Floors:	concrete flat slab	slab thickness (mm)	127
Beams:	cast-insitu concrete	overall depth x width (mm x mm)	1000x450
Columns:	cast-insitu concrete	typical dimensions (mm x mm)	900x900
Walls:	load bearing concrete	#N/A	

Lateral load resisting structure

Lateral system along:	non-ductile concrete moment frame	**Note: Define along and across in detailed report!**		
Ductility assumed, m:	1.25		note typical bay length (m)	
Period along:	3.00	0.00	estimate or calculation?	calculated
Total deflection (ULS) (mm):	300		estimate or calculation?	calculated
maximum interstorey deflection (ULS) (mm):	75		estimate or calculation?	calculated
Lateral system across:	non-ductile concrete moment frame			
Ductility assumed, m:	1.25		note typical bay length (m)	
Period across:	3.00	0.00	estimate or calculation?	calculated
Total deflection (ULS) (mm):	300		estimate or calculation?	calculated
maximum interstorey deflection (ULS) (mm):	75		estimate or calculation?	calculated

Appendix E - Detailed Engineering Evaluation spreadsheet - D73- 12-storey RC frame hotel building (1 of 2)

Separations:

north (mm):		leave blank if not relevant
east (mm):		
south (mm):		
west (mm):	500	

Non-structural elements

Stairs:	precast, half height	describe supports	Cast in bolt anchors to floor slab
Wall cladding:	precast panels	thickness and fixing type	
Roof Cladding:	Membrane	substrate	
Glazing:	aluminium frames		
Ceilings:	strapped or direct fixed		
Services(list):			

Available documentation

Architectural	full	original designer name/date	
Structural	full	original designer name/date	
Mechanical		original designer name/date	
Electrical		original designer name/date	
Geotech report	full	original designer name/date	

Damage

Site:
(refer DEE Table 4-2)

Site performance:	Good	Describe damage:	
Settlement:	none observed	notes (if applicable):	
Differential settlement:	none observed	notes (if applicable):	
Liquefaction:	none apparent	notes (if applicable):	
Lateral Spread:	none apparent	notes (if applicable):	
Differential lateral spread:	none apparent	notes (if applicable):	
Ground cracks:	none apparent	notes (if applicable):	
Damage to area:	slight	notes (if applicable):	

Building:

	Current Placard Status:	yellow		
Along	Damage ratio:	11%	Describe how damage ratio arrived at:	Estimate
	Describe (summary):	Cracking of beams & columns		
Across	Damage ratio:	11%		
	Describe (summary):	Cracking of beams & columns		
Diaphragms	Damage?:	yes	Describe:	Minor cracking
CSWs:	Damage?:	yes	Describe:	Beam/col joints, columns, stairs, blockwalls
Pounding:	Damage?:	no	Describe:	
Non-structural:	Damage?:	yes	Describe:	Minor to precast cladding panels

Recommendations

	Level of repair/strengthening required:	significant structural and strengthening		Describe:	
	Building Consent required:	yes		Describe:	
	Interim occupancy recommendations:	do not occupy		Describe:	
Along	Assessed %NBS before e'quakes:	28%	28% %NBS from IEP below	If IEP not used, please detail assessment methodology:	
	Assessed %NBS after e'quakes:	25%			
Across	Assessed %NBS before e'quakes:	28%	28% %NBS from IEP below		
	Assessed %NBS after e'quakes:	25%			

Appendix E - Detailed Engineering Evaluation spreadsheet - D73- 12-storey RC frame hotel building (2 of 2)

Location

Building Name:	Building ID D201		Reviewer:	
	Unit / No: / Street		CPEng No:	
Building Address:			Company:	
Legal Description:			Company project number:	
			Company phone number:	
	Degrees / Min / Sec			
GPS south:			Date of submission:	31-Oct-11
GPS east:			Inspection Date:	01-Oct-11
			Revision:	
Building Unique Identifier (CCC):			Is there a full report with this summary?	no

Site

Site slope:	flat	Max retaining height (m):	0
Soil type:	gravel	Soil Profile (if available):	
Site Class (to NZS1170.5):	D		
Proximity to waterway (m, if <100m):	60	If Ground improvement on site, describe:	
Proximity to clifftop (m, if < 100m):	0		
Proximity to cliff base (m,if <100m):	0	Approx site elevation (m):	13.70

Building

No. of storeys above ground:	13	single storey = 1	Ground floor elevation (Absolute) (m):	13.70
Ground floor split?	no		Ground floor elevation above ground (m):	0.00
Storeys below ground	1			
Foundation type:	mat slab		if Foundation type is other, describe:	combination mat slab of two way foundation be
Building height (m):	50.00		height from ground to level of uppermost seismic mass (for IEP only) (m):	50
Floor footprint area (approx):	520			
Age of Building (years):	40		Date of design:	1965-1976
Strengthening present?	no		If so, when (year)?	
			And what load level (%g)?	
Use (ground floor):	institutional		Brief strengthening description:	
Use (upper floors):	institutional			
Use notes (if required):				
Importance level (to NZS1170.5):	IL2			

Gravity Structure

Gravity System:	frame system		
Roof:	steel framed	rafter type, purlin type and cladding	timber/steel mix
Floors:	concrete flat slab	slab thickness (mm)	150
Beams:	cast-insitu concrete	overall depth x width (mm x mm)	685x600
Columns:	cast-insitu concrete	typical dimensions (mm x mm)	685x685
Walls:	non-load bearing	0	

Lateral load resisting structure

Lateral system along:	ductile concrete moment frame		6.4
Ductility assumed, m:	2.00	note typical bay length (m)	overal building period
Period along:	1.98	estimate or calculation?	calculated
Total deflection (ULS) (mm):	470	estimate or calculation?	calculated
maximum interstorey deflection (ULS) (mm):	58	estimate or calculation?	calculated
Lateral system across:	ductile concrete moment frame		6.4
Ductility assumed, m:	2.00	note typical bay length (m)	overal building period
Period across:	1.98	estimate or calculation?	calculated
Total deflection (ULS) (mm):	520	estimate or calculation?	calculated
maximum interstorey deflection (ULS) (mm):	60	estimate or calculation?	calculated

Note: Deflections based on 60% current IL2 loads with fully cracked properties

Appendix E - Detailed Engineering Evaluation spreadsheet - D201 - 13-storey RC frame office building (1 of 2)

Separations:			
north (mm):			
east (mm):			
south (mm):			
west (mm):			

Non-structural elements			
Stairs:	cast insitu	notes	cast in top, sliding base detail
Wall cladding:	precast panels	thickness and fixing type	varies
Roof Cladding:	Metal	describe	not inspected
Glazing:	aluminium frames		poor condition
Ceilings:	light tiles		
Services(list):			

Available documentation

Architectural	full	original designer name/date	Ministry of Works
Structural	full	original designer name/date	as above
Mechanical	full	original designer name/date	as above
Electrical	full	original designer name/date	as above
Geotech report	partial	original designer name/date	as above

Damage

Site:
(refer DEE Table 4-2)

Site performance:	minor near surface ejecta only	Describe damage:	
Settlement:	100-200mm	notes (if applicable):	
Differential settlement:	1:250-1:150	notes (if applicable):	
Liquefaction:	0-2 m³/100m²	notes (if applicable):	
Lateral Spread:	none apparent	notes (if applicable):	
Differential lateral spread:	none apparent	notes (if applicable):	
Ground cracks:	none apparent	notes (if applicable):	
Damage to area:	slight	notes (if applicable):	

Building:

	Current Placard Status:	green		
Along	Damage ratio:	0%	Describe how damage ratio arrived at:	numerous inspections of key structural element
	Describe (summary):	hairline flexural cracking in frames only		
Across	Damage ratio:	0%		
	Describe (summary):	hairline flexural cracking in frames only		
Diaphragms	Damage?:	no	Describe:	
CSWs:	Damage?:	no	Describe:	
Pounding:	Damage?:	no	Describe:	
Non-structural:	Damage?:	yes	Describe:	

Note: Damage ratio applies to primary structure only which we believe has remained elastic. Sme internal damage to infill panels, partions, etc.

Recommendations

	Level of repair/strengthening required:	minor non-structural		Describe:
	Building Consent required:	no		Describe:
	Interim occupancy recommendations:	full occupancy		Describe:
Along	Assessed %NBS before e'quakes:	60%	%NBS from IEP below	If IEP not used, please detail assessment methodology:
	Assessed %NBS after e'quakes:	60%		
Across	Assessed %NBS before e'quakes:	60%	%NBS from IEP below	
	Assessed %NBS after e'quakes:	60%		

Appendix E - Detailed Engineering Evaluation spreadsheet - D201 - 13-storey RC frame office building (2 of 2)

Location

Building Name:	Building ID D210 (East)			Reviewer:	
	Unit	No:	Street	CPEng No:	
Building Address:				Company:	
Legal Description:				Company project number:	
				Company phone number:	
	Degrees	Min	Sec		
GPS south:				Date of submission:	2012-07-02
GPS east:				Inspection Date:	2012-04-18
				Revision:	1
Building Unique Identifier (CCC):				Is there a full report with this summary?	yes

Site

Site slope:	slope < 1in 10	Max retaining height (m):	0
Soil type:	gravel	Soil Profile (if available):	The basement bears on a gravel layer that is a
Site Class (to NZS1170.5):	D		
Proximity to waterway (m, if <100m):		If Ground improvement on site, describe:	
Proximity to clifftop (m, if < 100m):			
Proximity to cliff base (m,if <100m):		Approx site elevation (m):	5.00

Building

No. of storeys above ground:	6	single storey = 1	Ground floor elevation (Absolute) (m):	5.20
Ground floor split?	yes		Ground floor elevation above ground (m):	0.20
Storeys below ground	1			
Foundation type:	strip footings		if Foundation type is other, describe:	strip footings under the exterior walls, pads und
Building height (m):	22.70		height from ground to level of uppermost seismic mass (for IEP only) (m):	
Floor footprint area (approx):	780			
Age of Building (years):	45		Date of design:	1965-1976
Strengthening present?	no		If so, when (year)?	
			And what load level (%g)?	
Use (ground floor):	other (specify)		Brief strengthening description:	
Use (upper floors):	other (specify)			
Use notes (if required):	hospital			
Importance level (to NZS1170.5):	IL3			

Gravity Structure

Gravity System:	load bearing walls		
Roof:	steel framed	rafter type, purlin type and cladding	lightweigt metal roofing on Woodtex panels on timber purlins
Floors:	concrete waffle slab	slab thickness (mm)	305
Beams:	none	overall depth x width (mm x mm)	
Columns:	cast-insitu concrete	typical dimensions (mm x mm)	457x610
Walls:	load bearing concrete	#N/A	200

Lateral load resisting structure

Lateral system along:	concrete shear wall		**Note: Define along and across**	enter wall data in "IEP period calcs"	
Ductility assumed, m:			**in detailed report!**	worksheet for period calculation	
Period along:	0.58	####	enter height above at H31	estimate or calculation?	estimated
Total deflection (ULS) (mm):	183			estimate or calculation?	estimated
maximum interstorey deflection (ULS) (mm):	40			estimate or calculation?	estimated
Lateral system across:	concrete shear wall			enter wall data in "IEP period calcs"	
Ductility assumed, m:				worksheet for period calculation	
Period across:	0.81	####	enter height above at H31	estimate or calculation?	estimated
Total deflection (ULS) (mm):	206			estimate or calculation?	estimated
maximum interstorey deflection (ULS) (mm):	45			estimate or calculation?	estimated

Appendix E - Detailed Engineering Evaluation spreadsheet - D210 - 7-storey RC shear wall/frame hospital building (1 of 4)

Separations:			
north (mm):		leave blank if not relevant	
east (mm):			
south (mm):			
west (mm):	100		

Non-structural elements			
Stairs:	cast insitu	notes	zigzag stairs cast in floor to floor surrounded by
Wall cladding:	other heavy	describe	precast panels with the insitu concrete shear w
Roof Cladding:	Metal	describe	metal roofing on Woodtex panels
Glazing:			
Ceilings:	fibrous plaster, fixed		mixture of plasterboard and heavy tiles
Services(list):			

Available documentation			
Architectural	none	original designer name/date	
Structural	full	original designer name/date	Mason Seward and Stanton 1967
Mechanical	none	original designer name/date	
Electrical	none	original designer name/date	
Geotech report	partial	original designer name/date	Post earthquake geotechnical assessment - Tonkin & Taylor, September 2011

Damage				
Site: (refer DEE Table 4-2)	Site performance:		Describe damage:	Some lateral spreading observed adjacent to t
	Settlement:	0-25mm	notes (if applicable):	Overall settlement of the site and building occu
	Differential settlement:	0-1:350	notes (if applicable):	Local slopes within the building of 13mm over
	Liquefaction:	none apparent	notes (if applicable):	No surface manifestation of liquefaction was ol
	Lateral Spread:	50-250mm	notes (if applicable):	Lateral spread occurred adjacent to the Avon R
	Differential lateral spread:	none apparent	notes (if applicable):	No lateral spread observed on the site away fro
	Ground cracks:	20-100mm/20m	notes (if applicable):	Ground cracks occurred in the road between th
	Damage to area:	slight	notes (if applicable):	Around Riverside East
Building:				
	Current Placard Status:	green		
Along	Damage ratio:	0%	Describe how damage ratio arrived at:	Damage ratio based on strength. Note that stra
	Describe (summary):	Cracking to the walls, columns and beams has reduced the stiffness of the building		
Across	Damage ratio:	0%		
	Describe (summary):	Cracking to the walls, columns and beams has reduced the stiffness of the building		
Diaphragms	Damage?:	yes	Describe:	Some cracking to the insitu floors
CSWs:	Damage?:	yes	Describe:	pier elements G-1 in the south wall 70%/1.8=39
Pounding:	Damage?:	yes	Describe:	Damage to seismic gap covers and evidence
Non-structural:	Damage?:	yes	Describe:	Some cracking to internal partitions and ceiling

Recommendations						
	Level of repair/strengthening required:	significant structural and strengthening			Describe:	Epoxy injection of cracks in the walls, columns
	Building Consent required:	yes			Describe:	For epoxy iinjection of cracks and strengthenin
	Interim occupancy recommendations:	full occupancy			Describe:	
Along	Assessed %NBS before e'quakes:	45%	####	%NBS from IEP below	If IEP not used, please detail assessment methodology:	Non-Linear Time History Analysis was carried
	Assessed %NBS after e'quakes:	45%				
Across	Assessed %NBS before e'quakes:	45%	####	%NBS from IEP below		
	Assessed %NBS after e'quakes:	45%				

Appendix E - Detailed Engineering Evaluation spreadsheet - D210 - 7-storey RC shear wall/frame hospital building (2 of 4)

Location

Building Name:	Building ID D210 (West)			Reviewer:	
	Unit	No:	Street	CPEng No:	
Building Address:				Company:	
Legal Description:				Company project number:	
				Company phone number:	
	Degrees	Min	Sec		
GPS south:				Date of submission:	2012-07-02
GPS east:				Inspection Date:	2012-04-18
				Revision:	1
Building Unique Identifier (CCC):				Is there a full report with this summary?	yes

Site

Site slope:	slope < 1in 10	Max retaining height (m):	0
Soil type:	gravel	Soil Profile (if available):	The basement bears on a gravel layer that is a
Site Class (to NZS1170.5):	D		
Proximity to waterway (m, if <100m):		If Ground improvement on site, describe:	
Proximity to clifftop (m, if < 100m):			
Proximity to cliff base (m,if <100m):		Approx site elevation (m):	5.00

Building

No. of storeys above ground:	6	single storey = 1	Ground floor elevation (Absolute) (m):	5.20
Ground floor split?	yes		Ground floor elevation above ground (m):	0.20
Storeys below ground	1			
Foundation type:	strip footings		if Foundation type is other, describe:	strip footings under the exterior walls, pads und
Building height (m):	22.70		height from ground to level of uppermost seismic mass (for IEP only) (m):	
Floor footprint area (approx):	780			
Age of Building (years):	45		Date of design:	1965-1976
Strengthening present?	no		If so, when (year)?	
			And what load level (%g)?	
Use (ground floor):	other (specify)		Brief strengthening description:	
Use (upper floors):	other (specify)			
Use notes (if required):	hospital			
Importance level (to NZS1170.5):	IL3			

<u>Gravity Structure</u>

Gravity System:	load bearing walls		
Roof:	steel framed	rafter type, purlin type and cladding	lightweigt metal roofing on Woodtex panels on timber purlins
Floors:	concrete waffle slab	slab thickness (mm)	305
Beams:	none	overall depth x width (mm x mm)	
Columns:	cast-insitu concrete	typical dimensions (mm x mm)	457 x 610
Walls:	load bearing concrete	#N/A	200

<u>Lateral load resisting structure</u>

Lateral system along:	concrete shear wall	**Note: Define along and across in detailed report!**	enter wall data in "IEP period calcs" worksheet for period calculation	
Ductility assumed, m:				
Period along:	0.58	#### enter height above at H31	estimate or calculation?	calculated
Total deflection (ULS) (mm):	183		estimate or calculation?	calculated
maximum interstorey deflection (ULS) (mm):	40		estimate or calculation?	estimated
Lateral system across:	concrete shear wall		enter wall data in "IEP period calcs" worksheet for period calculation	
Ductility assumed, m:				
Period across:	0.81	#### enter height above at H31	estimate or calculation?	calculated
Total deflection (ULS) (mm):	206		estimate or calculation?	calculated
maximum interstorey deflection (ULS) (mm):	45		estimate or calculation?	estimated

Appendix E - Detailed Engineering Evaluation spreadsheet - D210 - 7-storey RC shear wall/frame hospital building (3 of 4)

Separations:

north (mm):		leave blank if not relevant	
east (mm):	100		
south (mm):			
west (mm):			

Non-structural elements

Stairs:	cast insitu	notes	zigzag stairs cast in floor to floor surrounded by
Wall cladding:	other heavy	describe	precast panels with the insitu concrete shear w
Roof Cladding:	Metal	describe	metal roofing on Woodtex panels
Glazing:			
Ceilings:	fibrous plaster, fixed		mixture of plasterboard and heavy tiles
Services(list):			

Available documentation

Architectural	none	original designer name/date	
Structural	full	original designer name/date	Mason Seward and Stanton 1967
Mechanical	none	original designer name/date	
Electrical	none	original designer name/date	
Geotech report	partial	original designer name/date	Post earthquake geotechnical assessment - Tonkin & Taylor, September 2011

Damage

Site:
(refer DEE Table 4-2)

Site performance:		Describe damage:	Some lateral spreading observed adjacent to t
Settlement:	0-25mm	notes (if applicable):	Overall settlement of the site and building occu
Differential settlement:	0-1:350	notes (if applicable):	Local slopes within the building of up to 1:370 r
Liquefaction:	none apparent	notes (if applicable):	No surface manifestation of liquefaction was ol
Lateral Spread:	50-250mm	notes (if applicable):	Lateral spread occurred adjacent to the Avon R
Differential lateral spread:	none apparent	notes (if applicable):	No lateral spread observed on the site away fro
Ground cracks:	20-100mm/20m	notes (if applicable):	Ground cracks occurred in the road between th
Damage to area:	slight	notes (if applicable):	Around Riverside West

Building:

	Current Placard Status:	green		
Along	Damage ratio:	0%	Describe how damage ratio arrived at:	Damage ratio based on strength. Note that stra
	Describe (summary):	Cracking to the walls, columns and beams has reduced the stiffness of the building		
Across	Damage ratio:	0%		
	Describe (summary):	Cracking of the walls, columns and beams has reduced the stiffness of the building		
Diaphragms	Damage?:	yes	Describe:	Cracking to the diaphragm observed in the sou
CSWs:	Damage?:	yes	Describe:	pier elements G-1 in the south wall 70%/1.8=39
Pounding:	Damage?:	yes	Describe:	Damage to seismic gap covers and evidence o
Non-structural:	Damage?:	yes	Describe:	Some cracking to internal partitions and ceiling

Recommendations

	Level of repair/strengthening required:	significant structural and strengthening	Describe:	Epoxy injection of cracks in the walls, columns
	Building Consent required:	yes	Describe:	For epoxy iinjection of cracks and strengthenin
	Interim occupancy recommendations:	full occupancy	Describe:	Epoxy injection has been completed to date in
Along	Assessed %NBS before e'quakes:	45% #### %NBS from IEP below	If IEP not used, please detail assessment methodology:	Non-Linear Time History Analysis. ULS capaci
	Assessed %NBS after e'quakes:	45%		
Across	Assessed %NBS before e'quakes:	45% #### %NBS from IEP below		
	Assessed %NBS after e'quakes:	45%		

Appendix E - Detailed Engineering Evaluation spreadsheet - D210 - 7-storey RC shear wall/frame hospital building (4 of 4)

Location

Building Name:	Building ID R74			Reviewer:	
	Unit	No:	Street	CPEng No:	
Building Address:				Company:	
Legal Description:				Company project number:	
				Company phone number:	
	Degrees	Min	Sec		
GPS south:				Date of submission:	15-May-12
GPS east:				Inspection Date:	Various - refer to report
				Revision:	3
Building Unique Identifier (CCC):				Is there a full report with this summary?	yes

Site

Site slope:	flat	Max retaining height (m):	
Soil type:	mixed	Soil Profile (if available):	
Site Class (to NZS1170.5):	D		
Proximity to waterway (m, if <100m):		If Ground improvement on site, describe:	
Proximity to clifftop (m, if < 100m):			
Proximity to cliff base (m,if <100m):		Approx site elevation (m):	

Building

No. of storeys above ground:	4	single storey = 1	Ground floor elevation (Absolute) (m):	
Ground floor split?	yes		Ground floor elevation above ground (m):	1.00
Storeys below ground	1			
Foundation type:	driven precast piles		if Foundation type is other, describe:	
Building height (m):	20.00		height from ground to level of uppermost seismic mass (for IEP only) (m):	
Floor footprint area (approx):	1600			
Age of Building (years):	100		Date of design:	Pre 1935
Strengthening present?	yes		If so, when (year)?	1995
			And what load level (%g)?	
Use (ground floor):	commercial		Brief strengthening description:	Concrete walls and floor diaphragm strengthen
Use (upper floors):	multi-unit residential			
Use notes (if required):	hotel / apartments			
Importance level (to NZS1170.5):	IL2			

Gravity Structure

Gravity System:	load bearing walls		
Roof:	concrete	slab thickness (mm)	200
Floors:	timber	joist depth and spacing (mm)	
Beams:	steel non-composite	beam and connector type	
Columns:			
Walls:	load bearing brick	#N/A	

Lateral load resisting structure

Lateral system along:	unreinforced masonry bearing wall - brick		**Note: Define along and across**	note wall thickness and cavity	various, no cavity
Ductility assumed, m:	1.00		**in detailed report!**		
Period along:	0.40	0.40	from parameters in sheet	estimate or calculation?	estimated
Total deflection (ULS) (mm):	60			estimate or calculation?	estimated
maximum interstorey deflection (ULS) (mm):	15			estimate or calculation?	estimated
Lateral system across:	unreinforced masonry bearing wall - brick			note wall thickness and cavity	various, no cavity
Ductility assumed, m:	1.00				
Period across:	0.40	0.00		estimate or calculation?	estimated
Total deflection (ULS) (mm):	60			estimate or calculation?	estimated
maximum interstorey deflection (ULS) (mm):	15			estimate or calculation?	estimated

Appendix E - Detailed Engineering Evaluation spreadsheet - R74 - 3-storey RC shear wall hotel building (1 of 2)

Separations:

north (mm):		leave blank if not relevant
east (mm):		
south (mm):		
west (mm):		

Non-structural elements

Stairs:	cast insitu	notes	
Wall cladding:	brick or tile	describe (note cavity if exists)	no cavity
Roof Cladding:	Membrane	substrate	concrete
Glazing:	timber frames		
Ceilings:	plaster, fixed		
Services(list):			

Available documentation

Architectural	none	original designer name/date	
Structural	partial	original designer name/date	
Mechanical	none	original designer name/date	
Electrical	none	original designer name/date	
Geotech report	partial	original designer name/date	

Damage

Site:
(refer DEE Table 4-2)

Site performance:	Reasonable	Describe damage:	Minor slumping of surrounding pavement
Settlement:	0-25mm	notes (if applicable):	
Differential settlement:	1:350-1:250	notes (if applicable):	
Liquefaction:	0-2 m²/100m³	notes (if applicable):	
Lateral Spread:	none apparent	notes (if applicable):	
Differential lateral spread:	none apparent	notes (if applicable):	
Ground cracks:	none apparent	notes (if applicable):	
Damage to area:	slight	notes (if applicable):	

Building:

	Current Placard Status:	green		
Along	Damage ratio:	0%	Describe how damage ratio arrived at:	
	Describe (summary):			
Across	Damage ratio:	0%		
	Describe (summary):			
Diaphragms	Damage?:	no	Describe:	
CSWs:	Damage?:	no	Describe:	
Pounding:	Damage?:	no	Describe:	
Non-structural:	Damage?:	yes	Describe:	Plaster and paint

Recommendations

	Level of repair/strengthening required:	minor structural	Describe:	Refer to the report
	Building Consent required:	yes	Describe:	
	Interim occupancy recommendations:	full occupancy	Describe:	Refer to the report
Along	Assessed %NBS before:	67% #### %NBS from IEP below	If IEP not used, please detail assessment methodology:	Comparison of design loads used to strengthe
	Assessed %NBS after:	67%		
Across	Assessed %NBS before:	67% #### %NBS from IEP below		
	Assessed %NBS after:	67%		

Appendix E - Detailed Engineering Evaluation spreadsheet - R74 - 3-storey RC shear wall hotel building (2 of 2)

Location

Building Name:	Building ID R86			Reviewer:	
	Unit	No:	Street	CPEng No:	
Building Address:				Company:	
Legal Description:				Company project number:	
				Company phone number:	
	Degrees	Min	Sec		
GPS south:				Date of submission:	2011-12-19
GPS east:				Inspection Date:	refer to report
				Revision:	
Building Unique Identifier (CCC):				Is there a full report with this summary?	yes

Site

Site slope:	flat	Max retaining height (m):	0
Soil type:	silty sand	Soil Profile (if available):	400mm topsoil +1.0m silty sand, sandy gravel
Site Class (to NZS1170.5):	D		
Proximity to waterway (m, if <100m):	60	If Ground improvement on site, describe:	
Proximity to clifftop (m, if < 100m):			
Proximity to cliff base (m,if <100m):		Approx site elevation (m):	10.00

Building

No. of storeys above ground:	6	single storey = 1	Ground floor elevation (Absolute) (m):	
Ground floor split?	no		Ground floor elevation above ground (m):	150mm
Storeys below ground	0			
Foundation type:	pads with tie beams		if Foundation type is other, describe:	
Building height (m):	20.00		height from ground to level of uppermost seismic mass (for IEP only) (m):	14.2
Floor footprint area (approx):	600			
Age of Building (years):	22		Date of design:	1976-1992
Strengthening present?	yes		If so, when (year)?	
			And what load level (%g)?	
Use (ground floor):	commercial		Brief strengthening description:	
Use (upper floors):	other (specify)			
Use notes (if required):	Accommodation			
Importance level (to NZS1170.5):	IL2			

Gravity Structure

Gravity System:	frame system		
Roof:	steel framed	rafter type, purlin type and cladding	timber rafter & purlins, Hardies Shingles
Floors:	precast concrete with topping	unit type and depth (mm), topping	Interspan, 100mm, 75mm
Beams:	precast concrete	overall depth (mm)	550
Columns:	cast-insitu concrete	typical dimensions (mm x mm)	500 x 250
Walls:	load bearing concrete	#N/A	

Lateral load resisting structure

Lateral system along:	concrete shear wall		**Note: Define along and across**	note total length of wall at ground (m):	14
Ductility assumed, m:	2.00		**in detailed report!**	wall thickness (m):	0.3
Period along:	0.27	0.27	from parameters in sheet	estimate or calculation?	estimated
Total deflection (ULS) (mm):	75			estimate or calculation?	estimated
maximum interstorey deflection (ULS) (mm):	15			estimate or calculation?	estimated
Lateral system across:	concrete shear wall			note total length of wall at ground (m):	14.5
Ductility assumed, m:				wall thickness (m):	0.25
Period across:	0.28	0.28	from parameters in sheet	estimate or calculation?	estimated
Total deflection (ULS) (mm):	75			estimate or calculation?	estimated
maximum interstorey deflection (ULS) (mm):	15			estimate or calculation?	estimated

Appendix E - Detailed Engineering Evaluation spreadsheet - R86 - 6-storey RC shear wall hotel building (1 of 2)

Separations:			
north (mm):		leave blank if not relevant	
east (mm):			
south (mm):			
west (mm):			
Non-structural elements			
Stairs:	precast, half height	describe supports	Cast in at floor, Steel frame at mid ht
Wall cladding:	precast panels	thickness and fixing type	120mm; TCM 20's
Roof Cladding:	Shingles or shakes	describe	Hardies Shingles
Glazing:	aluminium frames		
Ceilings:	strapped or direct fixed		
Services(list):	Lift		
Available documentation			
Architectural	none	original designer name/date	
Structural	full	original designer name/date	
Mechanical	none	original designer name/date	
Electrical	none	original designer name/date	
Geotech report	full	original designer name/date	
Damage			
Site: (refer DEE Table 4-2) Site performance:	Satisfactory	Describe damage:	None
Settlement:	25-100m	notes (if applicable):	max variation 38mm, estimate > 50% construc
Differential settlement:	1:250-1:150	notes (if applicable):	locally 1:200
Liquefaction:	none apparent	notes (if applicable):	
Lateral Spread:	none apparent	notes (if applicable):	
Differential lateral spread:	none apparent	notes (if applicable):	
Ground cracks:	none apparent	notes (if applicable):	
Damage to area:	none apparent	notes (if applicable):	
Building: Current Placard Status:	green		
Along Damage ratio:	7%	Describe how damage ratio arrived at:	estimate of effect of cracking
Describe (summary):	cracking to shear walls =reduced stiffness		
Across Damage ratio:	0%		
Describe (summary):			
Diaphragms Damage?:	no	Describe:	
CSWs: Damage?:	yes	Describe:	Cracking to stair soffitts
Pounding: Damage?:	no	Describe:	
Non-structural: Damage?:	yes	Describe:	Cladding panel cracking
Recommendations			
Level of repair/strengthening required:	minor structural	Describe:	cracking to shear walls in long direction
Building Consent required:	no	Describe:	
Interim occupancy recommendations:	full occupancy	Describe:	
Along Assessed %NBS before:	86%	86% %NBS from IEP below	If IEP not used, please detail assessment methodology:
Assessed %NBS after:	80%		
Across Assessed %NBS before:	86%	86% %NBS from IEP below	
Assessed %NBS after:	86%		

Appendix E - Detailed Engineering Evaluation spreadsheet - R86 - 6-storey RC shear wall hotel building (2 of 2)

Location

Building Name:	Building ID R163			Reviewer:	
	Unit	No:	Street	CPEng No:	
Building Address:				Company:	
Legal Description:				Company project number:	
				Company phone number:	
	Degrees	Min	Sec		
GPS south:				Date of submission:	
GPS east:				Inspection Date:	1 Dec 2011 and 6 Dec 2011 and July 2013
				Revision:	4
Building Unique Identifier (CCC):				Is there a full report with this summary?	yes

Site

Site slope:	flat	Max retaining height (m):	
Soil type:		Soil Profile (if available):	
Site Class (to NZS1170.5):	D		
Proximity to waterway (m, if <100m):		If Ground improvement on site, describe:	
Proximity to clifftop (m, if < 100m):			
Proximity to cliff base (m,if <100m):		Approx site elevation (m):	6.20

Building

No. of storeys above ground:	8	single storey = 1	Ground floor elevation (Absolute) (m):	
Ground floor split?	no		Ground floor elevation above ground (m):	
Storeys below ground	1			
Foundation type:	steel screw piles		if Foundation type is other, describe:	reinforced concrete retaining wall with sheet pil
Building height (m):	27.00		height from ground to level of uppermost seismic mass (for IEP only) (m):	
Floor footprint area (approx):				
Age of Building (years):	9		Date of design:	1992-2004
Strengthening present?	no		If so, when (year)?	
			And what load level (%g)?	
Use (ground floor):	commercial		Brief strengthening description:	
Use (upper floors):	multi-unit residential			
Use notes (if required):				
Importance level (to NZS1170.5):	IL2			

Gravity Structure

Gravity System:	load bearing walls		
Roof:	steel framed	rafter type, purlin type and cladding	
Floors:	precast concrete with topping	unit type and depth (mm), topping	Dycore , 200mm, 90mm topping
Beams:	cast-insitu concrete	overall depth x width (mm x mm)	700X600
Columns:			with some larger beams as well
Walls:	load bearing concrete	#N/A	

Lateral load resisting structure

East-west	Lateral system along:	concrete shear wall		note total length of wall at ground (m):	
	Ductility assumed, m:	1.25		wall thickness (m):	0.25
	Period along:	0.40	#### enter height above at H30	estimate or calculation?	calculated
	Total deflection (ULS) (mm):			estimate or calculation?	
	maximum interstorey deflection (ULS) (mm):			estimate or calculation?	
North-south	Lateral system across:	concrete shear wall		note total length of wall at ground (m):	
	Ductility assumed, m:	1.25		wall thickness (m):	0.25
	Period across:	0.30	#### enter height above at H30	estimate or calculation?	calculated
	Total deflection (ULS) (mm):			estimate or calculation?	
	maximum interstorey deflection (ULS) (mm):			estimate or calculation?	

Appendix E - Detailed Engineering Evaluation spreadsheet - R163 - 8-storey RC shear wall/frame residential building (1 of 2)

Separations:			
north (mm):	300	leave blank if not relevant	
east (mm):			
south (mm):			
west (mm):			

Non-structural elements			
Stairs:	precast, half height	describe supports	4 side Spiral, cast in landings
Wall cladding:	precast panels	thickness and fixing type	
Roof Cladding:	Metal	describe	
Glazing:	aluminium frames		
Ceilings:	plaster, fixed		
Services(list):			

Available documentation

Architectural	none	original designer name/date	
Structural	full	original designer name/date	
Mechanical	none	original designer name/date	
Electrical	none	original designer name/date	
Geotech report	none	original designer name/date	

Damage

Site:
(refer DEE Table 4-2)

Site performance:		Describe damage:	
Settlement:	none observed	notes (if applicable):	
Differential settlement:	none observed	notes (if applicable):	
Liquefaction:	none apparent	notes (if applicable):	
Lateral Spread:	none apparent	notes (if applicable):	
Differential lateral spread:	none apparent	notes (if applicable):	
Ground cracks:	none apparent	notes (if applicable):	
Damage to area:	none apparent	notes (if applicable):	

Building:

	Current Placard Status:	yellow		
Along	Damage ratio:	55%	Describe how damage ratio arrived at:	used qualitative value for before, and quantitati
	Describe (summary):	conservative estimate based on upper level steel framing only, damage ratio elsewhere assumed less substantial		
Across	Damage ratio:	55%		
	Describe (summary):	conservative estimate based on upper level steel framing only, damage ratio elsewhere assumed less substantial		
Diaphragms	Damage?:	no	Describe:	minor cracks and spalling
CSWs:	Damage?:	no	Describe:	
Pounding:	Damage?:	no	Describe:	
Non-structural:	Damage?:	yes	Describe:	plasterboard linings, cladding

Recommendations

	Level of repair/strengthening required:	minor structural	Describe:	Lift weld plates, upper level steel braces
	Building Consent required:	yes	Describe:	
	Interim occupancy recommendations:	full occupancy	Describe:	refer to quantitative report
Along	Assessed %NBS before:	75%	75% %NBS from IEP below	
	Assessed %NBS after:	34%		
Across	Assessed %NBS before:	75%	75% %NBS from IEP below	
	Assessed %NBS after:	34%		

Appendix E - Detailed Engineering Evaluation spreadsheet - R163 - 8-storey RC shear wall/frame residential building (2 of 2)

Location

Building Name:	Building ID R202	Reviewer:	
	Unit / No: / Street	CPEng No:	
Building Address:		Company:	
Legal Description:		Company project number:	
		Company phone number:	
	Degrees / Min / Sec		
GPS south:		Date of submission:	
GPS east:		Inspection Date:	Feb to July 2011
		Revision:	
Building Unique Identifier (CCC):		Is there a full report with this summary?	yes

Site

Site slope:	flat	Max retaining height (m):	
Soil type:	silty sand	Soil Profile (if available):	
Site Class (to NZS1170.5):	D		
Proximity to waterway (m, if <100m):	80	If Ground improvement on site, describe:	
Proximity to clifftop (m, if < 100m):			
Proximity to cliff base (m,if <100m):		Approx site elevation (m):	40.00

Building

No. of storeys above ground:	6	single storey = 1 / Ground floor elevation (Absolute) (m):	5.00
Ground floor split?	no	Ground floor elevation above ground (m):	0.00
Storeys below ground	1		
Foundation type:	raft slab	if Foundation type is other, describe:	basement formsa waffle slab
Building height (m):	45.00	height from ground to level of uppermost seismic mass (for IEP only) (m):	45m
Floor footprint area (approx):	1620		
Age of Building (years):	40	Date of design:	1965-1976
Strengthening present?	no	If so, when (year)?	
		And what load level (%g)?	
Use (ground floor):	public	Brief strengthening description:	
Use (upper floors):	commercial		
Use notes (if required):			
Importance level (to NZS1170.5):	IL2		

Gravity Structure

Gravity System:	frame system		
Roof:	steel framed	rafter type, purlin type and cladding	steel frames and timber rafters, lightweight roof
Floors:	concrete flat slab	slab thickness (mm)	150
Beams:	cast-insitu concrete	overall depth x width (mm x mm)	868x762
Columns:	cast-insitu concrete	typical dimensions (mm x mm)	968x968
Walls:	non-load bearing	0	

Lateral load resisting structure

East-west	Lateral system along:	ductile concrete moment frame	note typical bay length (m)	9.8
	Ductility assumed, m:	3.00		
	Period along:	2.40	#### enter height above at H30 / estimate or calculation?	calculated
	Total deflection (ULS) (mm):	300	estimate or calculation?	calculated
	maximum interstorey deflection (ULS) (mm):	50	estimate or calculation?	calculated
North-south	Lateral system across:	ductile concrete moment frame	note typical bay length (m)	9.8
	Ductility assumed, m:	3.00		
	Period across:	2.20	0.00 / estimate or calculation?	calculated
	Total deflection (ULS) (mm):	350	estimate or calculation?	calculated
	maximum interstorey deflection (ULS) (mm):	45	estimate or calculation?	calculated

Appendix E - Detailed Engineering Evaluation spreadsheet - R202 - 6-storey RC frame office building (1 of 2)

Separations:

north (mm):		leave blank if not relevant
east (mm):		
south (mm):		
west (mm):		

Non-structural elements

Stairs:	precast, half height	describe supports	steel beams and corbel details
Wall cladding:	precast panels	thickness and fixing type	concrete 150thk, glazing to north
Roof Cladding:	Metal	describe	
Glazing:	aluminium frames		
Ceilings:	none		
Services(list):	fire sprinkler, power, lighting		

Available documentation

Architectural	full	original designer name/date	
Structural	full	original designer name/date	
Mechanical	full	original designer name/date	
Electrical	full	original designer name/date	
Geotech report	full	original designer name/date	

Damage

Site:
(refer DEE Table 4-2)

Site performance:	Geotechnical investigation undertaken	Describe damage:	
Settlement:	none observed	notes (if applicable):	
Differential settlement:	none observed	notes (if applicable):	
Liquefaction:	0-2 m²/100m³	notes (if applicable):	
Lateral Spread:	none apparent	notes (if applicable):	
Differential lateral spread:	none apparent	notes (if applicable):	
Ground cracks:	none apparent	notes (if applicable):	
Damage to area:	slight	notes (if applicable):	

Building:

	Current Placard Status:	green		
Along	Damage ratio:	5%	Describe how damage ratio arrived at:	estimated
	Describe (summary):	refer to report		
Across	Damage ratio:			
	Describe (summary):	refer to report		
Diaphragms	Damage?:	yes	Describe:	localised hairline cracking
CSWs:	Damage?:	no	Describe:	
Pounding:	Damage?:	no	Describe:	
Non-structural:	Damage?:	yes	Describe:	light weight walls gib damage

Recommendations

	Level of repair/strengthening required:	minor structural	Describe:	see attached report
	Building Consent required:	yes	Describe:	see attached report
	Interim occupancy recommendations:	full occupancy	Describe:	
Along	Assessed %NBS before:		#### %NBS from IEP below	
	Assessed %NBS after:			
Across	Assessed %NBS before:		#### %NBS from IEP below	
	Assessed %NBS after:			

Appendix E - Detailed Engineering Evaluation spreadsheet - R202 - 6-storey RC frame office building (2 of 2)

Location

Building Name:	Building ID R901	Reviewer:	
	Unit / No: / Street	CPEng No:	
Building Address:		Company:	
Legal Description:		Company project number:	
		Company phone number:	
	Degrees / Min / Sec		
GPS south:		Date of submission:	
GPS east:		Inspection Date:	various - refer full report
		Revision:	
Building Unique Identifier (CCC):		Is there a full report with this summary?	yes

Site

Site slope:	flat	Max retaining height (m):	0
Soil type:	gravel	Soil Profile (if available):	
Site Class (to NZS1170.5):	D		
Proximity to waterway (m, if <100m):		If Ground improvement on site, describe:	
Proximity to clifftop (m, if < 100m):			
Proximity to cliff base (m,if <100m):		Approx site elevation (m):	24.00

Building

No. of storeys above ground:	6	single storey = 1	Ground floor elevation (Absolute) (m):	24.00
Ground floor split?	no		Ground floor elevation above ground (m):	0.00
Storeys below ground	0			
Foundation type:	driven precast piles		if Foundation type is other, describe:	
Building height (m):	21.25		height from ground to level of uppermost seismic mass (for IEP only) (m):	21.25
Floor footprint area (approx):	570			
Age of Building (years):	41		Date of design:	1965-1976
Strengthening present?	no		If so, when (year)?	
			And what load level (%g)?	
Use (ground floor):	educational		Brief strengthening description:	
Use (upper floors):	educational			
Use notes (if required):				
Importance level (to NZS1170.5):	IL2			

Gravity Structure

Gravity System:	frame system		
Roof:	steel framed	rafter type, purlin type and cladding	UB portal frame, steel purlins, metal roofing
Floors:	precast concrete with topping	unit type and depth (mm), topping	165
Beams:	cast-insitu concrete	overall depth x width (mm x mm)	914 x 508
Columns:	cast-insitu concrete	typical dimensions (mm x mm)	762 x 610
Walls:	non-load bearing	0	

Lateral load resisting structure

Lateral system along:	ductile concrete moment frame	**Note: Define along and across in detailed report!**		
Ductility assumed, m:	4.00		note typical bay length (m)	
Period along:	0.90	0.89 from parameters in sheet	estimate or calculation?	calculated
Total deflection (ULS) (mm):	145		estimate or calculation?	calculated
maximum interstorey deflection (ULS) (mm):	49		estimate or calculation?	calculated
Lateral system across:	ductile concrete moment frame			
Ductility assumed, m:	4.00		note typical bay length (m)	
Period across:	1.40	0.00	estimate or calculation?	calculated
Total deflection (ULS) (mm):	350		estimate or calculation?	calculated
maximum interstorey deflection (ULS) (mm):	109		estimate or calculation?	calculated

Appendix E - Detailed Engineering Evaluation spreadsheet - R901 - 6-storey RC frame university building (1 of 2)

Separations:

north (mm):		leave blank if not relevant	
east (mm):			
south (mm):			
west (mm):			

Non-structural elements

Stairs:	precast, half height	describe supports	fixed at floor level, sliding support at landings
Wall cladding:	precast panels	thickness and fixing type	100 mm with head channel top restraint
Roof Cladding:	Metal	describe	Galvanised standing seam
Glazing:	aluminium frames		
Ceilings:	heavy tiles		
Services(list):			

Available documentation

Architectural	full	original designer name/date	
Structural	full	original designer name/date	
Mechanical	full	original designer name/date	
Electrical	full	original designer name/date	
Geotech report	none	original designer name/date	

Damage

Site:
(refer DEE Table 4-2)

Site performance:	Fine	Describe damage:	
Settlement:	none observed	notes (if applicable):	
Differential settlement:	none observed	notes (if applicable):	
Liquefaction:	none apparent	notes (if applicable):	
Lateral Spread:	none apparent	notes (if applicable):	
Differential lateral spread:	none apparent	notes (if applicable):	
Ground cracks:	none apparent	notes (if applicable):	
Damage to area:	none apparent	notes (if applicable):	

Building:

	Current Placard Status:	green		
Along	Damage ratio:	0%	Describe how damage ratio arrived at:	
	Describe (summary):			
Across	Damage ratio:	0%		
	Describe (summary):			
Diaphragms	Damage?:	no	Describe:	
CSWs:	Damage?:	no	Describe:	
Pounding:	Damage?:	no	Describe:	
Non-structural:	Damage?:	yes	Describe:	

Recommendations

	Level of repair/strengthening required:	minor structural		Describe:	epoxy injection, stair landing modification, link l
	Building Consent required:	yes		Describe:	
	Interim occupancy recommendations:	full occupancy		Describe:	
Along	Assessed %NBS before e'quakes:	67%	#### %NBS from IEP below	If IEP not used, please detail assessment methodology:	Linear Elastic Analysis
	Assessed %NBS after e'quakes:	67%			
Across	Assessed %NBS before e'quakes:	67%	#### %NBS from IEP below		
	Assessed %NBS after e'quakes:	67%			

Appendix E - Detailed Engineering Evaluation spreadsheet - R901 - 6-storey RC frame university building (2 of 2)

Location

Building Name:	Building ID R902			Reviewer:	
	Unit	No:	Street	CPEng No:	
Building Address:				Company:	
Legal Description:				Company project number:	
				Company phone number:	
	Degrees	Min	Sec		
GPS south:				Date of submission:	
GPS east:				Inspection Date:	Oct 2011 - Jun 2012
				Revision:	1
Building Unique Identifier (CCC):				Is there a full report with this summary?	no

Site

Site slope:	flat	Max retaining height (m):	
Soil type:	mixed	Soil Profile (if available):	
Site Class (to NZS1170.5):	D		
Proximity to waterway (m, if <100m):		If Ground improvement on site, describe:	
Proximity to clifftop (m, if < 100m):			
Proximity to cliff base (m,if <100m):		Approx site elevation (m):	

Building

No. of storeys above ground:	3	single storey = 1	Ground floor elevation (Absolute) (m):	
Ground floor split?	no		Ground floor elevation above ground (m):	
Storeys below ground	1			
Foundation type:	raft slab		if Foundation type is other, describe:	tension ties for buoyancy in SE corner
Building height (m):	15.00		height from ground to level of uppermost seismic mass (for IEP only) (m):	15
Floor footprint area (approx):	7200			
Age of Building (years):	11		Date of design:	1992-2004
Strengthening present?	no		If so, when (year)?	
			And what load level (%g)?	
Use (ground floor):	other (specify)		Brief strengthening description:	
Use (upper floors):	institutional			
Use notes (if required):				
Importance level (to NZS1170.5):	IL3			

Gravity Structure

Gravity System:	load bearing walls		
Roof:	concrete	slab thickness (mm)	varies
Floors:	precast concrete with topping	unit type and depth (mm), topping	600TT, 100; 300 hollowcore, 75
Beams:	cast-insitu concrete	overall depth x width (mm x mm)	800x1000
Columns:	cast-insitu concrete	typical dimensions (mm x mm)	300x600
Walls:	load bearing concrete	#N/A	250

Lateral load resisting structure

Lateral system along:	concrete shear wall		**Note: Define along and across**	note total length of wall at ground (m):	220
Ductility assumed, m:	1.25		**in detailed report!**	wall thickness (m):	250
Period along:	0.27	0.00	from parameters in sheet	estimate or calculation?	calculated
Total deflection (ULS) (mm):	225			estimate or calculation?	estimated
maximum interstorey deflection (ULS) (mm):				estimate or calculation?	
Lateral system across:	concrete shear wall			note total length of wall at ground (m):	162
Ductility assumed, m:	1.25			wall thickness (m):	300
Period across:	0.27	0.00	from parameters in sheet	estimate or calculation?	calculated
Total deflection (ULS) (mm):	225			estimate or calculation?	estimated
maximum interstorey deflection (ULS) (mm):				estimate or calculation?	

Appendix E - Detailed Engineering Evaluation spreadsheet - R902 - 3-storey RC shear wall/frame public assembly building (1 of 2)

Separations:			
north (mm):		leave blank if not relevant	
east (mm):			
south (mm):			
west (mm):			

Non-structural elements			
Stairs:	precast, full flight	describe supports	top of flight cast in to floor slab
Wall cladding:	precast panels	thickness and fixing type	125mm steel brackets with cast-in inserts
Roof Cladding:	Metal	describe	cast-in vemo inserts used typically to
Glazing:	aluminium frames		tie steel brackets to RC wall
Ceilings:	light tiles		
Services(list):	Services generally ok		

Available documentation			
Architectural	full	original designer name/date	
Structural	full	original designer name/date	
Mechanical	full	original designer name/date	
Electrical	full	original designer name/date	
Geotech report	partial	original designer name/date	

Damage

Site: (refer DEE Table 4-2)			
Site performance:	Reasonble	Describe damage:	
Settlement:	25-100m	notes (if applicable):	some accoss building
Differential settlement:	0-1:350	notes (if applicable):	settlement obvious
Liquefaction:	none apparent	notes (if applicable):	none
Lateral Spread:	none apparent	notes (if applicable):	
Differential lateral spread:	none apparent	notes (if applicable):	
Ground cracks:	0-20mm/20m	notes (if applicable):	only at edge of basement on grade
Damage to area:	slight	notes (if applicable):	

Building:				
	Current Placard Status:	green		
Along	Damage ratio:		Describe how damage ratio arrived at:	
	Describe (summary):	minimal to structure, some cladding panels		
Across	Damage ratio:			
	Describe (summary):	minimal to structure, some cladding panels		
Diaphragms	Damage?:	yes	Describe:	minor cracking along the 1st floor slab in rear
CSWs:	Damage?:	no	Describe:	
Pounding:	Damage?:	no	Describe:	
Non-structural:	Damage?:	yes	Describe:	some cladding panels, glazing façade and par

Recommendations				
	Level of repair/strengthening required:	minor non-structural	Describe:	minor cracking in floor slab, re-level building
	Building Consent required:	yes	Describe:	repairs and building re-leveling
	Interim occupancy recommendations:	partial occupancy	Describe:	staff only, restrict areas around damaged clado
Along	Assessed %NBS before:		71% %NBS from IEP below	If IEP not used, please detail assessment methodology:
	Assessed %NBS after:			
Across	Assessed %NBS before:		71% %NBS from IEP below	
	Assessed %NBS after:			

Appendix E - Detailed Engineering Evaluation spreadsheet - R902 - 3-storey RC shear wall/frame public assembly building (2 of 2)