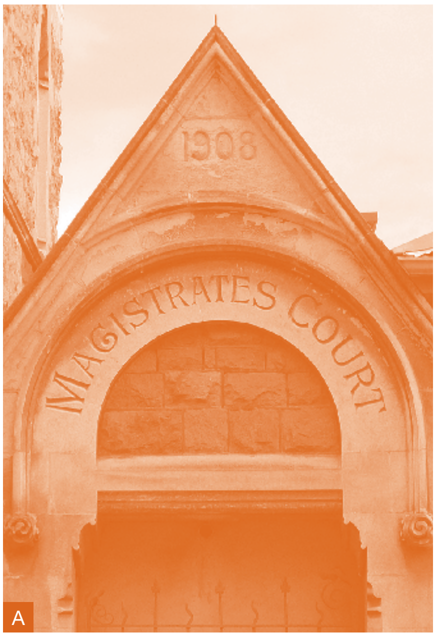
Canterbury Earthquakes
Royal Commission
Te Komihana Rūwhenua o Waitaha

H.2

FINAL REPORT

VOLUME 4
EARTHQUAKE-PRONE BUILDINGS



A. The former Magistrates Court building, built between 1880 and 1909, survived the earthquakes with only minor damages due to strengthening work carried out in 1997 (source: Paul Roper-Gee)

B. The top floor of the Press Building, completed in 1909, collapsed in the February 2011 earthquake leading to the death of one person and the serious injury of another. The building was demolished (source: PhotoSouth)

C. The Iconic Bar building on the corner of Manchester and Gloucester Streets was severely damaged in the February 2011 earthquake. The collapsing façades of the unreinforced masonry building killed one employee (source: Dmytro Dizhur)

D. Westende Jewellers on the corner of Manchester and Worcester Streets had been on this site for 30 years until it was badly damaged in the September 2010 earthquake (source: Dmytro Dizhur)

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Letter of Transmittal

To His Excellency, Lieutenant General The Right Honourable Sir Jerry Mateparae GNZM, QSO Governor-General of New Zealand

Your Excellency

Pursuant to the Orders in Council dated 11 April 2011 and 7 February 2012 appointing us to be a Royal Commission of Inquiry into Building Failure caused by the Canterbury Earthquakes and to provide a Final Report not later than 12 November 2012, with a first part delivered by 29 June 2012, we now humbly submit the second part of our Final Report for Your Excellency's consideration.

We have the honour to be

Your Excellency's most obedient servants

Hon Justice Mark Cooper (Chairperson)

Sir Ronald Carter

Adjunct Associate Professor Richard Fenwick

Dated at Wellington this 8th day of October 2012.

Introduction

This Volume of the Report is about "earthquake-prone" buildings. Section 1 gathers together and briefly gives the context of the recommendations made in the subsequent sections.

In section 2 we discuss the evolution of New Zealand Standards for the design of buildings to resist earthquake shaking. We also discuss the history of the statutory provisions for dangerous and earthquake-prone buildings, and address the requirements of the existing law, contained in the Building Act 2004. In section 3 we briefly outline the range of building types in the Christchurch Central Business District (CBD). Although there was a greater proportion of unreinforced masonry buildings there than in some other city centres, the range of building types in central Christchurch at the time of the February earthquake was not dissimilar to the range that exists in the central business districts of other cities in New Zealand. Section 4 records the results of our investigation into the performance of particular earthquake-prone buildings that failed in the February earthquake causing death. Section 5 discusses the subject of unreinforced masonry buildings, and section 6 the processes involved in assessing and strengthening existing buildings. We recommend particular strengthening works for unreinforced masonry buildings. In section 7 we return to the existing law, refer to some problems arising from the drafting of the Building Act, review options for reform and make recommendations for change.

This Volume must be read in the context of earlier Volumes of our Report. There is a detailed discussion in section 2 of Volume 1 about the nature of the earthquake risk that must be taken into account by building designers in New Zealand. That part of the Report also discusses the way in which knowledge about earthquake risk is translated into the relevant Standards that are used to comply with the Building Code. Section 3 of Volume 1 gives a brief introduction to the key concepts that underlie the ways in which buildings are designed to meet the known risk of earthquakes.

Section 2 of Volume 1 also describes the nature and severity of the Canterbury earthquakes of 2010–2011. As stated in section 2.7.1.1 of that section, the peak ground accelerations in central Christchurch during the September earthquake were close to those that would have been used to design new buildings under the current Earthquake Actions Standard, NZS 1170.5:2004[1]. With some qualifications (which are stated in that section of the Report), the shaking experienced in the Christchurch CBD was generally comparable to that anticipated for a 500-year return period earthquake on the Class D soils that are found there. The shaking experienced in the CBD during the February earthquake was significantly more intense. As noted in section 2.7.1.3 of Volume 1, the recorded response spectra (a concept addressed in Volume 1, section 3) generally exceeded those for the design 2,500-year recurrence period earthquake, except for shorter periods of about 0.3 seconds or less.

The way in which buildings performed in these two events casts light on the adequacy of the current design Standards and practices. That has been the subject of detailed consideration in Volume 2 of the Report, where we have discussed the "representative sample" of buildings referred to in the Terms of Reference (apart from the CTV building and the substantial number of unreinforced masonry buildings that we address in this Volume) and made recommendations for change to existing practices.

However, the performance of buildings in the earthquakes is also important because of what can be learned from it about New Zealand's existing policy approach to buildings that are considered to be earthquake-prone. That is the subject of this Volume.

Terms of Reference

For ease of reference, the Royal Commission's Terms of Reference are again set out in full in Appendix 2 of this Volume.

Under the Terms of Reference for the first part of the inquiry, the Royal Commission is required to consider the performance in the earthquakes of a "reasonably representative" sample of buildings. The Terms of Reference leave to the Royal Commission the decision about which buildings should be investigated, apart from the four buildings that are specifically referred to (the CTV, PGC, Forsyth Barr and Hotel Grand Chancellor buildings).

We provided our report on the PGC, Forsyth Barr and Hotel Grand Chancellor buildings in Volume 2. We decided at an early stage that we should consider, as part of the representative sample, all of the buildings whose failure caused loss of life in the February earthquake, even where those buildings were located outside the central area defined by the four avenues and Harper Avenue. Section 4 of this Volume of the Report sets out the results of that part of our inquiry, leaving only the CTV building to be dealt with in a subsequent volume.

The Terms of Reference are also specific that we must review the legal and best practice requirements in respect of earthquake-prone buildings. Under the heading "Inquiry into legal and best-practice requirements", they direct us to inquire into and report on:

> (d) the adequacy of the current legal and best-practice requirements for the design, construction, and maintenance of buildings in central business districts in New Zealand to address the known risk of earthquakes and, in particular—
>
> (ii) the legal requirements for buildings that are "earthquake-prone" under section 122 of the Building Act 2004 and associated regulations, including—
>
> (A) the buildings that are, and those that should be, treated by the law as "earthquake-prone"; and
>
> (B) the extent to which existing buildings are, and should be, required by law to meet requirements for the design, construction, and maintenance of new buildings; and
>
> (C) the enforcement of legal requirements; and
>
> (iii) the requirements for existing buildings that are not, as a matter of law, "earthquake-prone", and do not meet current legal and best-practice requirements for the design, construction, and maintenance of new buildings, including whether, to what extent, and over what period they should be required to meet those requirements …

This Volume contains our report and recommendations on those matters.

References

1. NZS 1170.5:2004. *Structural Design Actions Part 5: Earthquake Actions – New Zealand*, Standards New Zealand.

Section 1: Summary and recommendations – Volume 4

In this Volume we discuss the question of how to define and treat existing buildings in New Zealand that are likely to perform poorly in earthquakes. We have outlined the development of building standards, legislation and policies in New Zealand since the major development of urban centres commenced. We have reviewed the particular characteristics of unreinforced masonry (URM) buildings, which form a significant proportion of New Zealand's earlier buildings and lack the capacity to resist seismic actions when compared to more recent structures using steel and reinforced concrete.

Failure of such buildings resulted in the deaths of 39 people in the 22 February 2011 earthquake. We have examined these building failures, along with two other building failures of a different construction and one domestic fireplace collapse, and report our findings on these. We also have considered how existing buildings may be assessed for their seismic resistance, and looked particularly at how unreinforced masonry buildings may be retrofitted to increase their seismic resistance.

We recommend a number of changes to the legislation, policies and practices underpinning how New Zealand addresses the issue of earthquake-prone buildings. The numbering of these recommendations continues from the recommendations made in Volumes 1 to 3 of our Report.

Free-standing masonry walls

The collapse of a free-standing masonry wall of unknown structural strength in the February 2011 earthquake resulted in a death (see section 4.7 of this Volume of our Report). We consider such walls should either be adequately restrained or demolished.

Recommendation

We recommend that:

71. Free-standing masonry walls of unknown structural strength should be adequately restrained or demolished.

Assessing existing buildings

The Royal Commission considers that improving New Zealanders' understanding of the nature of a building they may be purchasing, using or passing by, is important. We consider that developing a grading system for existing buildings that is more easily understood by territorial authorities, building owners, tenants and the general public would be highly beneficial. Such a grading system could be based on or similar to that already set out in the New Zealand Society for Earthquake Engineering Initial Evaluation Process (IEP) Recommendations entitled *Assessment and Improvement of the Structural Performance of Buildings in Earthquakes*, dated June 2006 and referred to in this Volume of our Report as the NZSEE Recommendations[1], using letter grades A to E. The advantage of this form of grading system is that the general public are familiar with such grades and could more easily understand that a D or E grade would indicate a building that poses a clear earthquake risk.

Conversely, buildings receiving higher grades may be able to attract higher rental returns and/or lower insurance premiums.

Assessing existing buildings is a complex task. The Royal Commission considers the NZSEE Recommendations are generally sound. However, the Initial Evaluation Process (IEP) and Detailed Assessment processes should be reviewed to take into account the risk that plans may not accurately record actual construction decisions and materials, especially for older buildings. The resulting new practice standards or methods for evaluating existing buildings should also be given regulatory standing and monitored, to ensure consistency in application and use, given the potential resulting classification as an "earthquake-prone building" under the Building Act 2004. There is a discussion in section 6.2.5 of this Volume that should be taken into account in assessing the potential seismic performance of buildings designed under Standards earlier than those that currently apply. Those assessing such buildings should be familiar with these matters.

Recommendations

We recommend that:

72. The Ministry of Business, Innovation and Employment should work with territorial authorities, building owners, the New Zealand Society of Earthquake Engineering and other interested parties to develop a grading system for existing buildings that is able to be understood by the general public and adequately describes the seismic performance of a building.

73. The Ministry of Business, Innovation and Employment should review the New Zealand Society of Earthquake Engineering Recommendations entitled *Assessment and Improvement of the Structural Performance of Buildings in Earthquakes* and, in conjunction with engineering practitioners, establish appropriate practice standards or methods for evaluating existing buildings.

    These practice standards or methods should have regulatory standing, and be monitored by the Ministry of Business, Innovation and Employment for consistency of application.

74. Structural engineers assessing non-URM buildings should be familiar with the practical assessment considerations discussed in section 6.2.5 of this Volume. Those considerations should also be referred to in the practice standards or methods developed in accordance with Recommendation 73.

The Royal Commission has reservations about the use of 15% damping, and the assumption of a structural ductility factor of 2 and an S_p factor of 0.7 for use with unreinforced masonry elements.

We consider that the use of the undefined term "new building standard" or "NBS" conveys an incorrect expectation of how a building will perform in an earthquake and that the term "ultimate limit state" or "ULS" is more accurate. We consider that the Ministry of Business, Innovation and Employment should clearly describe to territorial authorities and the public the difference between the expected behaviour of an existing building prior to collapse and the behaviour of a building that complies with the current Building Code.

Recommendation

We recommend that:

75. Further research should be carried out into the suitability of assuming 15 per cent damping, and a structural ductility factor of 2 and an S_p factor of 0.7, in assessing unreinforced masonry elements.

76. The Ministry of Business, Innovation and Employment should clearly describe to territorial authorities and the public the difference between the expected behaviour of an existing building prior to collapse, and the behaviour of a building that complies with the current Building Code.

Improving existing buildings

We consider that there is a demonstrated need in the interests of public safety for the hazardous elements of unreinforced masonry (URM) buildings to be strengthened throughout New Zealand. We consider that falling hazards such as chimneys, parapets and ornaments should be secured or removed. In addition, we consider that the external walls of all URM buildings should be supported by retrofit, even in areas of low seismicity. We also consider that the design actions for the elements and connections to be strengthened should be based on the provisions in NZS 1170.5:2004: *Section 8 – Requirements for Parts and Components*[2].

Recommendations

We recommend that:

77. For unreinforced masonry buildings, falling hazards such as chimneys, parapets and ornaments should be made secure or removed.
78. The design actions for the elements and connections to be strengthened should be based on the provisions in NZS 1170.5:2004: Section 8 – *Requirements for Parts and Components*.
79. The external walls of all unreinforced masonry buildings should be supported by retrofit, including in areas of low seismicity.
80. The detailed assessment of unreinforced masonry buildings that are earthquake-prone should take into account the potential need to:

    a ensure adequate connection between all structural elements of the building so that it responds as a cohesive unit;

    b increase the in-plane shear strength of masonry walls; or

    c introduce high-level interventions (such as the insertion of steel and/or reinforced concrete frames) to supplement or take over the seismic resisting role from the original unreinforced masonry structure.

    Such buildings should be strengthened in accordance with the findings of that detailed assessment.
81. Recommendations 75 to 80 should be undertaken within the same timeframes as recommended in Recommendations 82 to 86 for unreinforced masonry buildings.

Earthquake-prone buildings policy and legislation

It is important that territorial authorities are able to address appropriately buildings that pose a danger in an event such as an earthquake. The Royal Commission recommends a number of changes that should be made to the legislation governing how territorial authorities address earthquake-prone buildings in their districts. These include recommendations to enable territorial authorities to ensure that timely improvements are made to URM buildings. The Royal Commission considers that, to protect life safety, there is no justification to set the shaking level to be resisted for earthquake-prone structures at greater than one third of the requirements for a new building. However, because some elements of URM buildings pose a particular source of danger, we consider that a higher level of protection should be given to them: in particular, chimneys, parapets, ornaments and external walls.

We are also of the opinion that the maximum time permitted to complete the evaluation and strengthening of existing buildings should be set nationally.

However, territorial authorities should also be empowered to adopt earthquake-prone building policies that are stricter than the minimum statutory requirements (as to the level of strengthening or the time allowed for implementation) where they consider that is appropriate, taking into account particular economic considerations, building characteristics, and/or seismic circumstances that are relevant to their districts. Adoption of a policy that exceeded the minimum statutory requirements would require the territorial authority to follow the special consultative procedures of the Local Government Act 2002.

There are some buildings that are very seldom used and are so located that their failure in an earthquake is most unlikely to cause loss of life, or serious injury to passers-by. An example is rural churches. We consider that there is a good case for such buildings to be exempt from the general legislative requirements for earthquake-prone buildings. If that policy position is adopted, we consider it should be set out in legislation so that one rule applies nationally.

Recommendations

We recommend that:

82. The Building Act 2004 should be amended to require and authorise territorial authorities to ensure completed assessments of all unreinforced masonry buildings within their districts within two years from enactment of the Amendment, and of all other potentially earthquake-prone buildings within five years from enactment.
83. The legislation should be further amended to require unreinforced masonry buildings to be strengthened to 34% ULS within seven years from enactment of the Amendment and, in the case of all other buildings that are earthquake-prone, within 15 years of enactment.
84. The legislation should be further amended to require that, in the case of unreinforced masonry buildings, the out-of-plane resistance of chimneys, parapets, ornaments and external walls to lateral forces shall be strengthened to be equal to or greater than 50% ULS within seven years of enactment.
85. The legislation should provide for the enforcement of the upgrading requirements by territorial authorities, with demolition (at owner's cost) being the consequence of failure to comply.
86. The legislation should allow territorial authorities to adopt and enforce a policy that requires a shortened timeframe for some or all buildings in the district to achieve the minimum standard required by the legislation, after following the special consultative procedures in the Local Government Act 2002.
87. The legislation should allow territorial authorities to adopt and enforce a policy that requires a higher standard than the minimum ULS required by the legislation for some or all buildings in the district, after following the special consultative procedures in the Local Government Act 2002.
88. The legislation should allow territorial authorities to adopt and enforce a policy that requires a higher standard of strengthening for buildings of high importance or high occupancy, where public funding is to be contributed to the strengthening of the building or where the hazard to public safety is such that a higher standard is justified, after following the special consultative procedures in the Local Government Act 2002.
89. Guidance should be provided by the Ministry of Business, Innovation and Employment to territorial authorities on the factors to be considered in setting discretionary policies under the amended legislation. These factors should include the nature of a community's building stock, economic impact, numbers of passers-by for some buildings, levels of occupancy, and potential impact on key infrastructure in a time of disaster (e.g. fallen masonry blocking key access roads).
90. The legislation should exempt buildings that are very seldom used and are so located that their failure in an earthquake is most unlikely to cause loss of life, or serious injury to passers-by.

Issues with defining a building as dangerous and/or earthquake-prone

The Royal Commission notes that there are questions about the proper interpretation of sections of the Building Act 2004, including the interrelationship of the earthquake-prone buildings provisions and other sections of the Act. There is some uncertainty about whether a part, or parts, of a building (for example, parapets) fall within the definition of "earthquake-prone" as set out in section 122 of the Building Act 2004. We also consider it important that territorial authorities are able to immediately repair or demolish a building that was not considered earthquake-prone before an earthquake, but poses a danger after being damaged in a recent earthquake.

Recommendations

We recommend that:

91. The Building Act 2004 should be amended to make it clear that sections 122 and 124 of the Act apply to parts of a building.
92. The Building Act 2004 should be amended to empower territorial authorities to take action where a building is not deemed dangerous under section 121 or earthquake-prone under section 122, but requires immediate repair or demolition due to damage caused by an event such as an earthquake.

Adjacent and adjoining buildings

The Canterbury earthquakes showed there can be a significant risk to buildings that are next to damaged or dangerous buildings. The Building Amendment Bill (No. 4), currently before Parliament, would go some way towards addressing this issue, if enacted in the form in which it was introduced. The proposed amendment alters sections 124 and 125 of the Building Act 2004 to give territorial authorities the ability to restrict entry to affected buildings for particular purposes or to particular persons. We do not think it is necessary to go further, in the context of our recommendation that there should be set statutory timeframes for the strengthening of earthquake-prone buildings generally.

We heard evidence about lack of communication of knowledge about the state of buildings between people making decisions about the building, building owners, tenants and neighbours. Sharing of knowledge and information can reduce the level of risk that dangerous structures create. As examples, tenants were not advised of risk; neighbours did not appreciate the possibility of an adjacent collapse; and the Earthquake Commission (EQC) assessors felt constrained by privacy obligations.

We have noted that the privacy provisions of the Earthquake Commission Act 1993 inhibit the sharing of information and we recommend an amendment to these provisions. We also consider that engineers, other professionals and building owners should all have a duty to share information with each other when they become aware of a building in a potentially dangerous condition.

Recommendations

We recommend that:

93. The proposed amendments to sections 124 and 125 of the Building Act 2004 in the Building Amendment Bill (No. 4) should be enacted.
94. Section 32(4) of the Earthquake Commission Act 1993 should be amended to allow for disclosure of information that may affect personal safety. A suggested wording is set out in section 4.25.4.3 of this Volume.
95. Legislation should provide for:
    - a a duty to disclose information that a building is in a dangerous or potentially dangerous condition to the relevant territorial authority and any affected neighbouring occupier;
    - b the above duty to be applied to statutory bodies, engineers and other professional persons who have become aware of the information;
    - c a similar duty on building owners in respect of their own tenants and neighbouring occupiers; and
    - d the protection of those carrying out these duties in good faith from civil or other liability or allegations of professional misconduct.

Buildings divided into separately owned parts

The Royal Commission has considered whether there should be a requirement on all owners of parts of a building that will behave in an earthquake as a single structure to strengthen their part of the building at the same time. If this matter is not addressed, owners of different parts of a building may not take collective action at the same time, which would be more efficient, provident and effective.

A similar issue arises when walls become end walls as a result of the removal of walls on a neighbouring property, which have previously provided support to the adjoining building.

The objective of earthquake strengthening to a nationally-set standard within definite timeframes recommended above is unlikely to be achieved if owners of individual titles in what is effectively one building cannot be compelled to strengthen at a similar time. Providing through legislation an appropriate process by which the relevant issues could be resolved between owners is likely to result in more efficient, effective and timely implementation of the strengthening objectives.

Recommendations

We recommend that:

96. Legislation should ensure that all portions of a structure are included in the requirement to strengthen buildings to achieve the minimum level required by the legislation by the due date. In drafting the legislation, consideration should be given to providing for a fair process in which all owners of a building divided into separate titles may be required to strengthen the building at the same time.

97. Territorial authorities should be authorised and required to ensure the acceptable strength of remaining walls, particularly end walls, when issuing building consents for the removal of adjoining walls.

Altering an existing building

Section 112(1) of the Building Act 2004 prevents building consent authorities from issuing building consents for alterations unless satisfied that, after the alteration, the building will comply as nearly as is reasonably practicable with the provisions of the Building Code that relate to means of escape from fire and access and facilities for persons with disabilities. The Royal Commission heard evidence that section 112(1)(a)(ii) can operate as an impediment to building owners strengthening their buildings.

While it is important that egress from a building at a time of fire or earthquake (section 112(a)(i)) remains subject to this rule, we consider it would be preferable if building consents could be issued for strengthening works without the need to comply with the disabled access rule. We say that having regard to the need to strike an acceptable balance between cost and strengthening work, and the desirability of the latter actually being carried out.

Recommendation

We recommend that:

98. Section 112(1) of the Building Act 2004 should be amended to enable building consent authorities to issue building consents for strengthening works without requiring compliance with section 112(1)(a)(ii). The existing provision would continue to apply to building consents for other purposes.

Inclusion of residential buildings

Section 122 of the Building Act 2004 excludes buildings that are used wholly or mainly for residential purposes from classification as earthquake-prone, unless they are of two or more storeys, or contain three or more household units. This means the vast majority of dwellings are not covered by the legislation.

We consider there are clearly some elements of residential buildings that pose hazards in earthquakes, for example, URM chimneys, and it is desirable that these should be made more resilient. We also consider that the significance of this issue is one that will vary across New Zealand, depending on the seismic risk of the region and the nature of the housing stock. We therefore consider that this should be addressed by territorial authorities in consultation with their communities.

Recommendation

We recommend that:

99. The Building Act 2004 should be amended to authorise territorial authorities to adopt and enforce policies to address hazardous elements in or on residential buildings (such as URM chimneys), within a specified completion timeframe consistent with that applied to non-URM earthquake-prone buildings in their district.

Impediments to the rebuild, repair, or demolition of dangerous buildings – the Resource Management Act 1991 and the Historic Places Act 1993

District plans made under the Resource Management Act 1991 contain provisions that require resource consent applications to be made where buildings are scheduled for protection. The interaction between these provisions and the Building Act 2004 can act as an impediment to the rebuild, repair or demolition of dangerous buildings. In some cases, the consent of the New Zealand Historic Places Trust may be required for demolition of some buildings.

The Royal Commission considers that the immediate securing of dangerous buildings should not be impeded by the consent process and that life safety should be a paramount consideration for all buildings, regardless of heritage status. We consider that it would be appropriate for legislation to make it plain that, where a building is in a state that makes demolition or the carrying out of other works desirable to protect persons from injury or death, no consent for those works is required, regardless of whether the building is protected by a district plan or registered under the Historic Places Act.

Recommendation

We recommend that:

100. Legislation should provide that, where a building is in a state that makes demolition or protective works necessary to protect persons from injury or death, no consent is required, regardless of whether the building is protected by a district plan, or registered or otherwise protected under the Historic Places Act 1993.

Knowledge, information and education

The Royal Commission considers there is considerable confusion and misunderstanding among building owners, tenants and territorial authorities about the risk buildings pose in earthquakes, what an assessment of building strength means, the likelihood of an earthquake, and the legal obligations under the Building Act 2004 for earthquake-prone buildings. This contributes to inaction and delay in addressing earthquake-prone buildings.

It is desirable in particular that building owners have a better understanding of their rights and obligations. We believe that raising awareness about these matters would be of significant assistance in supporting action to address earthquake-prone buildings. We also consider that territorial authorities should be required to maintain and publish a schedule of earthquake-prone buildings, as the resulting awareness would be an effective means of encouraging the strengthening of existing buildings.

We have also concluded that there is a lack of knowledge amongst industry participants, such as insurers, valuers and property managers, about the risks involved with earthquake-prone buildings and the legal obligations under the Building Act 2004. This lack of knowledge has potentially prevented building owners and tenants making informed decisions about the risk from, and requirements for, earthquake-prone buildings. Parties who are in an advisory position to building owners and tenants need to ensure that they understand, to an appropriate level, the issues relating to earthquake-prone buildings, and that this information is communicated to those they are advising in an understandable way.

We have noted in this Volume that assessing and strengthening existing buildings is a task requiring specialist knowledge and expertise. We consider that territorial authorities and subject matter experts (such as academics and specialist practising structural engineers) would benefit from sharing information and research among themselves on assessing, and seismic retrofit techniques for, particular kinds of buildings.

Recommendations

We recommend that:

101. Territorial authorities should be required to maintain and publish a schedule of earthquake-prone buildings in their districts.

102. The Ministry of Business, Innovation and Employment should review the best ways to make information about the risk buildings pose in earthquakes available to the public and should undertake appropriate educational activities to develop public understanding about such buildings.

103. The engineering and scientific communities should do more to communicate to the public the risk buildings pose in earthquakes, what an assessment of building strength means, and the likelihood of an earthquake.

104. Industry participants, such as insurers, valuers, and property managers, should ensure that they are aware of earthquake risks and the requirements for earthquake-prone buildings in undertaking their roles, and in their advice to building owners.

105. The Ministry of Business, Innovation and Employment should support industry participants' awareness of earthquake risks and the requirements for earthquake-prone buildings through provision of information and education.

106. Territorial authorities and subject matter experts should share information and research on the assessment of, and seismic retrofit techniques for, different building types.

References

1. New Zealand Society for Earthquake Engineering (2006). *Assessment and Improvement of the Structural Performance of Buildings in Earthquakes*; *including Corregendum No.1.* Wellington, New Zealand: Author.

2. NZS 1170.5:2004. *Structural Design Actions, Part 5: Earthquake Actions – New Zealand*, Standards New Zealand.

Section 2:
Design standards and legislative history

2.1 The evolution of seismic design standards in New Zealand

The long history of earthquakes in New Zealand is addressed in section 2.6.3 of Volume 1 of the Report. In addition to the accounts of large earthquakes that have been handed down in Māori oral tradition, the history includes at least seven earthquakes of magnitude 7 or more between 1840 and 1904, and five magnitude 7 events between 1929 and 1931. The Buller or Murchison earthquake on 16 June 1929 resulted in 17 deaths. In the devastating Napier earthquake on 3 February 1931, 256 people died. Section 2.6.4 refers in particular to earthquakes that have previously struck in Canterbury.

2.1.1 Loadings Standards

In response to the Napier earthquake, the Model Building Bylaws[1] published by the Standards Institute in 1935 contained the first specifications related to earthquake resistance. The seismic provisions of the 1935 Standard required buildings to be designed to resist horizontal forces equal to 8% of their gravity loads acting in a horizontal direction. For public buildings the 8% requirement was replaced by 10%. Until the late 1960s working stress design was used. This approach was then replaced by the ultimate strength method. In today's terms, the 8% and 10% would be approximately equivalent to 10% and 12.5% respectively of the standards required to be met by new buildings.

The approach of providing strength for a proportion of the gravity load acting in a horizontal direction was maintained through to 1955[2], but with the modification that a second distribution was introduced, in which the lateral force coefficient varied from zero at the base to 0.12 at the top of the building. The design actions were based on whichever distribution gave the higher design action. It is also worth noting that parapets and attachments were required to be designed for 50 per cent of the weight of the parapet or other element acting in a horizontal direction.

In the early 1960s it was realised that ductility was as important as strength. Initially it was considered that if the standard design provisions were satisfied there would be adequate ductility. However, earthquakes around the world soon indicated that this was not the case. Blume et al.[3] in 1961 highlighted the need to detail reinforced concrete beams and columns for ductility. Research into detailing to ensure members would behave in a ductile manner when overloaded has continued from that time and it remains an active research topic today. The University of Canterbury was active in this research in the late 1960s and it is still heavily involved in this work. These endeavours were supported by The University of Auckland over the same time period and by Central Laboratories when it was owned by the Ministry of Works.

The different levels of seismicity in New Zealand were recognised in 1965 by NZSS 1900:Chapter 8.3:1965[4], which divided the country into three regions. Zone A, which included Wellington had the highest seismicity. Zone B was an intermediate region that included Christchurch, while the low seismic zone, zone C, included Auckland and Dunedin. The design spectrum for each region was represented by three straight lines with the values given in the code of practice based on the assumption that the structures had an inherent displacement ductility of 4. The 1965 spectrum for Christchurch is shown in Figure 1, which also shows the corresponding spectra specified in later Standards.

The 1965 Standard introduced the equivalent static method of analysis (see section 3 of Volume 1 of this Report).

The Loadings Standard published in 1976 (NZS 4203: 1976[5]) introduced the requirement that the Standard was to be used in conjunction with revised material standards (steel, reinforced concrete, timber, and reinforced masonry), which all required specific detailing for ductility. Unreinforced masonry was effectively unable to be used to resist lateral forces in a building.

NZS 4203:1976[5] set out the design seismic loadings in terms of the potential ductility of the different materials and structural forms. The displacement ductility was given by $^4/_{SM}$, where *S* was the structural type factor, with values that range from 0.8–5. For ductile moment resisting frames, the value of S was 0.8 and for ductile walls it ranged from 1–2. For elastically responding structures, *S* ranged from 4–6 depending on the material. The maximum design displacement ductility was 5 for ductile concrete moment resisting frame buildings and 4 for structural wall buildings. The corresponding design inter-storey drift was calculated from the inter-storey drift sustained at the limit of elastic response multiplied by $^2/_{SM}$. Based on the equal displacement concept (see Volume 1 section 3), the design displacement was taken as about half the peak displacement. The maximum permissible design inter-storey drift for the ultimate limit state was set equal to 0.01 of the inter-storey height. The 1984[6] edition of NZS 4203 was similar to the 1976 version. However, the maximum permissible inter-storey drifts in the medium and low seismic zones were reduced, from 0.01–0.00875 and 0.0067 respectively, to compensate for P-delta actions. The material factor for ductile reinforced concrete was reduced to 0.8 as a result of the growing confidence with reinforced concrete. Many other minor changes were made.

The 1992 edition of NZS 4203[7] replaced the three seismic zones with a contour map, which defined the seismic hazard factor, Z. The design response spectrum was found by multiplying a nominal response spectrum for the appropriate soil type (rock or stiff soil, intermediate soil, or flexible deep soil) by Z, a risk factor R and a structural performance factor, S_p. The shape of the response spectra changed with the different soil characteristics. The value of R varied with the category of the building. It was 1 for normal multi-storey buildings but it increased to 1.3 for buildings required to be operational after an earthquake or other state of emergency. The S_p factor, which was given a value of two-thirds, was introduced to allow for a number of factors not specifically considered in design. The most significant of these was based on the observation that damage accumulates with the number and magnitude of the inelastic load cycles sustained in an earthquake. It was considered that a displacement that was sustained a number of times during an earthquake was a better guide to the damage than the peak displacement. The introduction of the S_p factor results in the peak displacement being equal to the design displacement divided by S_p. The confusion over peak and design drifts may have been a contributing factor to the damage sustained by stairs in the Canterbury earthquakes.

The Earthquake Actions Standard, NZS 1170.5:2004[8], adopted a similar approach to the previous loading Standard in defining the seismic design actions. However, the seismic hazard factor was updated to include recent research findings. In addition the Standard included:

- the drift modification factor, which makes an allowance for the difference in deflected shape profiles obtained from elastic based methods of analysis (equivalent static and modal response spectrum methods) and those obtained by the inelastic time history method of analysis;
- the requirement that the material strain limits in potential plastic hinge zones in the ultimate limit state do not exceed specified limits given in material standards;
- allowance for P-delta actions in accordance with a specified method; and
- capacity design steps, which were set out in detail.

Figure 1 shows the different design response spectra, given in the current and previous Standards, used for design of multi-storey buildings located on deep alluvial soils in Christchurch. The spectra are for buildings in which ductile concrete moment resisting frames provided the lateral force resistance. For the 2004 Standard[8] a structural ductility factor of 5 was assumed. While a value of 6 is permitted for the ultimate limit state, the serviceability limit state requirements make any value above 5 difficult to justify. For the other Standards, Figure 1 is based on the maximum permissible values of ductility: in the 1992 Standard[7] the maximum permissible structural ductility factor was 6 while in the 1976[5] and 1984[6] Standards the corresponding values were 5 and 6.25 respectively.

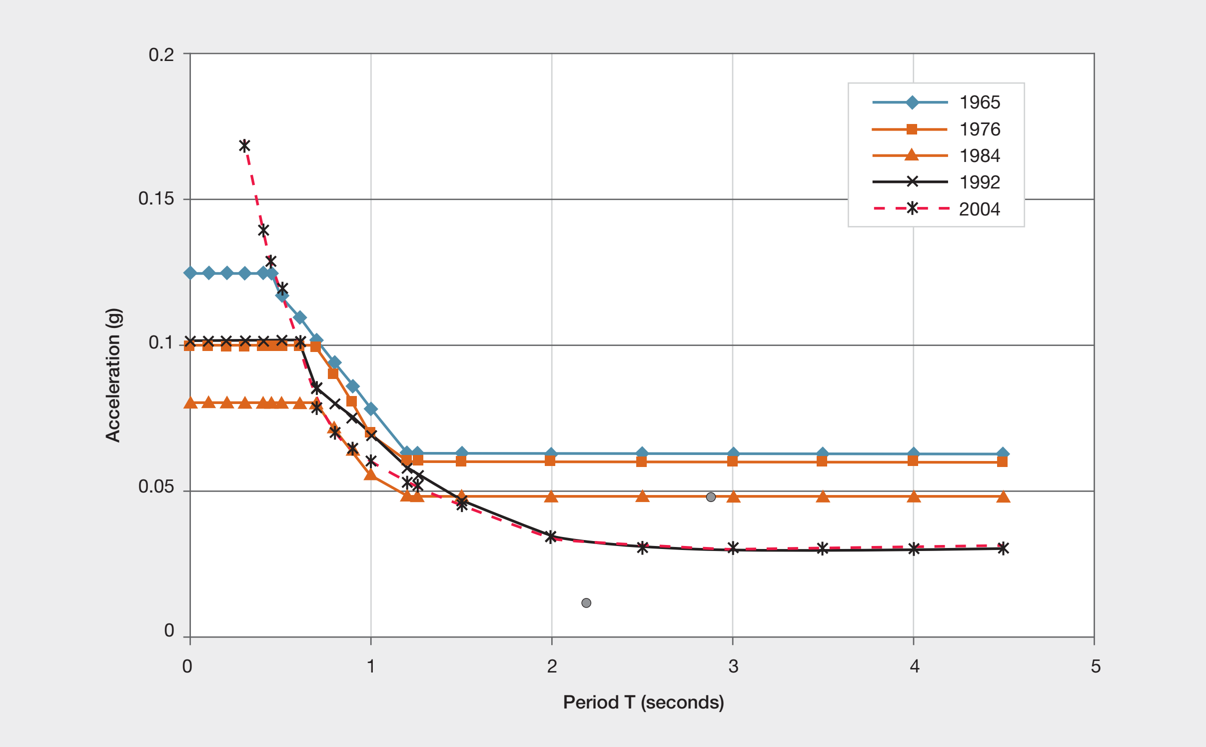

Figure 1: Response spectra used for design of reinforced concrete ductile moment resisting frame buildings in Christchurch on deep alluvial soils from 1965 to present day

2.1.2 Structural Concrete Standards

The initial concept of capacity design was conceived by Hollings[9] in the late 1960s. This concept involved selecting potential plastic hinge zones in the structure, detailing these so that they could sustain high inelastic deformation, and then designing the remainder of the structure to have sufficient strength to confine the inelastic deformation to the chosen locations. This is in effect telling the structure how to behave in the event of a major earthquake. Professors Park, Paulay and Priestley at the University of Canterbury extended the initial concepts of capacity design. While the basic concepts of capacity design were in place by the mid-to-late-1970s, many refinements were made subsequently and incorporated into later design standards.

From the late 1960s capacity design was practised by the Ministry of Works and a number of consulting engineering firms. At this stage the associated detailing that was necessary for ductile behaviour had not been fully defined. However, many of these structures were well designed and some have shown good performance in the Christchurch earthquakes despite the use of detailing that falls short of today's specifications. It was not until 1976, with the publication of NZS 4203:1976[5], that the requirements for capacity design were included in a design standard. At this stage there were still no material design standards that specified the detailing required to ensure that ductile behaviour would occur in individual members in the event of a major earthquake. However, detailed proposals were given in publications of the New Zealand Society for Earthquake Engineering[10] in the mid-to-late-1970s, and use was also made of information in overseas codes of practice such as ACI 318[11].

In 1982 the Concrete Structures Standard, NZS 3101: 1982[12], was published. This contained detailed information on detailing for ductility. This Standard was subsequently extended and updated in 1995[13] and 2006[14] as a result of findings from research in New Zealand and around the world.

The 1995 edition of NZS 3101[13] required all columns to be confined. The previous edition of NZS 3101[12] waived the requirement for confinement reinforcement where calculations indicated that the columns could sustain the ultimate limit state inter-storey drifts without inelastic deformation. This level of tie reinforcement in the columns did not provide effective confinement of the concrete or constraint against buckling of the longitudinal reinforcement. Consequently the inter-storey drift that could be sustained before failure was severely limited. The option of permitting some columns to be unconfined was removed in the 1995 edition of the Standard[13] given the uncertainty involved in the drift calculations.

The 2006 edition of NZS 3101[14] specified material strain limits in potential plastic hinge zones. Some ductile detailing and strength calculations in connection with capacity design were modified in light of recent research findings.

Flexural cracking in reinforced concrete members reduces the effective stiffness of structural members. The extent of the reduction depends on the magnitude and distribution of bending moments in the member, the axial load level and the grade of longitudinal reinforcement. Very different allowances have been made for this effect over the years. Different recommendations on the effective stiffness values appropriate for use in seismic analyses have been given in NZSS 1900:Chapter 9.3:1964[15], NZS 4203: 1976[5] and in the 1982[12], 1995[13] and 2006[14] editions of NZS 3101. In all cases the recommended stiffness values have been given as a proportion of the section properties calculated from gross sections.

The development of the Standards and changes made over the years need to be understood by those who are assessing whether buildings are earthquake-prone. We discuss some practical implications of this in section 6 of this Volume.

When concrete structures, which have been designed to previous design standards or codes, are assessed in terms of current design criteria, it is essential to allow for the different assumptions made with respect to the effective stiffness of section. Recommended values of the second moment of area (moment of inertia) in the different standards range from values based on the uncracked gross section to 0.35 times this value. Generally, the more recent standards have recommended the use of lower stiffness values, as it was believed that the magnitude of deformation was more important than the strength level.

2.1.3 Structural Steel Standards

There are relatively few buildings in Christchurch where the seismic resistance depends on the strengths of steel frames. It is only in the last two decades that structural steel has become widely used. These structures have the advantage of being designed to recent design standards and at a time when the significance of liquefaction of foundation silts and sands was understood.

The first full New Zealand Standard (previously an Australian Standard with a New Zealand supplement had been used) dealing with structural steel for buildings, NZS 3404:1989[16], was published in 1989. It included sections covering capacity design and ductile detailing. This Standard was updated in 1992[17] and again in 1997[18] as research advanced and different forms of construction were developed.

2.1.4 Further information on Standards

Detailed comparisons and information on the scope of the current and previous design codes/standards can be obtained from Fenwick and MacRae[19]; MacRae et al.[20], and Smith and Devine[21].

Fenwick and MacRae compare a range of ductile reinforced concrete moment resisting frame multi-storey buildings designed to design standards over the last six decades. The buildings are compared in terms of their relative stiffness, strength and ductility in terms of the design standards current in 2009.

MacRae et al. detail the differences in the loading, structural steel and structural concrete standards that have been used in New Zealand over the last six decades.

Smith and Devine set out the contents and changes in the New Zealand Masonry Standards over the last few decades.

2.2 Overview of the development of the regulatory framework for dangerous and earthquake-prone buildings

The Building Act 2004 contains detailed provisions for dangerous and “earthquake-prone” buildings. The latter term was not introduced until the Municipal Corporations Amendment Act 1968. We now briefly trace the development of the relevant regulatory framework down to the present day.

2.2.1 Dangerous buildings: 1900–1968

In what appears to have been the first enactment of the New Zealand legislature in this field, section 350 of the Municipal Corporations Act 1900 provided that councils could exercise certain powers in relation to buildings considered to be “in a ruinous condition, so as to be dangerous to persons in the adjoining buildings or to passers-by”. In this provision, the word “building” explicitly included any part of a building.

The powers given to the council were set out in the Twelfth Schedule of the Act, and included the powers to fence off the building to prevent persons approaching nearer to it than would be safe, to give notice requiring the building owner to secure the building or pull it down, to obtain a court order if the notice was not complied with and, if the order was not complied with, to carry out the work itself and recover the cost of doing so.

The provisions were repeated in section 292 of the Municipal Corporations Act 1908 and, with insignificant alteration, in section 297 of the Municipal Corporations Act 1920 and section 304 of the Municipal Corporations Act 1933. Under the Municipal Corporations Amendment Act 1948, the ambit of the provisions was extended to include buildings that were "dilapidated" as well as ruinous.

The Municipal Corporations legislation was consolidated in a new statute enacted in 1954. Section 300 of the Municipal Corporations Act 1954 dealt separately with buildings considered by the local authority to be "dangerous", "deserted", and "dilapidated or ruinous". In the case of dangerous buildings, councils were empowered to put up a hoarding or fence so as to "prevent persons approaching nearer thereto than is safe" and to give notice to the building owner requiring removal of the danger. Removal could be "by securing or taking down the building within a time specified in the notice." Magistrates were empowered, on an application by the council served on the owner, to order that the building be secured or taken down, and if such orders were not complied with, the council was again empowered to itself carry out the necessary work, and recover the costs of doing so from the owner.

2.2.2 The Municipal Corporations Amendment Act 1968 and its successors

A significant change in the legislation was introduced by the Municipal Corporations Amendment Act 1968. The legislative history makes it clear that the change was a response to the decision of the then Supreme Court (now the High Court) in *Lower Hutt City v Leighton and another,* decided in 1964[22]. In that case the Council had purported to decide that a building was dangerous under section 300 of the Municipal Corporations Act 1954 on the basis that it would be a danger to the public in the event of an earthquake. The Court held that a building could only be considered dangerous within the meaning of section 300 if it was in a dangerous condition at the time that the council served a notice under the section. This conclusion was based on the clear indications that the Court found in the wording of section 300 that it was dealing with buildings that constituted a present danger. The Court held that this would include cases:

> ...in which the danger may not be immediately present but will be present within a foreseeable time in the near future as the result of progressive deterioration due to weather, usage, traffic vibration or the like.

However, the section could not be applied where the danger would:

> …arise only in the event of a major earthquake, for the reason that it is unpredictable whether such an earthquake would come within any given time or even whether it would come at all.

When moving the second reading of the Bill that became the Municipal Corporations Amendment Act 1968, the Minister for Local Government, the Hon. D.C. Sheath[23], referring to the clause of the Amendment that is relevant here, said:

> Clause 20 is one of the most important clauses in the Bill and was one that gave the Local Bills Committee a good deal of work. It is the clause which will give councils powers in respect of buildings likely to be dangerous in an earthquake. Section 300 of the principal Act gives a council powers in respect of dangerous buildings. It may require an owner to remove the danger either by securing or taking down the building. It was held by the Supreme Court in 1964 that, in considering whether a building is dangerous for the purposes of this section of the principal Act, regard may be had only to the danger actually existing at the time when the council is taking action, and regard may not be had to a danger that would arise only in the event of an earthquake. Clause 20 remedies this deficiency, but the section may be operated only by councils to which it is applied by Order in Council made on the application of the councils concerned. The clause will not apply to wooden buildings, nor to other buildings if they are reinforced to standards that comply with the provisions of the present standard building bylaw relating to the design and construction of buildings to withstand earthquake shocks. Private dwelling houses are not affected unless they are of two or more storeys and contain three or more flats or apartments. Generally speaking the effect of these provisions is to give power to deal with unreinforced concrete or masonry buildings – with the exceptions I have mentioned – whose ultimate load capacity is likely to be exceeded in a moderate earthquake.

When the Bill was enacted, the clause that was referred to in the Minister's speech was inserted as section 301A of the Municipal Corporations Act. The substantive provisions included the following:

301A Powers of Council with respect to buildings likely to be dangerous in earthquake –

(1) In this section –

"Building" means a building constructed wholly or substantially of unreinforced concrete or unreinforced masonry; and includes any part of a building so constructed; but does not include any building used wholly or principally as a private dwelling, unless the building is of two or more storeys and contains three or more residential flats or apartments:

"Council" means a Council to which this section applies pursuant to an Order in Council under subsection (2) of this section:

"Masonry" means any construction in units of burnt clay, concrete, or stone laid to a bond in and joined together with mortar:

"Moderate earthquake" means an earthquake that would subject a building to seismic forces one-half as great as those specified in New Zealand Standard Model Building Bylaw (NZSS 1900: Chapter 8: 1965[4]) for the zone (as described in that bylaw) in which the building is situated:

"Unreinforced masonry" means masonry classified as unreinforced masonry by Chapter 9.2: 1964[24] of the said bylaw.

(2) The Governor-General may from time to time, by Order in Council made on the application to the Minister by the Council concerned, declare that any specified Council shall be a Council to which this section applies.

(3) Where the Council is satisfied that any building in the district (being a building to which this section applies), having regard to its condition, the ground on which it is built, its present and likely future use, and all other relevant matters will have its ultimate load capacity exceeded in a moderate earthquake and thereby constitute a danger to persons therein or in any adjoining building or on any adjoining land or to passers-by, the Council may, by notice in writing signed by the Mayor or Chairman, as the case may be, or by the Town Clerk or Engineer given to the owner, require the owner of the building within the time specified in the notice to remove the danger, either by securing the building to the satisfaction of the Council or by taking down the building. The Council shall also send a copy of the notice –

(a) To every person having a registered interest in the land, on which the building is erected under any mortgage or other encumbrance and

(b) To every person claiming an interest in the land which is protected by a caveat lodged under section 137 of the Land Transfer Act 1952 and for the time being in force; and

(c) Where the owner if not the occupier of the land within the meaning of the Rating Act 1967, to every occupier of the land within the meaning of that Act.

Following subsections dealt with procedures after the council had served a notice under the section, and included provisions for objection, and reference to a Magistrate's Court for confirmation, modification or setting aside of the notice.

This was the first legislative provision for buildings that were likely to be dangerous in the event of a future earthquake. It can be seen from subsection (1) that the section specifically applied only to unreinforced concrete and unreinforced masonry buildings, the latter defined by reference NZSS 1900:Chapter 9.2:1964[24]. As set out in subsection (3), the unreinforced concrete and masonry buildings to which the section applied were those which would have their:

> …ultimate load capacity exceeded in a moderate earthquake and thereby constitute a danger to persons therein or in any adjoining building or on any adjoining land or to passers-by…

The term "moderate earthquake" was also defined in subsection (1), by reference to NZSS 1900:Chapter 8:1965[4]. It was provided that a moderate earthquake was one that would subject a building to seismic forces half as great as those specified in Chapter 8.

Section 301A did not replace section 300 of the Act. Consequently, councils continued to have their existing powers in relation to dangerous buildings (and those that were ruinous, dilapidated or deserted) under that section. The legislature apparently saw no need to amend section 300, and consequently it remained confined to cases where the building could be said to be in a condition of a kind referred to in the section at the time that the council took action. In effect, Parliament accepted the correctness of the Supreme Court's interpretation of the section in *Lower Hutt City v Leighton and another*, but amended the Act to make special provision for buildings likely to be dangerous in a moderate earthquake. The result was a dual approach for dangerous buildings on the one hand, and those that might be dangerous in an earthquake on the other, which has remained a feature of the legislation down to the present day.

A provision equivalent to section 301A was enacted as section 624 of the Local Government Act by the Local Government Amendment Act 1979, as part of the consolidation of legislation affecting local government that began with the enactment of the Local Government Act 1974. The focus remained on buildings constructed wholly or substantially of unreinforced concrete or unreinforced masonry, and the references to the New Zealand Model Standard Building Bylaw, NZSS 1900:Chapter 8:1965[4] were retained.

It should also be noted that under both the Municipal Corporations Act 1954 and the Local Government Act 1974, councils could make bylaws regulating the construction, alteration and repair of buildings, including their resistance to "earthquake shocks". But the powers in relation to earthquake shocks could only be exercised in relation to "such parts of buildings" as were "being altered or repaired" or whose "resistance to earthquake shocks" would be "directly affected by the alterations or repairs".

2.2.3 The Building Act 1991 and the Building Code

The Building Act 1991 was a major reform, which introduced a fundamental change to the control of building construction in New Zealand. The system that had previously applied, under which territorial local authorities issued building permits for buildings which complied with local bylaws, was replaced by a performance-based national Building Code, under which building consents would be issued for buildings that met stated performance objectives. New Zealand Standards continued to be used, but not as provisions that could be adopted by councils and made part of their bylaws. Rather, the Standards, once cited or referenced under the Building Act, could be used to establish compliance with the Building Code.

The Building Code was contained in the Building Regulations 1992 made pursuant to section 48 of the Building Act. Regulation 3(2) provided that, except as otherwise provided in the Act, each building must achieve the performance criteria specified in the Building Code. A key feature of the Code was to state objectives, functional requirements and rules about performance. For structures, the stated objective (Clause B1.1) was to:

> (a) safeguard people from injury caused by structural failure,
>
> (b) safeguard people from loss of *amenity* caused by structural behaviour, and
>
> (c) protect *other property* from physical damage caused by structural failure.

The stated functional requirement for structures (Clause B1.2) was as follows:

> Buildings, building elements and sitework shall withstand the combination of loads that they are likely to experience during construction or alteration and throughout their lives.

One of the rules about performance (Clause B1.3.1) was that account must be taken of "all physical conditions" likely to affect the stability of buildings, and 18 separate physical conditions were set out. They included self-weight, imposed gravity loads arising from use, earth pressure, water, earthquake, snow, wind and adverse effects due to insufficient separation from other buildings.

These remain provisions of the Building Code, which continues in force under the Building Act 2004.

The provisions of the 1991 Act followed the pattern established by previous legislation, making separate provision for dangerous and earthquake-prone buildings. However, section 64 of the Act defined dangerous buildings in a way that specifically excluded earthquakes as a basis on which a building could be categorised as dangerous, which had not been a feature of the previous legislation. Under section 66 of the Act, a building was deemed to be earthquake-prone if:

> …having regard to its condition and to the ground on which it is built and because of its construction being either wholly or substantially of unreinforced masonry, it would have its ultimate load capacity exceeded in a moderate earthquake and thereby would be likely to suffer catastrophic collapse causing bodily injury or death to persons in the building or to persons on any other property or damage to any other property.

The section defined a "moderate earthquake," as had been consistently done since the Municipal Corporations Amendment Act 1968, by reference to the New Zealand Standard Model Building Bylaw NZSS 1900:Chapter 8:1965[4], which was now applied "notwithstanding its revocation". Once again, the seismic forces used to define the "moderate earthquake" were specified to be "one-half as great" as those specified in the Bylaw. Consistently with the previous legislation, the definition of "unreinforced masonry" in NZSS 1900:Chapter 9.2:1964[24] continued to apply, again "notwithstanding its revocation". With changes that are immaterial for present purposes, the machinery provisions for the giving of notices and enforcement were also the same as those that previously applied.

However, in comparison with the previous legislation, the requirement that the building would be "likely to suffer catastrophic collapse" was an additional matter that needed to be satisfied before a building could be considered to be earthquake-prone. Previously, apart from the reference to the ultimate load capacity of the building being exceeded in a moderate earthquake, the legislation had referred only to buildings constituting a danger. Arguably, this reduced the pool of buildings that could otherwise have been the subject of notices given by territorial authorities under the Act. However, it appears from the attachments to a statement of evidence by Mr John Buchan provided to the Royal Commission by the Christchurch City Council, that the Council's Building Control Manager when the 1991 Act was enacted saw the new reference to catastrophic collapse as giving more clarity to the definition of "earthquake-prone" buildings.

Section 8 of the Act provided that buildings that existed before the Act came into force could not be required to comply with the Building Code "except as specifically provided to the contrary" in the Act. Insofar as buildings considered to be potentially earthquake-prone were concerned, there was no relevant provision "to the contrary" in the Building Act. As was previously the case, councils were able to exercise their powers to serve notice on earthquake-prone buildings, and require work to be done to reduce or remove the danger, but they could not require seismic strengthening work to be undertaken unless a building was in fact "earthquake-prone" as defined. In addition, although section 38 of the Act enabled councils in some circumstances to decline an application for a building consent for the alteration of an existing building, the seismic strength of the building was not one of the grounds on which that could occur. Further, the power to make bylaws regulating and controlling the construction of buildings (in section 684(22) of the Local Government Act) was removed; section 684A was inserted into the Act with the result that a council could not make a bylaw that purported to have the effect of requiring any building to achieve performance criteria additional to, or more restrictive than, those specified in the Building Act.

This was a significant change. Prior to enactment of the Building Act 1991, some councils (including Christchurch City Council) had relied on their bylaws to require seismic strengthening of some buildings when granting building permits for proposed building alterations, refurbishment and additions. The combined effect of the new statutory provisions meant that councils could no longer adopt that approach. It is clear from the attachments to the statement of evidence provided by Mr Buchan for the Christchurch City Council that the Council recognised that the 1991 Act had this effect.

2.2.4 The Building Act 2004

The Building Act 2004 replaced the 1991 Act. It contains the current law regulating building work and the setting of performance standards for buildings. It maintains the performance-based approach of the Building Act 1991 and, as noted above, the Building Code introduced in 1992 remains in force under its provisions.

As was the case with the 1991 Act, section 122(2) of the Building Act 2004 excluded buildings used wholly or mainly for residential purposes from the definition of earthquake-prone buildings, unless the buildings comprised two or more storeys, and contained three or more household units. The 2004 Act also maintained the separate provision for dangerous buildings on the one hand, and earthquake-prone buildings on the other. In accordance with this approach, earthquake-induced damage remained excluded from the definition of "dangerous building".

However, some significant changes were introduced in respect of earthquake-prone buildings. First, there was a new definition of "earthquake-prone" for the purposes of the Act. Under section 122(1), a building was earthquake-prone if:

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

As can be seen, the reference to NZSS 1900:Chapter 8:1965[4] was removed and replaced by a reference to regulations. The regulations made under the Act to define "moderate earthquake" are the Building (Specified Systems, Change the Use, and Earthquake-prone Buildings) Regulations 2005. Regulation 7 of those Regulations provides:

Earthquake-prone buildings: moderate earthquake defined

For the purposes of section 122 (meaning of earthquake-prone building) of the Act, moderate earthquake means in relation to a building, 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.

As can be seen from section 122 the definition of "earthquake-prone" was no longer confined to unreinforced concrete and unreinforced masonry buildings, and there was also no requirement that the building be one that would be likely to "collapse catastrophically". All that was necessary was that the building's ultimate capacity would be exceeded in a moderate earthquake, and would be likely to collapse causing injury, death or damage.

There was another very significant change. For the first time, territorial authorities were to be required to adopt policies on dangerous, earthquake-prone and insanitary buildings. That requirement was set out in section 131 of the Act which read as follows:

131 Territorial authority must adopt policy on dangerous, earthquake-prone, and insanitary buildings

(1) A territorial authority must, within 18 months after the commencement of this section, adopt a policy on dangerous, earthquake-prone, and insanitary buildings within its district.

(2) The policy must state –

(a) the approach that the territorial authority will take in performing its functions under this Part; and

(b) the territorial authority's priorities in performing those functions; and

(c) how the policy will apply to heritage buildings.

Under section 132 of the Act, councils were required to adopt policies under section 131 in accordance with the special consultative procedure set out in the Local Government Act 2002, a process that involves public submissions. After adoption, the policy could only be amended or replaced in accordance with the special consultative procedures. Section 132(4) provided that territorial authorities must complete a review of their policies within five years after adoption, and subsequently at intervals of not more than five years.

We discuss how territorial authorities have responded to the duties imposed by section 131 of the Act in section 7 of this Volume.

We also discuss in section 7 various issues that have arisen about the interpretation of the provisions of the Act in relation to earthquake-prone buildings.

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Note: Standards New Zealand was previously known as the Standards Institute of New Zealand.

Section 3: Building types in the Christchurch Central Business District

The Canterbury earthquakes have provided many examples of central business district (CBD) buildings that have successfully withstood shaking far greater than would be produced by the level of ground motion defined in current standards as the 'design level'. The majority of buildings, including many which were designed to earlier earthquake-resistant standards, fulfilled the Building Code objective of life safety.

However the earthquakes did result in the total collapse of some buildings and the failure of parts of others causing injury and death. In every case these failed structures either dated from an era before earthquake resistance was required in a New Zealand building standard, or were designed to a standard that has since been updated to require higher building capacity to withstand seismic actions.

The CBD of Christchurch has been continuously developed since the mid-nineteenth century. Early wooden structures were superseded by buildings made from brick and stone – materials which were considered more permanent and fire resistant. Designs were often reminiscent of European models. Commercial buildings built between 1880 and 1935 were predominantly unreinforced brick masonry of one, two and three storeys – frequently built as rows of separate tenancies divided by party walls. Stone masonry was the common choice for churches and public buildings having high gable ends and heavy roofing of clay tile or slate. Neither of these building types was constructed to resist earthquakes. There is a full discussion of the characteristics of unreinforced masonry buildings in section 5 of this Volume. Because of the uniformity of unreinforced masonry (URM) brick commercial buildings, it is possible to make recommendations that can be applied to this class as a whole.

After 1935, building structures of steel, timber and reinforced concrete were designed to resist lateral loads imposed by earthquake shaking according to standards in force at their date of construction. Consequently, when the February earthquake struck, the building stock of the Christchurch CBD comprised buildings of different materials, structural designs and scale, from single-storey timber residences to multi-storey office buildings (one comprising 29 levels) made of reinforced concrete. In contrast to the position with unreinforced masonry buildings, buildings built since the 1930s require assessment of earthquake resistance building by building. Building capability depends on the date and quality of the design, materials of construction and the structural form.

Architectural design in Christchurch has been regarded as amongst the most progressive in New Zealand – a pride in the quality and character of the city's building stock is evident. A very large number of heritage buildings existed in Christchurch. Sadly these were amongst the oldest and the most damaged.

Section 4: Individual unreinforced masonry buildings that caused fatalities

Forty-two people died as a result of building failures (other than the Canterbury Television and Pyne Gould Corporation buildings) in the 22 February 2011 earthquake. This section of the Report discusses the circumstances in which those deaths occurred.

4.1 Introduction

Thirty-six of those killed were in the Central Business District (CBD). The other six were in the suburbs. Over a period of six weeks the Royal Commission conducted hearings into the failure of the buildings that caused the deaths.

The collapse of an exposed brick internal chimney breast, which resulted in the death of a five-month-old baby, was not the subject of a hearing. However, the Royal Commission has investigated what occurred and that event also forms part of this Report.

The investigation into buildings that failed and caused the deaths of these 42 people is important because all but one of the buildings involved were older, unreinforced masonry (URM) buildings or brick or block structures.

Of the 42 deaths caused by the failure of individual buildings:

(a) 35 were as a result of the façade or walls of URM buildings collapsing onto:
   - pedestrians or persons in vehicles (26);
   - people in a neighbouring building (6);
   - people who had run out of a building to escape (3);

(b) four people were killed inside a URM building;

(c) one five-month-old baby was killed by a chimney breast collapse;

(d) one person who had run out of a building was crushed by a free-standing wall; and

(e) one person was killed when she was crushed by a six-tonne concrete spandrel that fell from a car park building onto her vehicle.

The fact that nearly 70 per cent of the deaths caused by these building failures were of people outside the buildings – in the main, pedestrians and persons in vehicles – highlights the issue of what to do about URM buildings as a very real community problem. It also graphically highlights the inadequacy of a passive earthquake-prone buildings policy and the need to urgently implement policies throughout New Zealand to, at the very least, address the potential dangers these buildings pose from collapsing façades, walls and parapets.

These hearings also addressed other issues raised by the Royal Commission's Terms of Reference including:

- the strengthening or retrofitting of URM buildings and the need for retrofit or strengthening measures to provide effective protection and not fail in a significant earthquake;
- the inspection and assessment of buildings following a large earthquake – in this case the 4 September 2010 and Boxing Day 2010 earthquakes;
- the way these buildings are assessed and the potential for collapse in a significant aftershock;
- the management of cordons in front of a damaged building following a significant earthquake, and the placement of such cordons so as to provide protection for the public by blocking off footpaths or, if necessary, roads; and
- communication of potential dangers posed by a building after a significant earthquake to relevant authorities, and to the owners and occupiers of potentially affected neighbouring properties.

The nature and characteristics of URM buildings, and techniques for and costs of strengthening these buildings are discussed in this Volume. Assessing and strengthening all existing buildings is discussed in section 6 and the legal requirements for earthquake-prone buildings are discussed in sections 2 and 7. Post-earthquake assessment and management of buildings is discussed in a later Volume of the Royal Commission's Report.

The Royal Commission's consideration of the buildings addressed in this section has been informed by information obtained during the course of our investigation, including information from building owners and occupiers, the Christchurch City Council (CCC) and, in some cases, witnesses to the collapse of the buildings. We were assisted in developing our understanding of the history and failure of the buildings by reports prepared for our inquiry by Mr Peter Smith, a structural engineer and principal of Spencer Holmes Ltd, an engineering firm based in Wellington. Mr Smith's reports were published on our website and he gave evidence at each hearing. So too did Mr Stephen McCarthy, Environmental Policy and Approvals Manager for the CCC, who supervised the collection of information from the CCC's files. We acknowledge their assistance.

We acknowledge too those who spoke at the hearings of the harrowing events they experienced and witnessed on 22 February and the suffering of the bereaved and those who were seriously injured.

The accounts given of the failure of the individual buildings have been intended to give as full an explanation as possible of why there was loss of life. We have also tried to make each account reasonably self-contained in the expectation that some of those who lost family members and friends may not wish to read all parts of this section in full. The result is a degree of repetition, which was unavoidable. However, it may also serve to emphasise the recurring observations about the consequences of passive earthquake-prone buildings policies. Taken collectively, the failures of these buildings and resultant loss of life have mounted a case which the Royal Commission finds compelling for definite timeframes to be imposed for the strengthening of earthquake-prone buildings.

Figure 2: The locations of buildings outside the CBD discussed in this section

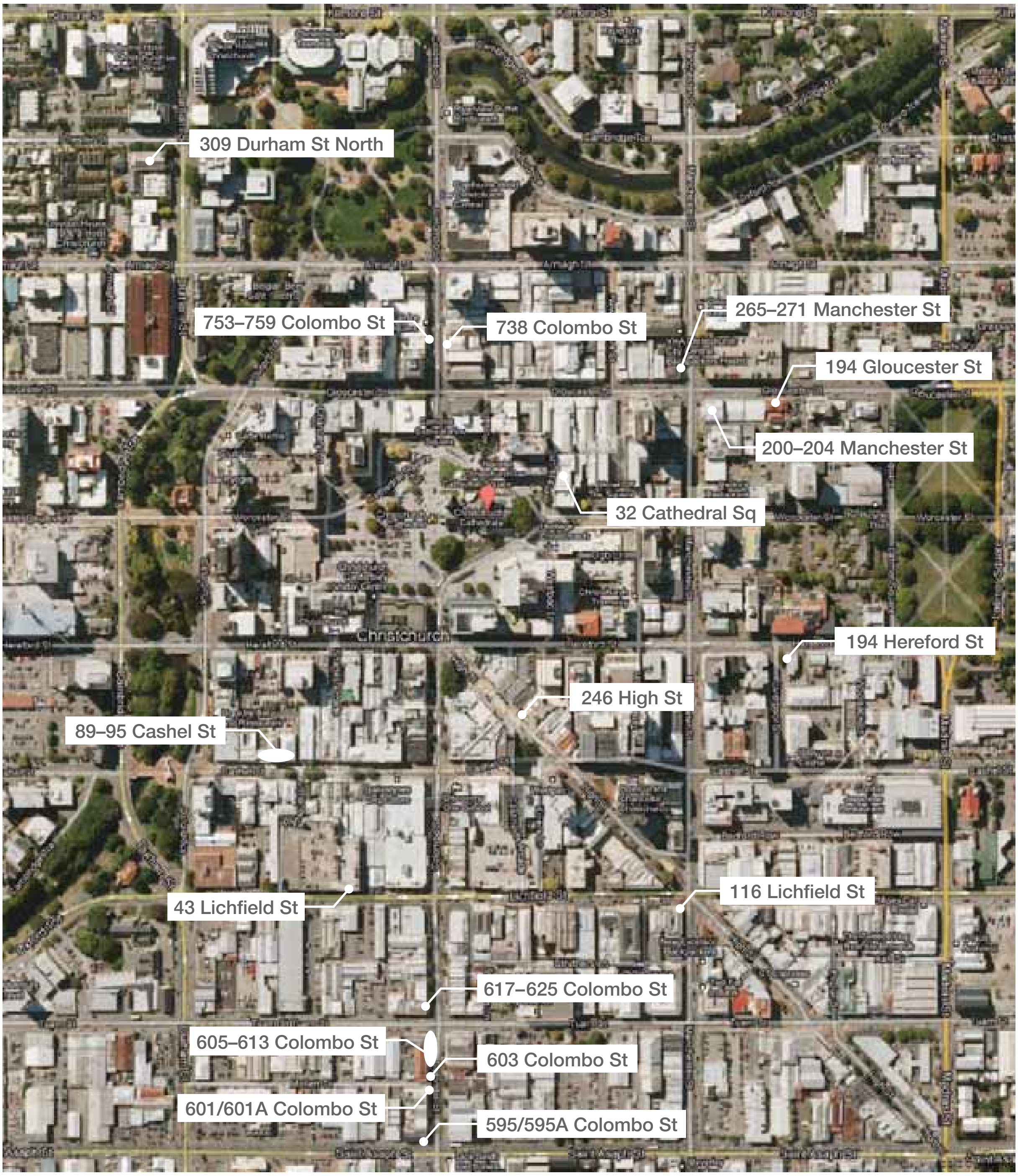

Figure 3: The locations of the individual buildings within the CBD discussed in this section

4.2 The CCC's earthquake-prone buildings policies

The discussion of the individual buildings that failed in the February earthquake frequently includes reference to the CCC's role as a local authority in relation to earthquake-prone buildings. As discussed in section 2 of this Volume, the powers of territorial authorities in relation to earthquake-prone and dangerous buildings have been derived from statutory provisions that have been changed on a number of occasions over the period relevant to the Royal Commission's inquiry. It is important that actions taken or not taken in relation to the individual buildings are seen in the context of the extent and limits of the CCC's statutory powers.

These issues were addressed by the CCC in its report to the Royal Commission on *Building Safety Evaluation Processes in the Central Business District following the 4 September 2010 Earthquake*[1]. They were also addressed in a brief of evidence by Mr R. Buchan, which has not been formally read at a public hearing but has been provided to the Royal Commission and published on the Royal Commission's website. Mr Buchan's statement outlined the history of relevant statutory provisions, starting with section 301A of the Municipal Corporations Act 1954 that was applied to the CCC on 12 June 1969. In addition, Mr McCarthy referred to the CCC's powers in his evidence at the hearings about some of the individual buildings.

The history of the development of the statutory provisions in relation to the control of earthquake-prone and dangerous buildings is outlined in section 2 of this Volume and the present law is addressed in more detail in section 7. It is appropriate to reiterate here that under the Municipal Corporations Act regime, the CCC adopted policies that were designed to secure the seismic strengthening of buildings when or if building alterations, repairs, additions or refurbishment works were proposed. In this respect, the CCC (and other councils) were able to rely on bylaws made under the Municipal Corporations Act, and the Local Government Act. Under the Act, the powers of the CCC were to give notice requiring the owner "to secure the building to the satisfaction of the Council" and a notice could be given in the case of buildings that would have their ultimate load capacity exceeded in a moderate earthquake and were considered to "constitute a danger to persons therein or in any adjoining building or on any adjoining land or to passers-by". Mr Buchan gave details of the manner in which the CCC exercised those powers, down to the enactment of the Building Act 1991. It is clear that some progress, albeit slow, was made in the 1970s and 1980s and we record that in the latter part of 1975, CCC began a comprehensive survey of the central area with the aim of classifying each building.

The Building Act 1991 introduced a definition of "earthquake-prone building" that was in some respects more restrictive than had previously applied. This required that the building be "likely to suffer catastrophic collapse causing bodily injury or death to persons" in a moderate earthquake. In addition, unless a building was considered to be dangerous, seismic strengthening could generally only be required where there was a change of use, in accordance with section 46(2). Councils could no longer rely on their building bylaws to require strengthening where repair, additions or refurbishments were proposed. Further, section 8 of the 1991 Act provided that nothing in the Act was to be read as requiring any building completed before the Act's coming into force to meet the requirements of the Building Code. The CCC evidently took the view that these changes prevented it from requiring owners to upgrade their buildings notwithstanding that the building may have been identified as needing to be strengthened in the processes that had been followed under the previous legislation. Overall, we accept that the CCC's ability to require seismic strengthening was reduced by the enactment of the 1991 Act.

Under section 131 of the Building Act 2004, all territorial authorities are required to adopt a policy on dangerous and earthquake-prone buildings. The CCC[2] conducted seminars in the period from 14 June to 5 October 2005 before resolving to publish a draft policy for consultation purposes on 15 December 2005. In formulating the draft policy, the CCC had regard to guidance material that had been provided by the former Department of Building and Housing[3] (DBH), which we refer to as the DBH Guidelines. That document is discussed in section 7 of this Volume but it is appropriate to also refer to some of the same material here because it will give context for the discussion of the CCC's earthquake-prone buildings policies. We record that the DBH Guidelines envisaged a process in which territorial authorities would carry out a desktop evaluation of their building stock to ascertain which buildings had the potential to be earthquake-prone and therefore suitable for closer consideration. Buildings in that category would then be subject to an Initial Evaluation Process (IEP). If the building was considered to be earthquake-prone, it would be subject to further steps, depending on the substance of the CCC's policy. The former DBH Guidelines, reflecting the permissive nature of the provisions of the Building Act, outlined two "Principal Approaches" that territorial authorities could adopt. It described these as "active" or "passive".

Under an active approach, it was said that the territorial authority would set timetables for action and guidelines of performance levels for upgrading. Under the passive approach, a detailed assessment of a building and any action taken to improve its structural performance would be triggered by an application under the Building Act for building alteration, change of use, extension of the life of the building or subdivision. The DBH Guidelines noted:

> …this second approach has the significant disadvantage that it relies on a somewhat haphazard order of remediation based essentially on an owner's intention for a building. This could lead to some significant high-risk buildings being untouched for a long period of time.
>
> On the other hand, the cost of administering such a programme would be significantly less than for an active programme.

The CCC's draft policy[2] published in December 2005 included timeframes for strengthening earthquake-prone buildings of 15–30 years. However, having considered the submissions received in the consultation process the CCC[4] decided to remove the timeframes.

Under section 132 of the Building Act, the CCC was required to review its policy, which it did in a process that included the adoption of a draft new policy[5] in March 2010. The major change recommended in the new draft policy was the introduction of timeframes for strengthening that would apply from 1 July 2012. The CCC heard submissions on the draft new policy in June 2010. The new policy had not been finalised by the time of the September earthquake.

The CCC has suggested that it was pursuing an active approach in relation to earthquake-prone buildings. We accept that the CCC had undertaken a process in which it was endeavoring to identify likely earthquake-prone buildings by carrying out a desktop review of buildings within its district, that it reviewed its 2006 policy ahead of the five-year deadline proposed by the Building Act and that it had decided when it published the 2010 draft policy that timeframes for action should be established. To that extent, it was taking action. In the case of most URM buildings, the requirement of the CCC policy was that strengthening should take place within 30 years from the date that the owners were notified that their building was potentially earthquake-prone. The CCC committee[6] that heard submissions on the draft policy recommended that the 30-year period be reduced to 20 years. The committee's reasoning included the following:

> The Panel considers that an active approach involving timeframes for strengthening is necessary to reduce the risk to the public in an earthquake, and that the proposed categories and timeframes are largely appropriate. It is concerned, however, about the level of hazard posed by unreinforced buildings, many of which have been known to be an earthquake risk since the late 1960s or early 1970s. This is the type of building that failed with catastrophic effects, including for people in the streets, in the Napier earthquake of 1931.

When the policy was formally adopted on 10 September 2010 (six days after the September earthquake), the 30-year period was reduced to 20 years.

During the hearing at which the Royal Commission considered the issue of earthquake-prone buildings policies, on 14 November 2011 the Mayor of Christchurch, Mr Bob Parker, described the policy as "a relatively passive approach". Having considered Mr Buchan's statement, the CCC's report and the evidence given at the hearings on the individual buildings, the Royal Commission considers that the CCC's earthquake-prone buildings policies as they stood in 2006 and at the time of the September earthquake can fairly be described as passive in nature. The CCC then resolved that timeframes should be imposed. We accept that, even if a more active approach had been taken from 2006, it is still unlikely that the URM buildings that failed in the February earthquake would have been strengthened prior to the earthquake.

There are observations in the accounts given of the individual building failures that are critical of actions or omissions of the CCC. Those observations must be seen in the context of the difficult challenges that were presented by the September earthquake and subsequent aftershocks. The CCC was not the only territorial authority that adopted a passive approach to the strengthening of earthquake-prone buildings. It was, however, the only territorial authority to experience such a destructive earthquake since the Napier earthquake of February 1931.

4.3 Building fatalities

The Commissioners are conscious that our Report is largely of a technical nature. However, at the forefront of our minds have been those who lost their lives as a result of the earthquake of 22 February 2011 and those left behind who loved them. Our thoughts have also been with those who were injured and their families.

To honour those who died, we asked their families to tell us about their loved ones. The words that follow reflect what they said. We thank the families for their willingness to share this information publicly, given the personal nature of their grief.

All but one of the biographies relate to people who were killed by older, unreinforced masonry (URM) buildings or brick or block structures. The one exception is Linda Arnold.

Biographies of other people who died as a result of the earthquake in the PGC and CTV buildings are published elsewhere in this Report.

39 Bishop Street, St Albans

Baxtor Gowland

Master Baxtor Gowland, five months, was only 2.6 kilograms when born as the surviving boy of twins. When the earthquake struck he was lying on a blanket in front of the fireplace, asleep at Flat 3, 39 Bishop Street, St Albans. The exposed brick fireplace collapsed in the earthquake and Baxtor was found by his mother, underneath the fireguard which had been covered in bricks.

The flat had been damaged as a result of the September 2010 earthquake, including damage to the chimney which had been removed. However, the exposed brick fireplace had not been removed.

Baxtor, who already loved Postman Pat, sport and music, is described as a smiley, sociable and alert baby.

Baxtor is survived by Breanna Gowland (mother).

89/89A, 91 and 93 Cashel Street

Melissa Neale

Ms Melissa Neale, 41, was walking in Cashel Street with her mother, Margaret Neale, intending to go to the Trocadero Bakery for lunch. They were a short distance from the building when the earthquake struck. Melissa's body was located under collapsed building material around 89/89A, 91 and 93 Cashel Street.

Melissa, who was an operations manager for artworks retailer Real Aotearoa, was born at St George's Hospital, Christchurch, on St Patrick's Day 1969, the beloved identical twin sister of Amanda. Melissa also had a close relationship with her brother, Damian.

Melissa is described as a vibrant, happy, positive, loving person with plenty of energy and a love of life. Family and friends were very important in her life and her hobbies were walking, gardening, cooking, reading, and especially travelling, which she spent a lot of her life doing.

Melissa is survived by Margaret Neale, Amanda Neale and Damian Neale.

Jillian Murphy

Ms Jillian Murphy (known as 'Jilly'), 48, had arranged to meet friends for lunch in Oxford Terrace. She was meeting her friend Debbie Lawson, owner of Deval clothes shop, 89A Cashel Street, in her store before lunch. Jilly was trying on a jacket when the earthquake struck. Debbie, a staff member and another customer went out the front door. Jilly, who was facing the back part of the store, chose to exit the building via the rear door. The neighbouring building at 91 and 93 Cashel Street, City Mall, collapsed onto the rear part of the store.

Jilly, an air traffic controller, loved the outdoors and would often cycle with her partner Richard. She was extremely fit, capable of riding 100km with ease. She went to the gym frequently and enjoyed walking her golden retrievers Milly and Bayley. She loved clothes and shopping. She always looked stunning no matter what she wore.

Jilly was very family-oriented and loved family holidays. She is described as a truly beautiful woman in the complete sense of the word. She was a devoted and loving mother and partner, and also a well-respected colleague of her workmates. She had a significant number of friends both in New Zealand and around the world. Jilly was an attractive, bright, intelligent woman who always had time for anyone and everyone.

She is survived by her children Bond (aged 16) and Taylor (aged 18), partner Richard Green and his son Sam (aged 21).

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93 Cashel Street

Christopher Homan

Mr Christopher Homan (known as 'Chris'), 34, and his wife Christine were in Cashel Street, standing in the vicinity of 93 Cashel Street, when the front of the buildings at 89/89A, 91 and 93 Cashel Street collapsed.

Chris had a great sense of humour. As a child, he would tell people his name was Fred Jackson and he was an adopted child from Ireland. Ever since, his family had known him as Fred.

Chris gained an apprenticeship as a painter when he left school and remained with the same painting company up until his death. He worked his way up from a brush hand to an operations manager over the years. He also enjoyed basketball and cricket.

He was thoughtful, generous and loving. At 1.95m, he was a tall man with a huge heart.

He is survived by Chris (his wife), Liam (son, aged two), Nanette (mother), Adrian (father, known as 'Sam'), Patrick (brother) and Melanie (sister).

Shane Tomlin

Mr Shane Tomlin, 42, was a pastry baker at the Trocadero Bakery, 93 Cashel Street, in Cashel Mall. He was working at the bakery, on the first floor, when the earthquake struck.

A work colleague was standing near Shane and after the earthquake stopped, she saw a hole in the floor where he had been standing. Shane was located, conscious but badly injured, on the ground floor under the bakery premises in the TS Retail Store. He was taken to Christchurch Hospital but subsequently died as a result of his injuries.

Shane loved his work, his pet turtle, watching *Star Trek* and *Doctor Who*, cooking and gardening (but not flowers, only vegetables).

Shane valued his privacy and liked doing things alone. His family feel he would not have liked having his photo and information about him sent all over the world, being called the "face of the earthquake" and he would have said, "just leave me alone".

Shane's family are Doreen Tomlin (mother), Judith McLaughlin (sister), Raelene Miller (sister), Karen Franicevic (sister) and nine nieces and nephews ranging in age from five to 16 years. His father was the late Bernie Tomlin.

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32 Cathedral Square

Adrienne Lindsay

Mrs Adrienne Lindsay (known as 'Ady'), 54, was at work as an accounts clerk at The Press newspaper, Christchurch Press Building, 32 Cathedral Square, when the earthquake struck. She was in her office on the top floor of the Press building and was last seen ducking under her desk by a work colleague.

Ady, who enjoyed sports, is survived by Phil (husband), Josh and Kieran (sons).

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90 Coleridge Street

Stephen Cochrane

Mr Stephen Cochrane (known as 'Steve'), 43, was a cabinetmaker at Classique Furniture, 90 Coleridge Street. Steve was passionate about his trade and is best described as a craftsman cabinetmaker, an absolute perfectionist.

When the earthquake struck he was working at his bench inside the premises. He ran out the side door and down the driveway, where an unsupported concrete block wall toppled over, crushing him underneath it.

Steve loved sport, especially rugby, cricket, motor racing and golf. He was very proud of his garden, especially his new fruit trees just planted the weekend before he died, and now already bearing fruit a year later. He was happiest when spending time with his girls, Tania and Kylie-Marie.

Steve is described as an amazing man who did not have a bad bone in his body. Everyone, without exception, was warmed by and drawn to him. Kylie-Marie described her dad as "cool, friendly, caring, funny, awesome, fantastic, creative, loving, cruisy and happy".

Steve's family includes Tania Cochrane (wife), Kylie-Marie (daughter, aged 11), Marie Cochrane (mother), John Cochrane, Euan Cochrane and the late Dave Cochrane (brothers), Lyn Johannis and Jill Cochrane-Williams (sisters), and Hunter (Steve's dog).

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382 Colombo Street

Maureen Fletcher

Ms Maureen Fletcher, 75, was eating lunch at the Tasty Tucker Bakery, 380A Colombo Street, Sydenham, when the earthquake struck. She was sitting with a couple she had met only a few minutes before the earthquake, Margaret and Bruce Moon. A gable wall from the building next to the bakery collapsed onto the bakery premises.

Maureen was an outgoing person who had spent 18 years in Waiwera Ashram giving readings as a spiritual consultant before she moved back to Christchurch in 2005.

She is survived by her children Rodney, Malcolm, Jeffrey and 11 grandchildren.

593 Colombo Street

Matthew McEachen

Mr Matthew McEachen (known as 'Matti' or 'Matt'), 25, was employed as a tattooist at Southern Ink, 593 Colombo Street. He was last seen by a work colleague, Matthew Parkin, sitting at his desk. It appears that Matt ran out of the front door, as his body was found at the front of the building.

Matt, who was a very talented artist and tattooist, had a love of creative arts and music. He was a graphic artist and musician. He also loved family holidays and during his life had travelled to Australia, Fiji, Singapore, Malaysia, Borneo and Thailand with his family.

Matt was an inspiration to all who met him. He was an extremely positive, sensitive and caring person. He was creative, spiritual, and strongly believed that everyone's talents and potential were infinite. Matt always put other people's feelings before his own. He lived for his art, music, family and friends. It was often said that Matt was everybody's best friend.

Matt is survived by Jeanette and Bruce McEachen (parents) and Sarah (sister, aged 23).

595/595A Colombo Street

Rachel Conley

Ms Rachel Conley, 27, from the United States of America, had been on a working holiday in New Zealand with her good friend, Jessica Kinder. They had planned to visit Christchurch before flying home to the United States on 23 February 2011. While in Christchurch they decided to get tattoos and had been in the Southern Ink premises (593 Colombo St) minutes before the earthquake to make an appointment.

When the earthquake struck, Rachel had exited the building, walked several metres north along Colombo Street, and was adjacent to 595 Colombo Street. Jessica was with Rachel at the time but on the way out of the shop, Jessica paused to close the heavy sliding door while Rachel walked ahead. It was as Jessica walked to catch up with Rachel that the earthquake struck and Jessica saw Rachel struck by a falling slab of concrete.

Rachel had a passion for music, especially live shows. She loved to write. She had been living in New York City for seven years, originally to attend school. Prior to leaving for her trip, she was the assistant to the general manager of a Manhattan hotel. Her personality is described by her father as beautiful, with a smile not to be forgotten. She had friends from every walk of life and was an incredibly unbiased person. She was full of goodwill for everyone.

She is survived by Steve (father), Farris (mother), Deb (stepmother), Sam (brother) and Lauren (stepsister).

601/601A Colombo Street

Normand Lee

Mr Normand Lee, 25, died outside 601/601A Colombo St. He was a pedestrian walking near the building when the earthquake struck.

Normand had attended Cashmere High School and spent one year at Christchurch Polytechnic Institute of Technology before studying management at the University of Canterbury. After university he did a personal training course and worked on a cruise liner as a trainer. He returned to New Zealand in December 2010 and was about to start his own personal training business at Snap Fitness.

Normand was a keen sportsman who loved cricket and had played since he was young. He had been a member of the Sydenham Cricket Club and also played touch rugby, indoor soccer and indoor cricket. He had a keen interest in martial arts.

Normand is described as laidback, quiet by nature and easygoing. He had a quirky sense of humour and was very sociable. He did not worry about much and went out of his way to help family and friends. He was a very generous person.

His family include Karen and the late Sharon (sisters), Raymond (brother) and Mee Lai and Bak Cheong Lee (parents).

603 Colombo Street

Gabi Ingel

Mr Gabi Ingel, 23, died outside 603 Colombo Street (the intersection of Mollett and Colombo Streets). Gabi came to New Zealand in December 2010 to enjoy the scenery after backpacking around Asia for a few months. He met up with Ofer Levy, his best friend since the age of five, and the pair were travelling and hiking around New Zealand together. When the earthquake struck, they had just left Frienz Backpackers on Worcester Street and were heading towards a meeting point to be picked up to work for a day in a vineyard.

Gabi was due to return home to Israel to begin his studies in mathematics and computer science.

He enjoyed a variety of sports, including martial arts (he was the first person in Israel to get a black belt in Meijin Kai before the age of 18), rock climbing, trekking and kite surfing. He also loved music, computers and fixing things, from small devices to cars.

Gabi was a gifted boy who could do everything he set his mind to. He was very talented both in science subjects and physical activities. He was a very friendly person who made a lot of friends in Israel and the different countries he was travelling in. Gabi was also very sensitive, always willing to help others and had a great sense of humour. He and his family had great plans and expectations for his future.

He is survived by Gil Ingel (father), Fanya Ingel (mother), Ayelet Ingel (sister) and Ben Ingel (brother).

Ofer Levy

Ofer Levy, 22, an Israeli, was travelling around New Zealand with Gabi Ingel, his friend since the age of five. When the earthquake struck, they had just left Frienz Backpackers on Worcester Street and were heading towards a meeting point with a vineyard owner to work with him for the day. Ofer's body was found outside 603 Colombo Street, on the corner of Colombo and Mollett Streets.

Ofer had just completed his compulsory military service at home and travelled to New Zealand. He was due to return home three days after the earthquake and was looking forward to seeing his girlfriend and continuing to work on an old Volkswagen Beetle he was doing up. He also planned to start studying computer science at university.

Ofer was busy with many hobbies and activities, such as extreme downhill mountain biking, martial arts, car mechanics and nature trips with friends. He played jazz on the alto saxophone.

Ofer is described as good-looking, with a very big and tender heart. He always had a smile on his face, animated gestures, and he made people feel that it was never a problem to help them. Ofer was very friendly and honest, able to quickly have an open and honest conversation with complete strangers. He was a loving and caring son to his parents who welcomed a boy after having three daughters. Ofer was extremely responsible, generous, talented and graceful.

He is survived by Gliliah Levy (mother), Mordechai Levy (father), Michal Levy (sister), Dafi Toupotte (sister), Tamar Levy (sister), and a fish called Tony.

Joan and Graham Weild

Mrs Joan Weild, 76, was with her husband Mr Graham Weild, 77, when the earthquake struck. They were pedestrians on the west side of Colombo Street near the intersection of Mollett and Colombo Streets, outside 603 Colombo Street. The couple always did everything together and they were on their way home to Heathcote Valley at the time.

Joan was totally family-oriented and loved spoiling her grandchildren. She spent many hours knitting soft toys to donate to charities as gifts for Christmas.

Graham was an avid sailor and member of the Christchurch Yacht Club where he raced Lasers and Zephyrs. He was also a motorbike enthusiast and had owned many bikes over the years. In his early 70s he was still riding a trail bike.

Joan and Graham are survived by John Weild (son), Nicki Weild (daughter-in-law), Susan Davis (daughter), Michael Davis (son-in-law) and Andrew Weild (son).

605–613 Colombo Street

The Red Bus No. 702 was travelling north along Colombo Street when the earthquake struck. The bus was brought to an immediate stop approximately adjacent to 605 Colombo Street. A large amount of masonry and bricks fell onto the left side of the vehicle killing or injuring the occupants.

Jayden Andrews-Howland

School had finished early on 22 February 2011 and Master Jayden Andrews-Howland, 14, was travelling home on the bus. He had decided to take the bus that took a longer route home because he enjoyed riding on the buses.

Jayden was a much loved only child of Helen Andrews and John Howland. He enjoyed staying with his grandfather Archie and his dog. He liked playing on his Playstation and riding his bike. He loved to travel and dreamed of becoming a driver when he left school. He also had a dream of buying a campervan and travelling around New Zealand. Jayden's parents will now take on that dream in his honour.

Jayden is described as caring and honest, quiet, kind and loyal. He would do anything for anybody and he didn't judge anybody else but always accepted them for who they were.

Andrew Craig

The bus driver Mr Andrew Craig, 46, was taken to hospital, where he died later that afternoon as a result of his injuries.

Andrew had gained a diploma in horticulture from Lincoln University. He worked as a groundsman at Queen Mary Hospital for several years and was a volunteer fire fighter in Hanmer Springs. He went on to work for the Canterbury District Health Board as a driver for the elderly before becoming a driver for Red Bus about ten years before his death.

Andrew was a keen bargain hunter who often frequented the Riccarton Market and was well known at the local Salvation Army store. He is survived by Hugh (brother), Janine (sister-in-law), Lachlan (nephew, aged eight) and Rebecca (niece, aged four). He was the son of the late Ross and Gwynne Craig.

Philip Coppeard

Mr Philip Coppeard (known as 'Phil'), 41, had boarded the bus in Redcliffs half an hour before the earthquake and was heading to Canterbury University for an economics lecture. His ultimate aim was to complete a PhD in economics.

Phil was learning classical guitar. He was passionate about the environment and was a keen member of the Eastenders group (part of the Summit Road Society) as well as the Avon-Heathcote Estuary Ihutai Trust. He enjoyed walking in the Port Hills and playing golf. He loved sports and was a keen supporter of the Highlanders and Southland rugby teams as well as Ipswich Town Football Club.

Phil is survived by Barry and Barbara Coppeard (parents), Suzanne Craig (wife) and Joanne Morley (sister).

Lucy and Stuart Routledge

Mr Joseph Stuart Routledge (known as 'Stuart'), 74, and his wife Lucy, 74, were very close and always together. It was never Lucy or Stuart, but always Lucy and Stuart.

They were to change buses at the Christchurch Bus Exchange and travel to Akaroa, their favourite holiday destination, for a short break.

The couple lived in Sumner and were both very active in the Sumner community. They did volunteer work around the seaside village and were the caretakers for the key to the community pool.

Stuart loved botany and Lucy loved gardening. For years Stuart and Lucy tended the gardens at the Sumner Redcliffs RSA, of which they were active members.

Lucy had beaten cancer only eight months before. She is described as one of a kind – funny, thoughtful, caring, kind and loving.

Lucy and Stuart are survived by Stuart and John Cowen (nephews) and Marian Longmore (cousin).

Jeff Sanft

Mr Jeff Sanft, 32, was on his way to meet his two beloved little daughters for lunch.

Jeff, a butcher and boner, was well known in Canterbury rugby league circles. He was also very talented in art and music. He was the first cousin of Christchurch rapper 'Scribe', who had been staying with Jeff for two weeks prior to the earthquake.

Jeff was a very loving and caring man who had a lot of friends and time for everyone. His children were his everything. He is survived by Jeff and Christine Sanft (parents), Hazel (daughter, aged four) and Olive (daughter, aged two), and Hope Asi (partner).

Beverley and Earl Stick

Mr Earl Stick, 78, and his wife Mrs Beverley Stick, 71, had left their car at the Redcliffs supermarket and taken the bus so they could talk to one another and walk to the hospital from town. They were devoted to each other and had been married for 51 years.

Earl was a retired former builder and businessman. He had been involved in building hotels and was part of Trans Tours, with his work taking him to Mount Cook, Queenstown and even Vanuatu for a year.

Earl was a practical and resourceful man who gave of his time to the community. He had volunteered on community fire brigades and was a Rotary member in Queenstown and Christchurch. He received the Paul Harris Fellowship long life of active service award for tree planting.

Beverley was a hard-working person who had supported her husband's business as well as being a loving and wonderful mother and grandmother. She was a brilliant cook, baker and knitter and had made five home-spun wool blankets that were waiting in her cupboard for her great grandchildren. She loved her garden, played mah-jong and was active in her church and community.

The couple had travelled extensively around New Zealand and the world together.

Their family are Raemon Greenwood (daughter), Nicholas Stick (son), James and Christina Greenwood, Ellen and George Stick, and Charlize and Pascalle Stick (grandchildren), Olive Downes (sister), Crystal and Stuart Munro (sister and brother-in-law), Beryl and Ray Dineen (sister and brother-in-law), Coral and Les Nordstrand (sister and brother-in-law), and the late Gordon and Keith Stick (brothers).

625 Colombo Street

Jennifer Donaldson

Ms Jennifer Donaldson, 55, had been walking along Colombo Street after buying a birthday card on Colombo Street when the earthquake struck. She had been to a medical appointment at QEII Medical Centre at 11am and had planned to do some shopping outside the CBD in the afternoon. She was found in rubble from a collapsed building next to the building on the north-west corner of Tuam and Colombo Streets (outside 625 Colombo Street).

Jennifer liked walking and also enjoyed watching television. She loved knitting and was a caring, helpful mum and grandmother.

She is survived by Robb Donaldson (husband of 34 years), Brent (son, aged 32), Marie (daughter, aged 31) and Hayley (granddaughter, aged five).

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738 Colombo Street

Desley Thomson

Ms Desley Thomson (known as 'Des'), 32, was on her lunch break when the earthquake struck. She was killed by falling masonry outside 738 Colombo Street.

Desley, who worked as a logistics manager for Gardiner Smith, is described as having a bright personality, wonderful sense of style and a great can-do attitude.

She was passionate about cooking and entertaining, played touch rugby, was an avid reader and loved to walk. She had also travelled extensively overseas.

Desley is survived by Rae Maxted (mother), Ross Thomson (father) and Amy Pateman (sister).

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753 Colombo Street

Marielle Falardeau

Ms Marielle Falardeau, 60, a French Canadian, was found under collapsed building material outside 753 Colombo Street. She had been walking along the footpath when the earthquake struck.

Marielle, who worked as a nurse in Canada, was celebrating her semi-retirement by doing the trip of her life, travelling around New Zealand with her sister. She was scheduled to fly home on 23 February 2011 and had been shopping in Colombo Street for toy sheep souvenirs to take home for her friends.

Marielle enjoyed painting, singing, nature and her vegetable garden. She often said it was important to savour the present moment. She is dearly missed by four brothers, three sisters and many friends.

309 Durham Street North

Paul Dunlop

Mr Paul Dunlop, 67, was working inside the Methodist Church at 309 Durham Street North, dismantling and removing the pipe organ when the earthquake struck and the church collapsed. Paul was last seen approximately four metres from the altar. Paul was a passionate organist who played in churches around Christchurch. He also enjoyed woodturning.

He was a well-known Christchurch optometrist. The family practice, Paul Dunlop & Associates in New Regent Street, has served the Christchurch community for more than 110 years. Paul qualified as an optometrist in 1965 and ran the business with his wife Sue.

Paul is described as outgoing and with a huge love of people. He is survived by Sue (wife), Steven, Christopher and Peter (sons), Keith (brother) and Ruth (sister).

Scott Lucy

Mr Scott Lucy, 38, was working inside the Methodist Church, 309 Durham Street North, with colleagues, dismantling and removing the pipe organ when the earthquake struck. Scott was last seen running down the stairs inside the church during the earthquake.

Scott was a keen pilot and held private and commercial pilot's licences for both fixed-wing aircraft and helicopters. He also enjoyed fishing, shooting, model making and computers.

Scott had spent two years in the territorial force and 10 years in the hydrographic branch of the New Zealand Navy, where he received a personal commendation from the Marine Commander in 1996. From 2000–2011 he performed a variety of occupations including instructor, then chief instructor of a Boeing 737 flight simulator.

Scott was outgoing, kind, generous to a fault and very supportive and loyal to his family, friends and work associates. He displayed wide-ranging talents and abilities. He is survived by Gemma Shefford (fiancée), Aaron Lucy (brother), Tokyo (niece) and Bill and Hazel Lucy (parents).

Neil Stocker

Mr Neil Stocker, 58, was working inside the Methodist Church, 309 Durham Street North, dismantling and removing the pipe organ when the earthquake stuck. Neil was last seen standing on scaffolding inside the church.

Neil had worked for the South Island Organ Company for 42 years and was the company foreman. He had trained 12 apprentices in his time with the company and was a skilled craftsman. He had an extensive knowledge about organs, both mechanically and technically. He was methodical and self-disciplined, always checking everything.

Neil loved outdoor adventures and enjoyed tramping, mountain biking and road biking alongside his wife. He loved four-wheel driving and exploring the South Island's back country. In 2010 he travelled to an isolated village in Nepal with his wife, doing voluntary work, installing solar lighting in a Sherpa village in the middle hills called Damar.

Neil possessed a quiet inner strength. He was kind and caring with a smile that would light up a room. He was a perfectionist and no job was ever done half-heartedly. He is described as a "salt of the earth" man who was loyal and humble with a good sense of humour and a generous heart.

Neil is survived by Margaret Isobel Stocker (wife), Graham Stocker (brother), James Nicol (brother-in-law), Louise (daughter, aged 32), Shane (son, aged 24), grandchildren Ben, Caleb and Katie, and sisters-in-law Laura and Janet Nicol.

194 Gloucester Street

Ofer Mizrahi

Mr Ofer Mizrahi, 22, an Israeli, was in the driver's seat of a van parked outside 194 Gloucester Street, with three friends, when the earthquake struck. He saved his friends' lives by warning them it was an earthquake, then was crushed himself by falling concrete.

Ofer was born and raised at Kibbutz Magal in Israel, in an agricultural environment. He loved playing sport, especially football. He was a good handyman, willing to assist any of his friends when they needed it and always offering to help others. Friends and social life were very important to him and he was very much involved in initiating social activities, like parties, or helping small children in their summer camp to build a structure with rope and wood. For some time he was in charge of a local pub.

Ofer had just completed his compulsory military service in Israel and was thinking of studying agriculture, but before starting his studies he wanted to travel around the world and get to know it better. He had gone with a friend to South Africa to watch the Mondial football games and then joined another friend to travel in Australia and New Zealand. They met up with two girlfriends from school and were about to start their tour of New Zealand when the earthquake struck.

Ofer was warm and friendly. He loved his family: Rimona Mizrahi (mother), Gad Mizrahi (father), Omri (brother, aged 32), Oran (brother, aged 30) and Inbar (sister, aged 28).

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194 Hereford Street

Gregory Tobin

Mr Gregory Tobin (known as 'Greg'), 25, an Englishman, worked as a chef at Joe's Garage, 194 Hereford Street. He was in the kitchen at the time of the earthquake and was last seen by a work colleague, running out the front door onto Hereford Street where he was hit by falling masonry.

Greg served in the Royal Electrical and Mechanical Engineers section of the British Army before he trained as a chef at Hazlewood Castle, a prestigious hotel in England. Greg is remembered as an avid reader, talented wordsmith and MC. Music was also a big part of his life.

He was a loving and kind person, inspirational, creative and motivated. He had a passion for living and lived life to the full. He was a cherished son, brother and friend.

Greg is survived by Caroline and Alex Tobin (parents), and Alexander and Elliott Tobin (brothers).

246 High Street

Joseph Pohio

Mr Joseph Tehau Pohio (known as ‘Joe’), 40, had bought his lunch in the Link Centre, 248 High Street, and was on his way out through the High Street entrance when the earthquake struck. He saw a woman on the ground and bent over and reached out his hand to help her up, but he was killed when debris fell on him approximately five metres inside the High Street entrance. The adjacent building had collapsed and fallen through the roof of the Link Centre. The woman Joe tried to help described him in that moment as having a smile on his face, as if to reassure her, and seeming to be completely calm and in control.

Joe was a computer-aided draughtsman with the Christchurch City Council where he had worked for the past 23 years. He had also done Civil Defence training through the Council and had been a member of Urban Search and Rescue for 23 years.

Joe had a passion for old cars, was a keen musician and loved blues, reggae and rock music. He was keen on mountain biking and surfing and enjoyed spending time with his nephew Max, and watching *Star Wars* DVDs.

Joe is described as unassuming, a warm and caring man who fully valued life. He loved life but most of all he loved the people in it. He could relate particularly well to the very young and the elderly.

Joe’s family includes Arnold and Joy Pohio (parents), Hayley (sister), Max (nephew), Lucy (a cat which was killed 10 days before Joe died) and Henry (his dog, aged 14, which died three months after Joe).

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43 Lichfield Street

Linda Arnold

Ms Linda Arnold, 57, an account manager, was sitting in her car speaking on her cell phone when the earthquake struck. The car was parked at 43 Lichfield Street, which was a complex of four buildings owned by the retailing company J. Ballantyne & Co (Ballantynes).

Linda, who was a vivacious and outgoing person, enjoyed spending time with her friends and family. She also played an active part in church activities. Linda had a passion for acting, fashion and jewellery. She enjoyed helping others.

Linda is survived by Peter (husband), Alaster and Adrian (sons), Amanda, Erica and Karen (grandchildren).

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116 Lichfield Street

Owen McKenna

Mr Owen McKenna, 40, an Irishman from Emyvale, County Monaghan, was in his vehicle when the earthquake struck. It was the middle of three vehicles stationary at the traffic lights in the northbound lane of Manchester Street, at the intersection of Lichfield Street. Part of the Ruben Blades building at 116 Lichfield Street (corner of Manchester and Lichfield Streets) collapsed onto his car.

Owen, who was a trauma nurse/clinical coordinator at Christchurch Hospital, was a very kind and caring person who would go out of his way to help people. He was also a fun and hands-on dad.

Owen was passionate about all things Irish, especially Gaelic football. He was an excellent Irish dancer and was learning the tin whistle with his daughter, Grace.

Owen’s family are Sarah Lothian (wife), Grace (daughter, aged eight), Tadhg (son, aged five), Bernadette, Maria, Kieran, Angela, Enda, Brendan and Catherine (brothers and sisters), Teresa McKenna (mother) and the late Michael McKenna (father). Owen was the sixth of the eight children.

Kelsey Moore

Ms Kelsey Moore, 18, was carrying her five-week old daughter, Taneysha Prattley, and was walking with her partner, Glenn Prattley, near the intersection of Lichfield and Manchester Streets when the earthquake struck and the Ruben Blades building at 116 Lichfield Street collapsed.

Kelsey was a friendly, happy, caring, beautiful girl who was always willing to help others out, especially with children. She loved life, was always happy and planned to train as a childcare worker.

She is survived by Jason Moore (father), Adrienne Haines (mother), Glen Prattley (partner), Logan Moore (brother), Flynn Moore (brother) and Maia Moore (sister).

Taneysha Prattley

Miss Taneysha Prattley, five weeks old, was the youngest person to lose their life in the earthquake. She was with her mother Kelsey Moore when the front of the Ruben Blades building, 116 Lichfield Street, on the corner of Lichfield and Manchester Streets, collapsed, killing both Taneysha and her mother. Glen Prattley (father) and Rochelle Prattley (aunt) had been walking a few metres ahead when the earthquake struck.

Taneysha is described as a quiet baby who was light as a feather and enjoyed being with her mother and ‘Nan Nan’ (her grandmother).

She is survived by Glen Prattley (father), Jason Moore (pop/grandfather), Adrienne Haines (Nan Nan/grandmother), Logan and Flynn Moore (uncles), Maia Moore (aunt), Rochelle and Renee Prattley (aunts), Jeff, Glenn and Nick Prattley (uncles), Gail Prattley (grandmother) and Stan Prattley (grandfather).

Lisa Willems

Mrs Lisa Willems, 43, was in her car waiting at the lights near 116 Lichfield Street, at the corner of Lichfield and Manchester Streets, when the earthquake struck.

Lisa was a talented artist and musician who was also passionate about the outdoors. She was an avid tramper, mountain runner, sea kayaker and gardener. She enjoyed cycling and had cycle-toured around Europe.

Lisa was completing her final year of a law degree at Canterbury University and prior to this was a qualified psychiatric nurse and nurse practice consultant.

Lisa is described as a warm and loving person who brightened any room she walked into. She had a bubbly, effervescent personality and a beautiful smile. She was full of the joys of life. She devoted all her energy and love to her family and in particular her children, Olivia and Sam, whom she adored and doted over.

Lisa is survived by Ben Willems (husband), Olivia (aged 10), Sam (aged 8) and Shaid Darque (sister).

200–204 Manchester Street

Jaime Gilbert

Mr Jaime Gilbert, 22, was working as a hospitality supervisor at the Iconic Bar, 200–204 Manchester Street, with his sister Amy Cooney when the earthquake struck. They both exited the building and were showered with debris as the front of the building collapsed. Jaime died holding his sister's hand.

Jaime had trained at the National Academy of Singing and Dramatic Art, and was a talented musician and actor who enjoyed writing, performance music and acting in plays. He was also good at sport. Jaime was due to play the role of Laertes in the Repertory Theatre production of Hamlet three months after the earthquake. His father, Robert Gilbert, filled the role in his honour.

Jaime was a delightful, vibrant, spiritual young man. He loved his partner, Natalie, and cherished his two children. Jaime made each of his friends feel as though they were special to him. He was a person who gave of himself. He was talented yet humble, and he was destined to have a bright future in the arts.

He is survived by Natalie O'Brien (partner), Levi (son, aged six), India (daughter, aged six months), Robert Gilbert (father), Vicki McDowell (mother), Michelle Gilbert (stepmother), Peter Cooney and Jackson Gilbert (brothers), Amy Cooney and Olivia Harvey (sisters). Also the dog Jaime loved, Lady, an Irish wolfhound.

265–271 Manchester Street

Christopher Smith

Mr Christopher Smith (known as 'Smitty'), 48, died outside 269 Manchester Street when building debris fell on his car during the earthquake. Christopher had just dropped his son, Dean, off at school. He was rescued by the New Zealand Fire Service from inside the vehicle and taken across the road to the Orion Building, 218 Manchester Street. Despite medical treatment and CPR, Christopher died as a result of his injuries.

Christopher, who worked for Bosch Appliances, loved rugby and fishing. He was a man with a great wit and sense of humour. He had good friends and loved playing a practical joke on anyone he could. He was a family-oriented man who loved spending quality time with his wife and boys. He just loved life.

His family are: Liz Smith (wife), Marc, Jed (deceased), Dale, Dean and Craig (sons).

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7 Riccarton Road

Ross Bush

Mr Ross Bush, 75, a self-employed bricklayer, had been driving his motor vehicle and towing a trailer on the day of the earthquake. He was last seen at a job site in Glandovey Road, Fendalton. Ross had stopped at a dairy near 7 Riccarton Road to buy his lunch and was eating it in his parked vehicle when the earthquake struck.

Ross was a passionate cyclist who had been involved in competitions for 61 years. He was well known in the Christchurch cycling community and holds the New Zealand record for riding from Cape Reinga to Half Moon Bay.

Ross is described as an outgoing and sociable person who loved people, loved life and never wasted a moment.

He is survived by Suzanne (wife of 45 years), Nadine, Liana, Monique, Nicole and Greg (children), and Khalia, Corey, Dylan, Jordan, Amber, Daniel, Caitlin, Curtis, Tyler and Beau (grandchildren).

391/391A Worcester Street

Betty Dickson

When the earthquake struck, Ms Betty Dickson, 82, was a customer ordering fish at Wicks Fish Shop, 389A Worcester Street, as she had done every Tuesday for the past 15 years. During the earthquake, a large brick wall from the upper storey of 391A Worcester Street collapsed onto and through the roof of 389A Worcester Street. Betty died with Natasha Hadfield, who was serving her at the time.

Betty was a very active person. She was a life member of the Mount Pleasant bridge and gardening clubs and she frequently played tennis, golf and petanque. Betty did a lot of community and voluntary work including Meals on Wheels and Lifeline, as well as reading to the children at Woolston Primary School.

Betty is described as a person who was bright, bubbly and always had a smile on her face. She is survived by Kay (daughter), John and Scott (sons).

Natasha Hadfield

Mrs Natasha Hadfield, 38, was the co-proprietor of Wicks Fish Shop, 389A Worcester Street, with her husband Geoffrey. Natasha had worked in the shop for 10 years and had bought it with her husband in 2005. She was at work serving Ms Betty Dickson, when the earthquake struck. A large brick wall from the upper storey of 391A Worcester Street collapsed onto and through the roof of 389A Worcester Street during the earthquake, killing both women.

Natasha is described as ambitious, hardworking, reliable, honest and friendly. She loved all her family, and cherished her little boy Jayme, now nearly two years old. Natasha was kind-hearted and liked to help others less fortunate than herself. She had considered a career in nursing while at school.

She enjoyed motor racing and was a loyal Ford fan. She also liked rugby, supporting the Crusaders and the All Blacks. She played hockey and tennis, and was a good swimmer.

Natasha is survived by Geoffrey Hadfield (husband), Jayme (son, aged 1 year 11 months), Shirley-Anne Epere (mother), Kevin West (father), Shane and Michael West (brothers), Kaye Hadfield (mother-in-law), Errol Hadfield (father-in-law) and two pet cats, Stella and Bailey.

4.4 39 Bishop Street, St Albans

4.4.1 Introduction

Five-month-old Baxtor Gowland was killed in the February earthquake when an internal exposed brick chimney breast collapsed and crushed him at 39 Bishop Street (also known as 3/35 Bishop Street).

4.4.2 Background

Mrs Cheryl Baird and her former husband bought a property on the corner of Bishop and Purchas Streets together in 1978. In 1985 the title for the property was separated into three cross-leased titles and two units were sold. Mrs Baird retained the corner unit, 39 Bishop Street.

Mrs Baird has advised that at the time separate titles were formed, the CCC required strengthening of the building with five steel girders: one at the first floor landing level, one at the adjoining wall, one at each end of the building and one inside the apex of the roof. The CCC records obtained show no reference to this work. Mr Peter Smith, who prepared an independent assessment on the earthquake performance of the building, commented that the intent of this strengthening was unclear.

Mrs Baird has said that in the 1980s the internal chimney breast was remodelled by removing the mantelpiece and re-bricking from floor to ceiling with the original mantelpiece retained, resting on bricks that jutted out as part of that new brick work.

Figure 4: The internal chimney breast at 39 Bishop Street

This work was carried out by an Englishman who had immigrated to New Zealand to work as a mason. He was retired at the time. In Mrs Baird's opinion, the job appeared to have been competently carried out and the bricks seemed very secure.

4.4.3 The September earthquake

Information on events following the September earthquake has come from Mrs Baird and Ms Breanna Gowland. Mrs Baird's son, Mr Shaun McKenna, was living in the property with his then partner, Ms Gowland, and her baby son, Baxtor. As a result of the September earthquake there was significant cracking in the plaster adjacent to the chimney breast in the lounge. However, there was no cracking apparent in the brickwork. There were numerous other cracks in the plaster in the lounge.

The only significant damage to the exterior of the house appears to have been to the top of the chimney, from which bricks fell. However, the rest of the external chimney, which was against the side of the house, did not appear to be cracked or damaged. The chimney was subsequently removed and a tarpaulin cover placed over the hole, but no internal part of the chimney or chimney breast was removed.

Mrs Baird made a claim with the Earthquake Commission (EQC) and with her insurer in relation to damage to the house. Mr McKenna spoke to some EQC assessors who were looking at the middle flat in late January 2011 and asked them to look at the back flat as he was worried about whether they should be living there. The assessors said they could not themselves look at the flat but if he sent details of the EQC claim into EQC, EQC would attend to the matter. Apparently this was done but no reply was received.

No one from EQC had inspected the property or made an appointment to do so before 22 February 2011. No one from the CCC or any other official organisation had been to the property either.

4.4.4 The February earthquake

In the February earthquake all the brick chimney breast area inside the lounge collapsed (as did the external chimney). Just before the earthquake struck, Ms Gowland had left Baxtor sleeping on the floor in front of the fireplace. When the bricks collapsed they fell onto the baby, covering him under a fireguard. Although Baxtor was alive when the bricks were removed, he later died in hospital from his injuries.

Mrs Baird said her son Shaun later commented to her that when he was removing bricks to try to rescue Baxtor, he found that they were in big chunks rather than single bricks.

4.4.5 Issues

Although the potential for external chimneys to collapse now appears to be common knowledge in the community, we believe that the potential for internal fireplace brickwork to collapse is not as widely known. Removal of chimneys at and above roof level may be insufficient to prevent injury or death. We note that in a reply to an inquiry by counsel assisting the Royal Commission, EQC expressed the view that there is a greater need for public awareness of this. However, EQC noted that it is not a property inspection organisation and, therefore, does not have a policy in relation to the inspection of internal chimneys. It follows, therefore, that even if EQC had inspected the building before the February earthquake, it would not have been likely to recommend any remedial work, as there were no obvious signs of damage to the internal chimney breast.

In his report on the building, Mr Smith concluded that it was not possible to assess accurately the cause of the chimney failure that resulted in the death of Baxtor Gowland, whether the modification to the fireplace breast might have weakened the chimney and whether the chimney breast might not have been adequately secured to the remaining chimney elements. However, he has noted that chimneys constructed of unreinforced masonry are a hazard in severe earthquake shaking and that, where there are modifications to chimneys, the structure of the chimney is often weakened as the modifications are unlikely to be integrated into the original chimney structure.

We agree with Mr Smith’s view that consideration should be given to requiring domestic chimneys to be strengthened or demolished and that, following a significant earthquake, external brick chimneys and any exposed brick internal chimney breast may be hazards that need to be assessed and dealt with. We make an appropriate recommendation about this issue in section 7 of this Volume.

4.5 89, 91 and 93 Cashel Street

4.5.1 Introduction

These three buildings were situated side by side on the northern side of Cashel Street between Oxford Terrace and Colombo Street.

Information from police records established that when the February earthquake occurred:

- Mr Shane Tomlin was working at the Trocadero Bakery at 93 Cashel Street, on the first floor. Immediately after the earthquake, a work colleague who had been standing next to Mr Tomlin saw a hole in the floor where he had been standing. Mr Tomlin was found, conscious but badly injured, in the TS Retail Store on the ground floor underneath. He was taken to Christchurch Hospital but died as a result of his injuries.
- Ms Jillian Murphy was shopping with two friends in Deval, which was situated at 89A Cashel Street. It is unclear exactly where she and her friends were when the earthquake hit because the group appears to have exited the shop but Ms Murphy was in the building when it collapsed, trapping her under rubble. Her body was found under collapsed building material.
- Mr Christopher Homan and his wife Mrs Christine Homan were in Cashel Street, standing in the vicinity of 93 Cashel Street when the earthquake hit. Mr Homan's legs were trapped under rubble that fell as a result of the collapse of 91 Cashel Street. CPR was performed on him but he died at the scene.
- Ms Melissa Neale was walking in Cashel Street with her mother, Mrs Margaret Neale, intending to go to the Trocadero Bakery for lunch. They were a short distance from the building when the earthquake hit. Ms Neale's body was found under collapsed building material in the vicinity of 89, 91 and 93 Cashel Street (the evidence does not allow us to be more precise).

Figure 5: 91 Cashel Street before the February earthquake

4.5.2 The buildings

The buildings at 89 and 93 Cashel Street (on either side of the building at 91 Cashel Street) were owned by Hereford Holdings Ltd, the principal of which was Mr Antony Gough. The building at 91 Cashel Street was owned by West Mall Properties Ltd, the principal of which was Mr Tracy Gough (the brother of Mr Antony Gough).

We note that 89 Cashel Street was also referred to as 87–89A Cashel Street, and 93 Cashel Street was also referred to as 93–95 Cashel Street.

4.5.2.1 89 Cashel Street

The structure at 89 Cashel Street was a two storey URM and timber building with a lightweight roof. It appears to have been built around 1878 and was not listed as a heritage or protected building.

Although 89 Cashel Street appears to have had some work carried out on it historically, the degree to which this was structural is unclear. In any event, the building was likely to be earthquake-prone under the Building Act 2004.

Correspondence between the owners and the CCC in the 1980s indicated that the intention was to demolish the building and redevelop it, although this never took place. The building was occupied on the ground floor by two retail premises, Deval and 3 Wise Men, with accommodation on the first floor.

4.5.2.2 91 Cashel Street

The building at 91 Cashel Street (which included 91A) was a three storey unreinforced concrete and masonry structure with a lightweight roof on timber trusses. It was not listed as a heritage or historic building.

There was no evidence of any structural strengthening to 91 Cashel Street and it appears that it was in a relatively original state as at 4 September 2010. It was also likely to have been earthquake-prone in terms of the Building Act 2004. The building was occupied on the ground floor by 123 Mart. Mr Kurt Langer, a photographer, occupied the upper floors.

Mr Bryan Bluck of the CCC wrote to West Mall Properties on 22 August 1995 stating that an inspection had revealed that the upper floors were being used for residential purposes but no change of use from commercial to residential had ever been authorised. A reply from West Mall Properties on 24 August 1995 made no reference to whether there had been a change of use. However, it confirmed a discussion in relation to the installation of a fire alarm and the fact that it was intended that the building would be demolished within the next two years. There does not appear to be any further correspondence on the CCC file in relation to this issue.

At the hearing Mr Tracy Gough was referred to the CCC's letter of 22 August 1995. He said he had spoken to the tenant at that time and subsequently written to tell him he was not entitled to live in the building. When asked in cross-examination whether he had inspected the property to see whether there was any evidence of residential use, such as a bed, after he sent the letter to the tenant, Mr Gough said, "Yes, I have inspected the premises after. I wouldn't call it bedding but there was sort of, there was strange couches and things there…"

After the hearing, counsel assisting the Royal Commission obtained a report from the CCC's building file for 91A Cashel Street, which had been completed after the February earthquake. That report recorded that "Kurt and Karen Langer both live and operate Photography Studio on the second floor". The report listed various items they wished to have retrieved from the building by reference to their location in the building. That included a reference to "south side front bedroom" and "east side back bedroom". Counsel assisting the Royal Commission also obtained an email dated 13 April 2011 from Mr Langer to Mr Buzz March of Buzz March Construction, which stated, "We literally do have everything we own up there …" and listed various possessions he wanted to retrieve from the property. Counsel wrote to Mr Langer asking if he had lived in the building. Mr Langer sent a reply stating that he leased the top two floors of the building for a photography business but that he was "not living at the address".

Enquiries to the CCC revealed that the CCC report form referred to above was prepared by Ms Nicole Chen. Ms Chen has advised the CCC that she is no longer certain where the information on that form to the effect that Mr and Mrs Langer lived in the building came from.

The Royal Commission received a letter dated 26 March 2012 from Mr Gough's solicitor, enclosing a letter from Thompson Wentworth, the owner's property manager. That letter referred to an inspection of Mr Langer's tenancy in December 2011 (presumably this should have read 2010). Thompson Wentworth summarised its inspection by stating, "The premises was leased as a commercial property, was sign written Kurt Langer Photography and appeared to be a working photography studio inside". The letter from Mr Gough's solicitor recorded that they had contacted the property manager and enquired whether he had seen any bedding on his visits. Mr Andre Thompson, of Thompson Wentworth, said that he had seen no bedding, and that during his inspection there was nothing about the way the area was being occupied that led him to think that the occupation was anything but commercial.

4.5.2.3 93 Cashel Street

The building at 93 Cashel Street was a two storey URM structure built around 1885. It does not appear to have had any heritage or historic places classification.

Although the building appears to have had reasonably extensive structural strengthening carried out progressively from 2007 to 2009 on individual tenancies on the ground floor, the CCC still considered the building to be earthquake-prone. The Trocadero Bakery occupied the ground floor and first floor, and TS Retail Store was also on the ground floor.

4.5.3 Events relating to 91 Cashel Street following the September earthquake

After the September earthquake, it was noted in a CCC Level 1 Rapid Assessment on 6 September that 91 Cashel Street had a fallen chimney and accordingly a yellow placard was allocated.

In early September, a visual inspection of the ground floor was carried out by Harrison Grierson Consultants Ltd, structural engineers, on behalf of the owner. Harrison Grierson concluded that "the ground floor retail is structurally sound and safe to occupy, and the status has been assessed as green. Upper levels to remain as yellow, limited access until debris are removed". They noted that the assessment was based on a visual inspection of accessible areas only.

On 10 September 2010, Powell Fenwick, structural engineers, carried out a walk-through inspection for the owner. The inspection noted that the building was "not in immediate danger of structural collapse" but that brick chimneys on the upper floor should be removed urgently. They recommended a more detailed structural inspection and evaluation "in due course to confirm the ongoing structural stability of the building".

A second walk-through inspection by Powell Fenwick on 29 September noted significant cracks in the parapet to the rear of the building, which it said should be further investigated from the roof level. There was no evidence to suggest that this further and more detailed inspection was ever carried out. In fact, Mr Tracy Gough conceded in evidence that he did not obtain a detailed structural inspection of the building before 22 February 2011.

A CCC Level 2 Rapid Assessment on 12 October 2010 noted that the chimney had been removed. It also noted a vertical crack the full height of the inside of the external wall of the stairwell, which needed to be checked by a Chartered Professional Engineer (CPEng). This was categorised as low risk and the building was assigned a green placard.

Two days later, on 14 October, the building was checked by a CPEng, Mr Martin Crundwell, from Opus. Mr Crundwell was not able to gain access to the building to inspect the crack in the stairwell, but he examined the building as best he could externally, including using binoculars from the other side of the street. He noted vertical cracking in the western wall (which could have been old), corresponding to the location of the crack in the eastern wall that had been observed on 12 October. He suspected that the mechanism of this crack was the same as for the crack seen on the opposite side of the building. He also noted cracks in the street frontage at the joint between the walls and horizontal members. Mr Crundwell requested a CPEng report, because "how [the] building works structurally [is] not clearly understood and requires further study". He recorded his concern that "if [the] mechanism of seismic restraint is not well understood, there may be repercussions during subsequent aftershocks that are not apparent at this stage".

Mr Crundwell was asked in evidence why he had assigned a green placard to the building when further investigation was required. He said he thought that there would be a follow-up within a few days and that because he considered the cracks posed no more than a low risk, he considered "G2 (occupiable - repairs required)" was appropriate.

Mr Stephen McCarthy, from the CCC, gave evidence that Mr Crundwell's request was never actioned. He said that he and others at the CCC had questioned themselves as to why this was so and the answer they came up with was that from 14 October to 26 December there was a period of transition from Civil Defence notices to section 124 Building Act notices. Further, because the building had been allocated a green placard, it did not receive the same priority as buildings with red and yellow placards.

After the Boxing Day earthquake, a Level 1 Rapid Assessment of 91 Cashel Street noted "Loose bricks either end. Horizontal cracking". The building was assigned a red placard. The CCC served a notice under section 124 of the Building Act 2004 on the owner of 91 Cashel Street, recording those defects and requiring work to be completed by 31 January 2011. The notice affected the properties on either side (89 and 93) because of the risk to those buildings from the parapets at 91 Cashel Street.

A CCC Level 1 Rapid Assessment of 93–95 Cashel Street on 26 December 2010 assigned a green placard but noted cracking in the front façade, which it recommended should be reviewed by a structural engineer. This never happened. Mr McCarthy explained that the reason for this was that "the whole situation got over-run by the Boxing Day event".

Mr Andrew Brown, a structural engineer from Opus, acting on behalf of the owner, designed and oversaw make-safe work for 91 Cashel Street to address the damage indicated in the Building Act notice. Mr Brown conducted a brief external visual inspection to determine whether there was any other damage as a result of the Boxing Day earthquake, and a brief internal examination (excluding the ground floor, to which he could not obtain access).

Mr Alistair Boyce of Opus inspected the make-safe work and then completed a standard CCC CPEng certificate (modified to refer to the structural integrity of the building being restored or partly restored to its state prior to 26 December 2010, rather than its state before 4 September 2010). Mr Boyce said that in completing the certificate he relied on Mr Brown's advice that he had inspected the building for any additional damage. Neither Mr Brown nor Mr Boyce was aware of the inspection and recommendations by their colleague Mr Crundwell on 14 October 2010.

Mr Peter Smith, who provided an independent report to the Royal Commission, stated that in the February earthquake large sections of the eastern wall of 91 Cashel Street fell onto 93 Cashel Street. Equally significant portions of the western wall façade failed and fell onto the building at 89 Cashel Street. A portion of the frontage fell onto Cashel Street.

Figure 6: 89, 91 and 93 Cashel Street after the February earthquake

4.5.4 Issues

4.5.4.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

4.5.4.1.1 Approach to earthquake-prone buildings

We do not know whether the failure of 91 Cashel Street would have been prevented if any strengthening had been carried out before the February earthquake. However, as Associate Professor Jason Ingham's reports[7] to the Royal Commission showed, any significant strengthening gives a building a better chance of withstanding an earthquake. This highlights the problem inherent in a passive approach by a territorial authority to earthquake-prone buildings.

4.5.4.1.2 Possible change of use

We have referred above to the evidence and information about the "change of use" issue in regard to 91 Cashel Street. There appears to be an inconsistency between the information on the CCC file on the one hand and the letters from Mr Gough's solicitor and Thomas Wentworth on the other. Clearly the matter is relevant to the issue of whether the building was required to be substantially strengthened prior to the September earthquake. We are unable to resolve this issue on the evidence before us. We direct the attention of the CCC to this issue and recommend that it should consider making further enquiries.

4.5.4.2 Assessment of the building following the September and Boxing Day earthquakes

This case highlights the risks inherent in relying solely on a damage-based assessment of a URM building after a significant earthquake.

In this case we note:

- the lack of follow up by the owner of 91 Cashel Street in relation to the recommendation by Powell Fenwick for a more detailed engineering inspection;
- the failure of the CCC to action Mr Crundwell's request for a detailed CPEng engineering evaluation of 91 Cashel Street;
- the limited nature of the inspection carried out by Mr Brown following the make-safe work after Boxing Day prior to completion of the CPEng certificate; and
- the lack of follow up of the Level 1 Rapid Assessment of 93-95 Cashel Street following Boxing Day in which a structural evaluation by an engineer was recommended.

We cannot speculate what might have been the outcome if a detailed evaluation of 91 Cashel Street had been carried out. We are left only with the certainties that there was no such evaluation and that the building suffered a significant failure in the February earthquake with the resulting loss of four lives.

4.6 32 Cathedral Square

4.6.1 Introduction

The Press building was situated at 32 Cathedral Square. It was an ornate four storey heritage building constructed in 1906.

At the time of the February earthquake, Ms Adrienne Lindsay was working on the top floor with seven or eight other staff members of *The Press* newspaper. She was killed when the roof collapsed as she sheltered under her desk on the top floor. Survivors were rescued by Urban Search and Rescue (USAR), who had to cut a hole through the collapsed roof to gain access to the top floor.

4.6.2 The building

The building consisted of four suspended concrete floors with a concrete basement car park and a concrete roof. Typical floor beams were a combination of steel angles and concrete. There were numerous iron and steel beams, and cast iron columns. Thick brickwork walls wrapped the perimeter of the building to the north, east and across the centre, in a combination of reinforced concrete brickwork and stonework frames to the southern and western walls. A large brick-and-stonework turret was located at the south-western corner, extending above roof level.

Figure 7: The south-western corner of The Press building before the February earthquake

Figure 8: The western wall of The Press building before the February earthquake

The original brick-and-stonework parapet extending above roof level was reduced in height in the 1970s, along with the installation of structural steel securing works to the southern and western wall parapets. It is thought that this was the only strengthening work undertaken on the building since it was first built.

A seismic risk buildings survey conducted by the CCC in 1991 gave the building a score of 13, which resulted in a B classification, meaning that remedial action was recommended within two years. A CCC hazardous appendage survey in 1992 recorded noticeable loose masonry and significant mortar deterioration.

Mr Stephen McCarthy from the CCC gave evidence that the CCC had not contemplated any action under its 2006 Earthquake-Prone Dangerous and Insanitary Buildings Policy, as it had been in discussions with the owner of the building, Ganellen Pty Ltd (Ganellen), for about three years regarding the owner's plan to strengthen the building. Mr McCarthy also noted that under the 2010 policy, this being a Category C building, the owner would have had up to 30 years to complete strengthening work unless a building consent application for significant alteration had been received by the CCC. No such application was received.

4.6.3 Events following the September earthquake

After the September earthquake, CCC Level 1 and 2 Rapid Assessments on 5 September recorded minor damage including cracking, which was to be assessed by the owner. The building was assigned a green placard and classified as G1 (Occupiable, no further investigation required). On 6 September a further Level 2 Rapid Assessment noted cracking to a masonry wall and a loose balustrade to the turret tower. The building was assigned G2 (Occupiable, repairs required) and the owner notified of the repairs required.

Ganellen obtained a structural evaluation report from Lewis Bradford, Consulting Engineers (Lewis Bradford), dated 16 September 2010. It was recorded that the inspection was of a general nature and was an initial structural evaluation but no detailed seismic analysis had been undertaken. The report noted that Lewis Bradford had been asked to inspect the payroll area in the north-western corner of the third floor. Significant cracks in the brick wall on the north-western corner of level three were observed, temporary structural steel securing was designed and installed to secure that corner, and the area was cordoned off.

Lewis Bradford recommended the construction of a new in situ shear wall within the following two to three weeks. However, it transpired at the hearing that, on reconsideration, Mr Ashley Wilson, the structural engineer who had carried out the Lewis Bradford inspection, was of the view that this timescale had been ambitious and it might take longer to devise a permanent solution. In his view, while the interim securing that was provided for the northern wall could not be a permanent solution because of weather-proofing and heritage issues, it should have provided adequate support in the weeks and months that followed. At that time he considered that the work carried out would be sufficient for the period in which *The Press* intended to remain in the building: the newspaper was intending to move out in February 2011.

The tenants, *The Press* newspaper, instructed Harrison Grierson Consultants Ltd (Harrison Grierson) to inspect the building and report on its structural integrity. In his report of 15 September, Mr Andrew Thompson of that firm noted various items of damage, although the only ones said to require further assessment were diagonal cracking and loose bricks in the north-eastern corner of the eastern exterior of the third level. Harrison Grierson recommended that the interior pinboard lining be removed to enable inspection of the interior face of this wall. Large cracks in the north-western corner of the third storey were noted, as well as the “emergency strengthening” that had been applied to the wall. The view was expressed that this wall had been sufficiently stabilised until permanent remedial works were designed and constructed.

The report concluded that, with the exception of the areas identified, the building was structurally sound and safe to occupy and that the green placard status was appropriate.

The following areas of damage were noted in an earthquake response report completed by Ganellen:

- payroll office at north-western corner of level three (suspected diagonal shear failure);
- turret railing; and
- stone parapet above main entrance.

Lewis Bradford submitted a structural damage report to Ganellen in October 2010. As with the September report, it was based on a visual inspection. While observing that the building had performed surprisingly well considering the large floor plates, heavy construction and its age, the report noted structural damage throughout. There was significant damage in three main areas: the north-western brick wall at level three, the north-eastern brick wall at level three, and the stonework to the southern and western perimeter frames. The report detailed specific repair work for each of those areas.

Ganellen then put the ongoing structural work required up for tender. Mr Michael Doig, the New Zealand Development and Business Director of Ganellen, said that a tender from Holmes Consulting Group (HCG) was accepted, essentially because it was believed that the analytical methodology (which had been outlined by Mr John Hare of HCG to the owner) “…would provide a better structural solution for the repair of the building”.

HCG took over from 10 November 2010 and undertook a number of inspections in November and December, before providing its initial findings to Ganellen in a report dated 22 December 2010. HCG noted that the strength of the building in its then damaged but temporarily secured state would equate to about 50% of the current new building standard (NBS).

After the Boxing Day earthquake, a CCC Level 1 Rapid Assessment on 26 December 2010 on the same day noted “general brick cracking including risk that neighbour’s parapet on east side could fall on the Press building”. The building was assigned a red placard and a notice under section 124 of the Building Act 2004 was served on the owners.

As a result, the building was evacuated and inspected by HCG on 26 December 2010. Damage was noted to the northern wall and central shear wall on level three, the base of the brick turret at roof level and the piers at the southern wall on levels one to three. In a site report dated 27 December 2010, Mr Hare recommended propping and shoring of the northern and southern walls and propping and shoring to restore the pier strength to the northern and southern façades, which were considered critical load-bearing elements.

A second site visit was conducted by Mr Ben Dare of HCG on 7 January 2011 to inspect the securing works that had been carried out as recommended in Mr Hare’s site report of 27 December and to observe any further damage. Mr Dare noted that the work recommended by Mr Hare to the southern and northern walls and the stairwell had been completed. He also observed that the parapet from the adjacent building (Worcester Tower) had collapsed into the lightwell of The Press building and that a concrete lintel beam below the parapet had sustained a series of moderate-sized cracks. He recommended that temporary waterproofing be installed and the owner of Worcester Tower be notified to deal with the parapet issue. Later that day, Mr Dare sent an email to Mr Nick Jennings of Ganellen, attaching his site report dated 7 January 2011 and stating, "If the additional securing works have been completed, the immediate threat to the tenants of the building will have been removed and it should be safe to occupy on Monday". He then received a phone call from Mr Jennings, who told him that the loose sections of the parapet had been removed and temporary waterproofing installed.

On 12 January 2011 Mr Dare completed a CPEng certificate, a form the CCC required to be signed by a chartered professional engineer (CPEng) before the yellow or red placard on a building could be changed to green and the CCC would accept that the issues raised by a notice under section 124 of the Building Act had been dealt with. The certificate stated that interim securing measures had been taken to restore the structural integrity and performance of the building to at least the condition that existed prior to the earthquake on 26 December 2010. It was sent to the CCC, which then treated the requirements of the Building Act notice as having been satisfied and approved the building for occupation. *The Press* reoccupied the building at that point and remained in occupation until the February earthquake.

Various proposals for strengthening work were provided by HCG because, although a formal assessment had not been completed, it was clear that the building's residual strength after the September and Boxing Day earthquakes would have been less than 33% NBS had it not been for the securing work that had been done. None of these proposals was able to be put into effect before the February earthquake.

In the February earthquake the building suffered severe structural damage including:

- collapse of the third (top) floor including the roof;
- collapse of most of the parapets;
- collapse of the turret; and
- cracks to the southern and western façades.

Figure 9: The roof and eastern wall of The Press building after the February earthquake

Figure 10: The western wall and roof of The Press building following the February earthquake

In his report to the Royal Commission, Mr Peter Smith noted that subsequent photos of the building indicated that "failure of the roof diaphragm over the internal wall allowed the northern portion of the roof to translate in a north-easterly direction, rotating about the junction of the internal unreinforced masonry wall and the east wall. As the northern portion of the wall translated, the northern portion of the roof failed at several of the supporting beam lines".

In Mr Smith's opinion, the northern wall was a very significant part of the torsional resistance to the building. He noted that unfortunately it had not been possible to draw any conclusion as to what had happened to that wall when the building failed. However, he raised a concern with the allocation of a green placard to the building following a Level 1 Rapid Assessment when in fact there was "some reasonably significant damage at the upper level of the building". This was particularly of concern, he said, given that this was a four storey building. He also sounded a caution in relation to the allocation of the green placard when the securing work put in place by Lewis Bradford was seen as temporary. In his view, "we need to be careful to make sure when we give a building a green sticker that we are totally happy this could stay on for some time".

Mr Smith also noted that the issue of vertical acceleration was an important one in relation to the upper floors of unreinforced masonry (URM) buildings. In his view, steps would have to be taken in future "to provide resistance against the detrimental effects of vertical accelerations".

4.6.4 Issues

4.6.4.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

This building had remained in a relatively original condition and does not appear to have had any significant structural strengthening carried out during its history. In common with many other URM buildings, it is an example of an approach that did not require any structural strengthening under the relevant CCC policies because there was never any application for a building consent.

4.6.4.2 Assessment of the building after the September and Boxing Day earthquakes

We note that after the September earthquake both Ganellen and the *The Press* took considerable care to ensure that the building was properly assessed by engineers.

We agree with Mr Smith's comments that care has to be taken in assessing URM buildings, particularly of this nature. The post-earthquake assessment of buildings is discussed in a Volume 7 of this Report.

We think there is merit in Mr Smith's view that, in designing the type of strengthening work that was completed on the north-western wall on the third floor of this building, it would have been appropriate for there to have been a more extensive consideration of the likely load that would come onto the wall in the event of a significant earthquake. As he said, this was an important element in the building at the upper level that should have been subjected to some analysis to be sure that it provided an appropriate level of strength.

Although we will never know now, had there been a more detailed engineering assessment of the building following the September earthquake, and a detailed assessment of the likely load on the north-western wall, higher levels of strengthening may have been required.

4.7 90 Coleridge Street

4.7.1 Introduction

Mr Stephen Cochrane was killed in the February earthquake when a concrete block wall collapsed and crushed him as he ran out of Classique Furniture at 90 Coleridge Street.

Mr Cochrane, who had been working in the building when the earthquake struck, ran out of the side door. Just as he began to run down the driveway the wall toppled over, crushing him underneath it. Efforts were made to rescue him by lifting the wall but he died as a result of being crushed.

4.7.2 The building

Mr Graeme Dreaver, the owner of Classique Furniture, bought the building about 10–12 years ago. On the eastern side of the building there is a driveway that accesses a sliding door. The wall in question was also on the eastern side of the property, very close and parallel to the boundary wall (which is the concrete side wall of the neighbouring building). The wall that failed was free-standing, about six metres high and three metres long.

When Mr Dreaver bought the property the wall was in the same state as prior to the February earthquake. The previous owner told him at the time of purchase that it had been part of a lean-to connected to the building by a roof extending across the driveway. Apparently that roof collapsed in heavy snows (likely in 1992), leaving the wall standing near the boundary where it had remained ever since.

4.7.3 Events following the September earthquake

There did not appear to be any structural problems with the factory building after the September and Boxing Day earthquakes. There was no Civil Defence or CCC assessment of the building between the September and February earthquakes.

During the February earthquake, sideways movement of the wall resulted in the top two layers of concrete blocks breaking off the wall and landing on the roof of the neighbouring building to the east. The rest of the wall fell in one piece in the opposite direction, towards the Classique Furniture building. Because the top two layers of blocks had already come off, the wall just cleared the sidewall of the building as it toppled over.

Mr Peter Smith stated in his report to the Royal Commission that the wall had two reinforcement rods (both approximately 20mm in width), one at each end. The owner has since advised the Royal Commission that there were four vertical reinforcing rods in the wall. Whatever the position was, it is apparent that the wall was inadequately reinforced to resist the effects of the February earthquake.

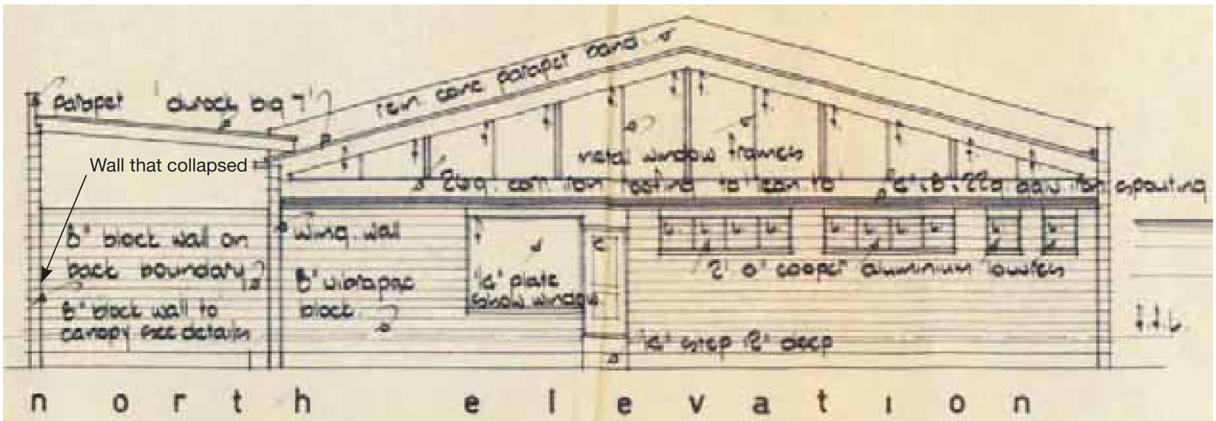


Figure 11: A section from the original plan of the building, showing the wall at left with its lean-to roof attached

Figure 12: The base of the wall after the collapse and removal of the wall

Mrs Tania Cochrane, Mr Cochrane's widow, gave evidence that she had expressed concerns to her late husband about the state of the wall and the danger it posed. She said she had seen cracking in the wall and that the wall was on a slight lean towards the building.

Mr Dreaver did not accept that the wall was cracked or on a lean. He said he had not really given any thought to the potential danger it might pose and that after the September earthquake he thought it must have had some reinforcing to have withstood that event. That evidence was supported by Mr Dreaver's employee, Mr Marc Hobson.

4.7.4 Issue

This case highlights the need for a cautious approach towards a free-standing masonry wall, the structural strength of which is unknown. Even putting to one side the difference in accounts of Mrs Cochrane on the one hand and Mr Dreaver and Mr Hobson on the other, and accepting there is an element of hindsight, we would have thought that a free-standing wall some six metres high and three metres long should have raised concerns after the September earthquake, given the ongoing significant aftershocks.

This case should serve as a lesson to other owners or occupiers of properties with masonry walls, the strength of which is unknown. Such walls should either be adequately restrained or demolished.

Recommendation

We recommend that:

71. Free-standing masonry walls of unknown structural strength should be adequately restrained or demolished.

4.8 382 Colombo Street

4.8.1 Introduction

A two storey URM (brick) building on the eastern side of Colombo Street in Sydenham housed two addresses, numbers 382 and 384. The southern end of that building was number 382. It was immediately adjacent to and north of number 380, which housed The Tasty Tucker Bakery and Coffee Bar. The bakery was part of a single storey building with a light metal roof, which had been constructed around 1972 and also housed the Sydenham branch of the ANZ Bank.

In the February earthquake, the parapet wall of the southern end of 382 Colombo Street collapsed outwards and through the roof of the Tasty Tucker Bakery.

Ms Cheryl Armour gave evidence at the hearing that she was working in the Tasty Tucker Bakery at the time of the February earthquake. When the earthquake struck, she had just served Mrs Maureen Fletcher, who was having her lunch in the bakery with a Mr and Mrs Moon. Ms Armour said that Mrs Fletcher was struck by a beam that fell from the roof. She said there were bricks falling from the ceiling and she thought Mrs Fletcher would have been killed instantly. Another customer, Ms Beverly Edwards, was pinned by a beam and Ms Armour attended to her. Ms Edwards was rendered paraplegic as a result of her injuries. Mr and Mrs Moon sustained some injuries but survived.

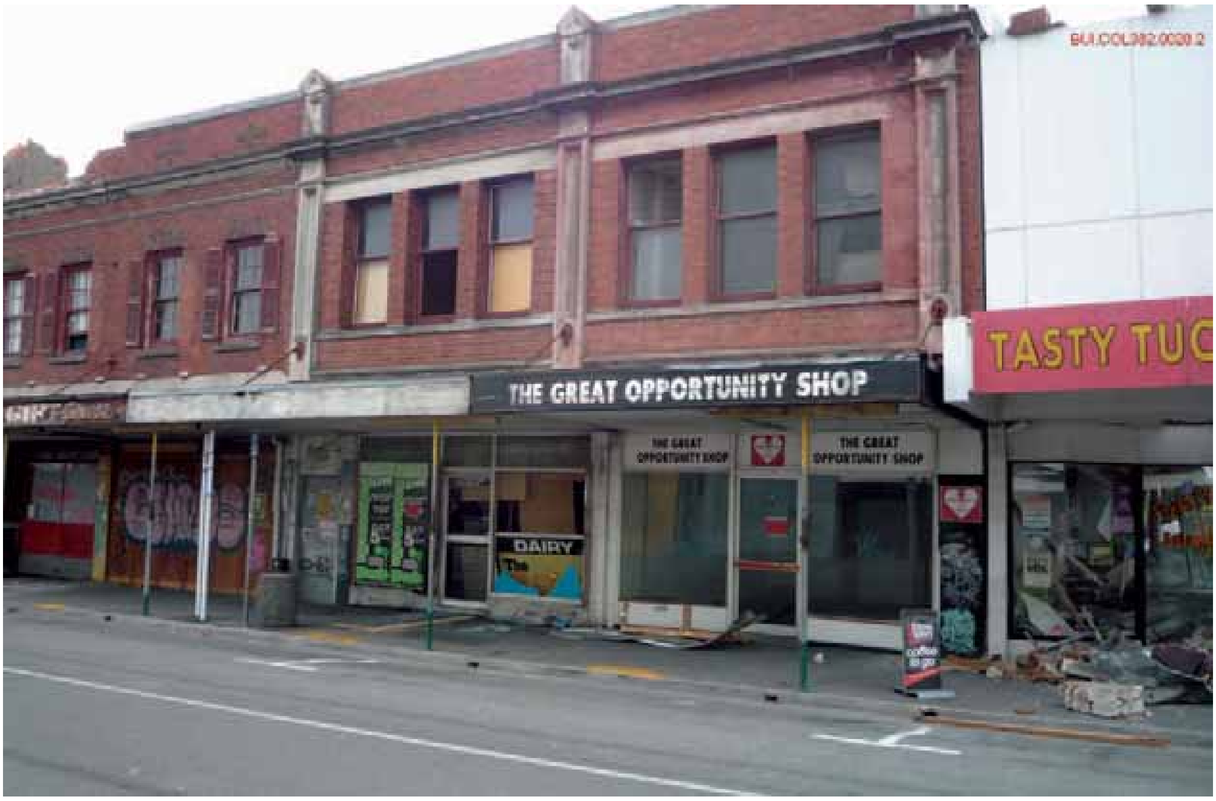


Figure 13: 382 Colombo Street and (at right) the Tasty Tucker Bakery, after the February earthquake

4.8.2 The building

The 382 Colombo Street address housed an opportunity shop and dairy downstairs and what appears to have been residential space upstairs (although that seems to be inconsistent with the CCC file). It was constructed with unreinforced brick walls, timber roof framing and a timber first floor. It was part of an integrated development involving buildings at 382–402 Colombo Street, which had common party walls.

Both the ground floor and the first floor façades had significant penetrations for windows. The south wall of the building, which adjoined the common boundary with 380 Colombo Street, was free of penetrations. The building had prominent parapets on Colombo Street and lower parapets along each side wall. CCC records indicate it was built in the 1920s. There appear to have been very few alterations to the building since its construction.

A CCC seismic risk buildings and hazardous appendage survey in 1993 gave the building a score of 12, which resulted in a classification of B/C, meaning recommended remedial action within two to 10 years. This was not followed up before the September earthquake.

Mr Yan Kin Min (also known as David Yan), a computer systems analyst, is the son of the owner, Mrs Boi Fong Yan. She is 83 years old. It appears that the building was effectively managed on her behalf by Mr Yan, his brother Mr Michael Yan (who lived in Auckland) and his sister Ms Eileen Yan (who lived in Christchurch). Mr David Yan said that no strengthening work had been carried out in the approximately 40 years that his mother had owned the property.

In 2007 the owner applied for a Project Information Memorandum (PIM) in relation to proposed alterations to create living quarters upstairs. The CCC issued a PIM that identified the building as potentially earthquake-prone. The owner then applied for a building consent. This was later cancelled at the request of the owner after the CCC asked for more information. It transpired at the hearing that the further information sought was details of earthquake strengthening that would be required, as the CCC viewed this as a change of use of the property. Mr Robert Ling, an engineer and friend of the owner, acted on behalf of the owner in relation to this application. In evidence, Mr Ling said that he submitted that it was not a change of use, but that this was not accepted. Mr Yan also claimed that residential use had pre-existed the application. Mr Ling said that the owner did not further pursue the building consent application because of the high cost of strengthening that would be required. They were also difficulties in providing suitable access arrangements.

4.8.3 Events following the September earthquake

4.8.3.1 Tasty Tucker Bakery: 380 Colombo Street

It appears from the CCC file that following an assessment on 7 September 2010, the Tasty Tucker Bakery building was allocated a green placard and continued to be occupied and used as a bakery/café.

4.8.3.2 382 Colombo Street

On 7 September a CCC Level 1 Rapid Assessment of the block of shops extending from 382–402 Colombo Street noted minor damage to the brick façade, which “could be damaged further by future aftershocks and the collapsed north wall of [a building to the north of that block]”. The building was allocated a yellow placard.

Mr David Yan said in evidence that he inspected the building with Mr Ling about 10 days after the earthquake. Mr Ling told the Royal Commission that there was a lot of cosmetic internal damage. He said there was substantial damage to the parapet walls on the north end and at the rear (eastern side) of the building. Mr Ling’s evidence was unclear as to the extent of any damage to the internal side of the south wall. However, when asked if he gave any thought to the stability of the building, Mr Ling said that he had looked at the external wall and did not see any external signs of distress on that wall.

Email correspondence of 29 October 2010 between Ms Esther Griffiths, project manager of the CCC’s Building Evaluation Transition Team (BETT), and Mr Gary Lennan indicates that the CCC had unsuccessfully attempted to contact the owner of 382, 384 and 490 Colombo Street. Mr Ling had been contacted that morning; apparently nothing had been done about these properties and Mr Ling had given no indication of urgency. The BETT view was that a notice under section 124(1)(c) of the Building Act 2004 should be served, requiring action by 15 November 2010.

The CCC wrote to Mrs Boi Fong Yan on 29 October 2010 enclosing the Building Act notice. The notice recorded “significant damage to structural walls, party walls, fire walls and/or structural frame (cracking, bowing, failed connections, spalling)”. The notice required work to be carried out by 15 November 2010 and gave the owner the option of seeking a time extension.

No repair work was ever carried out by the owner in response to that notice. Mr David Yan said in evidence that the CCC's letter of 29 October and the notice had been received by his sister Eileen, whose address was on the CCC's file as the mailing address for their mother. His sister, who he said could read English, had opened the letter and noticed that it related to the earthquake. She then passed it on to their brother, Mr Michael Yan, who was in Christchurch at the time, knowing that he would be visiting Mr David Yan. The latter said that his brother was a barrister in Auckland and had had some dealings with the CCC in relation to the building in late 2010 or early 2011. Mr Yan said that his brother had put the letter and notice in a bag, then taken the bag to Auckland and put it in a cupboard where it remained until after the February earthquake.

There was no CCC rapid assessment of the building following the Boxing Day earthquake. Mr Ling said that he considered the rear walls of the building were not safe, that he had told Mr Yan this after Boxing Day and that they should be propped. Mr Ling said that they had been propped with a timber beam and he thought that Mr Yan had had a friend carry this out. However, Mr Yan said in evidence that he had not had any work done on the building.

Mr David Yan gave evidence that a man called "John" (he did not know his surname) was living upstairs at 382 Colombo Street before the September earthquake and remained there after it. He said there was no tenancy agreement but John was paying rent in cash and he collected it occasionally.

Mr Yan said that he thought the reason 382 Colombo Street had a yellow placard was because of the collapse of the building to the north of it, and the potential danger to the front of number 382. Initially he said he thought that if John was not supposed to be there, someone like the CCC would have told him to leave; but later in evidence he said he did not think John should be there because of the yellow placard and he had told him a couple of times that he "should be moving on". He agreed that he had never told the CCC that John was living there. Later it was put to Mr Yan that the statement of Mr Peter Avnell (an Australian loss adjustor for Mr Yan's insurer) to the Royal Commission noted that tenants were still in occupancy. Mr Yan responded that there were two people living at 384 Colombo Street, which also had a yellow placard. He said that he believed they had subsequently moved out to the section "at the back".

Mr Ling said that when he became aware that there were tenants at 384 Colombo Street, he told Mr Yan and the tenants that the latter should not be there. He understood that the tenants moved out into a caravan at the rear of the property but that they were still using the bathroom in the building. Mr Ling accepted in evidence that he had certain obligations as an engineer if he was aware of potential danger from a building. However, he contended that he had effectively discharged this obligation by telling both Mr Yan and John that the latter should not be there. He said did not consider contacting the CCC.

Mr Avnell gave evidence that he inspected the building in January 2011 with Mr David Yan and Mr Ling. He formed the view that, because of the amount of damage (mainly inside), the building was a total loss and he told Mr Yan that. Mr Ling's evidence was at odds with this, in that he said Mr Avnell wanted to have the building repaired.

In relation to the south parapet wall, which he described as the "wing wall", Mr Avnell was concerned because it displayed signs of aged cracking and was on a tilt towards the north. His impression was that the tilt was quite old and he could not detect any signs of fresh cracking at the base of the wall. The main crack that concerned him did not appear to have been exacerbated by the recent earthquakes. Despite this, he was concerned that there could be further problems so he considered the wall potentially dangerous. Mr Avnell said that he did not recall making any specific reference to the integrity of the parapet or wall during his discussions with Mr Ling.

Mr Avnell said that he asked Mr Ling to complete a structural damage report and scope of works on the building. Mr Ling said in evidence that he was still working on this report at the time of the February earthquake. Mr Avnell suggested to Mr Yan that it "might be an idea" if the tenants in the property were asked to move out, because he did not consider it a safe place for people to be living in. Mr Ling said that at the time of the inspection he did not consider the south parapet wall to be dangerous. In cross-examination he conceded that, after looking at the evidence at the hearing and in particular the close-up photographs that Mr Avnell had taken, there might have been "an element of slight potential risk that it might collapse".

Figure 14: The rear of 382 and 384 Colombo Street, showing the wall and parapet of 382 (arrowed)

On 4 February 2011 Mr Mark Ryburn, a structural engineer on secondment from Opus, conducted an inspection, noting moderate damage to parapets, columns, plaster, corbels, walls and "damage to parapets and/or chimneys, and/or ornamental features that may pose a risk to the public and/or adjacent property". His report recommended that work be completed by 4 April 2011. The record noted that the building had been abandoned, although there were signs of occupation in the upper storey. This was not further investigated.

Mr Ryburn said that the purpose of the re-inspection appeared to have been to update the status of the building and check if there had been any further damage that might have necessitated a different placard. He said that he changed the placard of the building to red because there seemed to have been nothing done to the building, and because he also wanted to make sure that the occupants who appeared to be there knew that they should not be.

Mr Ryburn said he could not recall examining the south wall. He said that access and visibility from both the front and the rear of the property were limited, and that a fence prevented him from getting any closer at the rear of the property than the boundary between 384 and 386 Colombo Street.

The owner of the building housing the Tasty Tucker Bakery was not aware of the potential danger from the neighbouring parapet wall at 382 Colombo Street, although he knew there were problems with the building given the barricade fencing in front of it.

Mr Peter Smith said in his evidence to the Royal Commission that in the February earthquake, the south wall parapet failed along the roofline, following what appeared to be the ceiling lining, as if the ceiling had provided some restraint to that wall and stopped a total façade failure. He noted that the crack referred to by Mr Avnell in the parapet was about 600mm above the roofline.

Figure 15: The southern parapet wall of 382 Colombo Street, which collapsed onto the roof of the Tasty Tucker Bakery

Figure 16: The Tasty Tucker Bakery and Coffee Bar after the February earthquake

4.8.4 Issues

4.8.4.1 Application of CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

The requirement to complete substantial earthquake strengthening arose when the owner applied for a building consent in 2007. However, because of the cost of that strengthening, the application was not pursued.

A building that clearly required strengthening was consequently not strengthened. This illustrates the ineffectiveness of a passive earthquake-prone buildings policy in which the trigger for the requirement to strengthen was not consideration of public safety, but a proposal to alter a building for a change in use.

4.8.4.2 Assessment of the building (and in particular the south parapet wall) following the September earthquake

As we have commented in relation to other URM buildings, we agree with Mr Smith that, where there is the potential for a parapet to fall on an adjoining building, there is a risk in not assessing the capacity of the building in sufficient detail to include consideration of the connections of the walls to the roof framing.

In this case, Mr Ling's inspection appears to have been purely damage-based and focused on insurance issues. He did not give any consideration to the capacity of the south wall to withstand ongoing aftershocks. Mr Ryburn also conducted an essentially damage-based assessment as directed by the CCC. He was there to inspect the building for any further damage. His recollection was that he did not look at the south wall, so it follows that he did not give any specific consideration to whether it posed a danger to the adjoining property.

In our view, in future following a substantial earthquake a building such as this should have been allocated a red placard from the outset (and so too an adjoining premises such as Tasty Tucker Bakery) until falling hazard risks had been properly assessed.

We did not have any information before us in relation to the building that existed at 380 Colombo Street at the time of the redevelopment in 1972. However, it may well have been a two storey building adjacent to the existing two storey building at 382 Colombo Street. With the demolition of that building and its replacement by a single storey building, there was the potential of danger from the then exposed second storey of the south wall of 382 Colombo Street. There is a need for greater awareness of such potential danger. We also comment on this issue in our discussion on the failure of the building at 246 High Street.

4.8.4.3 Inaction by the owner

We have difficulty accepting the explanation given by Mr David Yan as to why the Building Act notice was not complied with. It must have been evident that this was an important document that required attention. An owner is legally obliged to respond to a Building Act notice and in this case the owner failed to take any steps to comply with the notice.

Compliance with the Building Act notice might not have addressed the potential risk posed by the south parapet wall, but a detailed assessment of the building by a competent engineer might have addressed that risk.

In relation to the issue of occupants in the building after it had been assigned a yellow placard, Mr Yan said that he had told John that he "should be moving on". Mr Ling said he told Mr Yan that John should not be there. Both men knew that the tenant should not be in the building. While they could have advised the CCC, neither took that action. It also became apparent at the hearing that there were two people occupying 384 Colombo Street who at some stage moved out to a caravan at the rear of the property but were still coming and going from the building. This should not have been the case, as 384 bore a yellow placard as well.

Further, the form completed by Mr Ryburn on 4 February 2011 indicated that people may have been occupying the building. However, the CCC had taken no action to investigate this prior to the February earthquake.

Although there is no evidence that John suffered any injuries in the February earthquake, in our view this case highlights the need for owners and territorial authorities to take steps to warn those using dangerous buildings about the risks they face, and to take action to prevent the occupation of such buildings.

We are also concerned that there were residential tenants at 382 and 384 Colombo Street after an application for a building consent for a change of use to convert the buildings to residential use had been withdrawn in 2007 because of the costs of the strengthening required. Mr Yan has claimed subsequent to the hearing that the use had pre-existed the application and that the application was simply to establish separate access. There is insufficient evidence for us to resolve this issue.

We draw this matter to the attention of the CCC to take such further action as they see fit.

4.9 593 Colombo Street

4.9.1 Introduction

Mr Matthew McEachan worked as a tattooist at Southern Ink Tattoos and was a tenant in the building at 593 Colombo Street. He was killed by falling rubble from the collapse of the Colombo Street façade as he tried to flee the building in the February earthquake.

4.9.2 The building

The building at 593 Colombo Street was a two storey URM building constructed in the early 1900s. It was situated on the corner of St Asaph and Colombo Streets with tenancies on both street frontages (187 St Asaph Street and 593A and 593B Colombo Street).

Southern Ink was the only tenant in the building at the time of the February earthquake.

Figure 17: 593 Colombo Street pictured before and after the February earthquake

It appears that no structural strengthening had ever been carried out and the building was essentially in its original condition on 4 September 2010. As there had been no applications for building consents in the past, the owners had not been required to carry out any structural strengthening.

Seismic risk and hazardous appendage surveys in 1991 and 1992 respectively highlighted concerns with the building's masonry. The seismic risk survey recommended remedial action within two years but no action was taken.

In evidence Mr Stephen McCarthy from the CCC said that the seismic risk survey was not followed up because the Building Act 1991 came into force in April 1992 and section 8 of the Act provided that the CCC could not require buildings to be upgraded to a higher standard than they had been built to previously.

Mr McCarthy agreed that an initial desktop evaluation of buildings was carried out when the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy 2006 came into effect and that this would have highlighted the result of the seismic risk survey for this building, but no action had been taken in relation to that survey.

Mr McCarthy speculated that the hazardous appendage survey was not followed up because it did not reveal an immediate danger.

4.9.3 Events following the September earthquake

The evidence the Royal Commission heard focused on events following the September earthquake. That evidence highlighted confusion and a breakdown in communication, both of which may have contributed to Southern Ink remaining in occupation of the building at the time of the February earthquake when that should not have been the case.

Mr Simon Wall, a CPEng of seven and a half years' experience, worked as a volunteer in the days following the September earthquake. He conducted a Level 1 Rapid Assessment on 5 September 2010. He allocated two different placards to the building: a yellow placard on 187 St Asaph Street and a green placard on the Colombo Street frontage.

His reason for doing this was that there was visible damage to the south-western corner of the building but not to the Colombo Street (eastern) end. He considered that the visible damage did not affect the eastern end. He said that he intended to put green placards on the door of each of the tenancies on Colombo Street, although he could not specifically recall doing this.

Evidence was given by Mr Peter Smith, who carried out an independent assessment of the earthquake performance of the building for the Royal Commission. In his view, the assignment of a yellow placard to the tenancy of 187 St Asaph Street should have resulted in yellow placards to all other tenancies in that building, so that the whole building should not have been occupied. Mr Smith was involved in the volunteer effort following the September earthquake and recalled a briefing in which an instruction was given to placard tenancies in the same building in that manner. Mr McCarthy expressed the view that the briefings for volunteers were comprehensive and included the instruction that Mr Smith had recalled. However, he noted that the damage to this building after September was limited to the south-western corner and that this may have been why the focus was on that part of the building. Mr McCarthy also said that on receipt of the rapid assessment reports for 187 St Asaph Street and 593 Colombo Street, the CCC would have opened separate files in relation to those tenancies.

On 13 October 2010, a CCC Level 2 Rapid Assessment of 187 St Asaph Street confirmed the yellow placard and recommended a detailed structural engineering evaluation. That same day, a CCC "Enforcement Team Notices Coversheet" noted under "Further Action" that a CPEng was to provide a report on the safety of the building and that there should be a Notice to Fix for work relating to the south-western street frontage. Mr McCarthy said in evidence that although the CPEng report was not followed up by the CCC, "there were priorities set, and where it was scheduled it would have eventually got done". There was no communication from the CCC to the owners at any stage of the need for such a report.

Mr Christopher Chapman, a property manager from Grenadier Real Estate Ltd, which trades as NAI Harcourts, gave evidence that Harcourts were contacted a few weeks before the September earthquake by the owners of the building (the Chang family, who at that time were living overseas) about the possibility of Harcourts managing the building. However, no management agreement was entered into. Then, after the September earthquake, the owners contacted Mr Chapman to see if he could help them deal with the building in the aftermath of the earthquake. Mr Chapman made it clear that at no time was there any concluded property management agreement, but said that he was "acting as a facilitator", assisting the owners and in effect representing their interests in discussions with engineers and tenants.

We note that Mr Matthew Parkin (one of the owners of the Southern Ink business) sent an email to Mr Chapman on 20 September 2010 in which he said he understood that Mr Chapman was the new property manager. In responding to that email, Mr Chapman did not disabuse Mr Parkin of this notion. Whatever the exact contractual position, Mr Chapman was effectively acting as a property manager. Consistent with Harcourts' approach to all of the buildings under their management, Mr Chapman arranged for an "initial earthquake inspection" of the building by Holmes Consulting Group (HCG).

A Level 2 Rapid Assessment was carried out by Mr Alistair Boys of HCG on 24 September 2010. Mr Boys' evidence was that there was a yellow placard at that time located on or adjacent to the front entry of the lingerie store at 593A Colombo Street, next to Southern Ink. Counsel for HCG produced a photograph taken on 4 October 2010, said to show a yellow placard on that entrance. Due to damage observed on internal inspection of the building, Mr Boys was of the view that the whole of the building should retain its yellow placard status and be unoccupied. He said that he was not aware that Southern Ink was still in occupation of 593B. He did not see any tenants in the building and did not go into the Southern Ink tenancy. He could not recall whether there was a placard on the entrance to Southern Ink. Mr Boys said that he spoke to

Mr Chapman on 24 September to report on his inspection of the building. While Mr Boys could not specifically recall telling Mr Chapman that the building "was yellow", he said he would have given him that information at a meeting following his inspection that day. It was his evidence that he told Mr Chapman that the yellow placard status of the building should remain.

At that meeting he handed Mr Chapman a handwritten site report that he had completed. That report did not include any reference to the yellow placarding. Subsequently, Mr Boys completed a typed site report which recorded, "Not safe to occupy (YELLOW tag remains in place)". This notation did not appear on the handwritten site report. Mr Chapman maintained at the hearing that he never received the typed site report. Subsequent to the hearing, HCG located an email that forwarded the typed site report to Harcourts on 29 September 2010, along with many other similar reports. A statutory declaration from Mr Ryan McCarvill of HCG confirmed that he had checked that this email had left HCG's email server and there was no evidence of any "non delivery report" being received. In a statutory declaration completed subsequent to the hearing, Mr Chapman said that he had never received this email and that his inquiries had established that this might have been because of the size of the attachments. He referred to another unrelated email that had been sent by Harcourts but never received and for which no "non delivery report" was received. We are unable to resolve this conflict in the evidence.

Mr Parkin confirmed that after the September earthquake the front door of Southern Ink initially had a green placard but that at some point it had been removed. He could not say when. It does not appear in the photograph taken on 4 October 2010. He confirmed that he recalled seeing the yellow placard on the central door of 593 Colombo Street, but again could not say when. We are aware from our inquiries into other buildings that the colour of some of the placards on buildings faded from green to yellow over time. While that may have happened in this case, we think it unlikely in the comparatively short period that elapsed before Mr Boys' inspection. Having considered all the evidence, we have concluded on the balance of probabilities that at some point between 5 September 2010 and 24 September 2010 a yellow placard was placed on the central doorway to 593 Colombo Street. However, there is no evidence before us to establish who placed the placard there and the date when that was done. It does not appear that there were any CCC-initiated inspections during that time, nor were any inspections initiated by the owners.

The next inspection of the building took place on 4 October 2010. It was carried out by Mr Richard Seville of HCG. Access to the building was gained via the Southern Ink premises. At that time Mr Kerry Parkin, Matthew Parkin's brother and business partner, was present and the business was in operation. Mr Seville said in evidence that when he saw Southern Ink in occupation it was his view that they should not be there, but he did not believe there was an immediate safety issue. Although it was not referred to in his brief of evidence or examination-in-chief, Mr Seville said in cross-examination that following the inspection of 4 October, he had contacted Mr Chapman by telephone and told him that the building was yellow-stickered and that the tenants should not be there. When Mr Chapman was recalled to give evidence on this issue, he said that Mr Seville had not told him that the building was yellow-stickered and that tenants should not be there. He produced a copy of his diary for 4 October 2010. Although it recorded a telephone call from Mr Seville, Mr Chapman said the call related to a property at 124 Lichfield Street. In submissions dated 27 January 2012, counsel for HCG, Mr Beadle, referred to the fact that on that page in Mr Chapman's diary there appeared to be a reference to 593 Colombo Street. This diary note indicates either that there was a conversation or at least there was an attempt by Mr Seville to contact Mr Chapman about this property, although it does not assist as to the content of any conversation.

Mr Seville emailed Mr Chapman on 6 October 2010 referring to the inspection on 4 October and the fact that the external walls of the building appeared to be moving out on three elevations and that a further inspection was necessary. He attached a site report dated 4 October 2010 that did not contain any reference to the placard or occupancy issue. The email also attached a short form agreement for the owners to sign in relation to temporary shoring and strengthening design. This was signed by the owners on 19 October 2010.

On 8 October 2010 Mr Chapman emailed Matthew Parkin and advised him that, from the structural engineer's report he had received "the other day", it might be some time before the building could be "tenanted legally". In evidence Mr Chapman explained that by "tenanted legally" he meant that the building could not be re-tenanted until the immediate repairs required had been carried out. It was not intended to imply that the Southern Ink premises were not "tenanted legally".

There was other email correspondence between Matthew Parkin and Mr Chapman between September 2010 and February 2011. In some of those emails Mr Parkin asked whether Southern Ink should be in occupation, given the damage to the building. Mr Chapman's replies were essentially to assure Mr Parkin that the building was being assessed by engineers who would report in due course. For example, in an email of 18 November 2010 Mr Parkin said, "It makes me nervous bringing the general public into the studio when you still haven't confirmed whether the building has been deemed safe or not". Mr Chapman replied on 19 November advising that he had a meeting scheduled with the owners on the following Monday to "sort out how we get this property sorted". Mr Chapman met with the owners and a representative from HCG (likely to have been Mr Paul Roberts) at the building on 24 November 2010. It appears that there was no advice from Mr Chapman regarding the result of this inspection until January 2011.

In an email dated 28 January 2011 Mr Chapman advised Mr Parkin that the engineers were at that time working on the "whole rebuilding/repair work required as well as having to build into that the requirement to earthquake strengthen to 67 per cent of the building code". Mr Parkin replied by email on 28 January 2011, "Sixty seven per cent sounds like a lot, is there quite a bit of damage up there? And if so how safe are we downstairs". Mr Chapman replied on 16 February 2011 saying, "I have finally received some repair plans which I have forwarded on to a contractor to price – these plans include repairs required now so we can re-tenant the empty spaces as well as works required to meet the CCC's 67 per cent seismic requirement". These plans had been forwarded by Mr Seville to Mr Chapman on 11 February 2011. Referred to by Mr Seville as "mark-ups", they showed the general concept for strengthening of the building, "split into what is required to be done now for occupancy and what is required to aim for 67 per cent". The immediate repairs required were marked in red and included strengthening work on the eastern (Colombo Street) frontage, including replacing columns on that side.

Mr Chapman forwarded the plans to the Chang family, care of Ms Joy Chang, despite having received an email from Ms Chang dated 23 January 2011 advising him that her family had decided that they would like to "hold off the repairs of the property" and "take over the property management" themselves while they were deciding "what to do with the property".

On 14 February 2011, Mr Mark Ryburn, a structural engineer on secondment to the CCC from Opus International Consultants Ltd, conducted a re-inspection of 187 St Asaph Street. His evidence was that he received a form from the CCC (headed "Engineer's Re-Inspection of Damaged Buildings") that had the address "187 St Asaph Street" typed on it. Mr Ryburn said that he inspected the St Asaph Street frontage of the building. He could not recall inspecting the Colombo Street frontage. He changed the placard on the 187 entrance from yellow to red. When asked to describe the level of such re-inspections, Mr Ryburn said they were "probably less thorough than a Level 1".

Mr Ryburn considered it was acceptable to place a red placard on part of a building as his inspection was not an overall assessment of the building but rather focused on the damage to which he had been directed. He noted on the re-inspection form that no work appeared to have been carried out on the south-western corner since 12 October 2010.

Mr Smith's report to the Royal Commission stated that the first-floor façade of the building failed by an outward rotation of the façade above the first-floor support in the severe shaking during the February earthquake.

Mr Smith made the point in evidence that there would only have been strength in the connections between the Colombo Street façade and the transverse walls if there was no damage. However, from the exterior it was virtually impossible to tell if there was any damage and in fact it might have been necessary to remove internal linings to identify any damage. Therefore a Level 1 Rapid Assessment was unlikely to reveal such damage and an internal inspection in which linings were also removed might be required.

4.9.4 Issues

4.9.4.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

The CCC had identified concerns with the masonry in this building in 1991 and 1992. Mr McCarthy noted that the building would have been deemed to be earthquake-prone under section 66 of the Building Act 1991 and would have continued to be regarded by the CCC as possibly earthquake-prone under the Building Act 2004.

The CCC's 2006 Earthquake-Prone Dangerous and Insanitary Buildings Policy did not require any structural strengthening of the building, given that no application for a building consent for change of use or significant alteration was lodged. The building was, therefore, in a relatively original state when the earthquakes began in September 2010.

The failure of this building in the February earthquake illustrates the risk to human life inherent in a passive approach in relation to earthquake-prone buildings. As Associate Professor Ingham's reports[7] to the Royal Commission show, and as Mr Smith noted in his evidence, the façade of an URM building has a much better chance of withstanding earthquake forces when it has been significantly strengthened.

4.9.5 Assessment of the building following the September earthquake

4.9.5.1 Placarding of individual tenancies

While we can understand how Mr Wall concluded that different placards could be assigned to the different tenancies in the same building (given his focus on the damage to the south-western corner), we are of the view that the intended CCC approach is preferable: tenancies within the same building should be assigned the same placard. Viewing a building as a multiple structure because of units or titles when it is a single structure is not helpful from a seismic resistance perspective, and results in the type of confusion that ensued in this case following the allocation of different placards.

It would seem that Mr Wall was not alone in assigning placards to a building in this way. Mr Chapman gave evidence of a property managed by Harcourts at 124 Lichfield Street that had two street frontages with different placards on each.

When Mr Ryburn inspected the building on 14 February 2011 he was directed by the address on the form he was given by the CCC to 187 St Asaph Street. This meant that he concentrated on that frontage.

We make recommendations about adjoining structures and buildings divided into separate units and tenancies in section 7 of this Volume.

4.9.5.2 Communication of assessments

Following the inspection by Mr Boys on 24 September 2010, HCG concluded that the whole of the building was “not safe to occupy (YELLOW tag remains in place)”. While in the past the presence of a yellow or red placard on a building was understood by owners, property managers and engineers to be notice to occupiers that the building was unsafe to occupy, the misunderstandings apparent from this case lead us to conclude that where an engineer finds damage to a building that is inconsistent with it being occupied, this needs to be clearly conveyed to those at risk by the owner, engineer and property manager alike, notwithstanding the presence of the yellow or red placard.

While there are factual issues that we cannot resolve (for example, in relation to the placement of the yellow placard on the central entrance of the Colombo Street frontage), it is clear to us that events occurred that sometimes were not entirely the fault of any individual, but which resulted in a breakdown in communication. In particular:

1. It is unfortunate that Mr Boys did not record his understanding of the placard status of the building in his handwritten site report dated 24 September 2010. While there is a dispute in the evidence that we cannot resolve (between Mr Boys and Mr Chapman over the content of their conversation following the inspection), and uncertainty as to whether the typewritten site report was received by Harcourts, if it had been made clear in the handwritten report given to Mr Chapman, it would have been obvious that the tenants should not remain in occupation. However, we accept that Mr Boys said he was not aware that the tenants remained in occupation and therefore would not have seen any immediate need to clarify the issue.
2. Mr Seville inspected the building on 4 October 2010 at a time when he must have known that the building was assigned a yellow placard and should not be occupied. He gave evidence that he did not have any immediate safety concerns but that he told Mr Chapman on the day of the inspection that the tenants should not be there. Mr Chapman denied being told this by Mr Seville. There is again insufficient basis for us to decide which of these accounts is correct. In hindsight, it would have been preferable for Mr Seville to have told the tenants directly of his concerns at the time of this inspection, which might have avoided any misunderstanding.

3. Mr Chapman was an experienced property manager who was faced with persistent queries from the tenants about the safety of the building. We are concerned that he does not appear to have communicated to the tenants at any stage that they should not be occupying the building, and in particular after receiving the email dated 11 February 2011 from Mr Seville with the mark-up plans showing the strengthening that had to be done before occupancy (some of that strengthening work involving the Colombo Street frontage). Mr Chapman conceded in evidence that he "possibly" should have told the tenants of Southern Ink about the fact that work was required before occupancy, rather than letting them continue to occupy the premises after receiving this email.

   Subsequent to the hearing, copies of management reports for September and December 2010 sent by Harcourts to the owners of the building were received by the Royal Commission. Both of these reports contain the following statements:

   a) under "Current Status", the phrase: "Structurally unsafe to occupy"; and

   b) under "Recommended Actions – Harcourts", the phrase: "Advise the tattoo tenant that landlord is unable to renew the lease as the premises are untenable (sic)".

   In an explanation sought by counsel for the Royal Commission in relation to the latter phrase, counsel for Harcourts advised that the word "untenable" should have been "untenantable" and that this advice to the owner reflected the extent of the structural work likely to be required to repair the building and to bring it up to an acceptable standard "which meant that no tenants would be able to enjoy meaningful occupation of the building while work was being carried out". Further, counsel submitted that Mr Chapman was effectively saying that the owner should not renew Southern Ink's tenancy. That lease was not renewed but went to a monthly tenancy at a reduced rental, to reflect the fact that there was some damage to the premises. Reliance was also placed on the confusion said to have been caused by the initial green placarding of those premises. In relation to the phrase "structurally unsafe to occupy", counsel in further submissions relied on the same explanation.

   Counsel for HCG submitted that the use of these phrases, in particular the latter, supports the proposition that Mr Chapman must have been aware that the premises as a whole were unsafe to occupy. We are reluctant to come to that conclusion in the absence of cross-examination on this further material. However, this does not alter, and if anything reinforces, the concerns we have expressed above, namely that Mr Chapman did not communicate to the tenants that they should not be in occupation of the building.

4. The same could be said of the owners who must have been aware that the Southern Ink premises remained occupied throughout, although we accept that they were relying on Mr Chapman to deal with the engineers and tenants.

While the various parties have given explanations for the continued occupation of a building that had been assigned a yellow placard, this will afford little comfort to the family of Matthew McEachen.

4.9.5.3 Cordons

The allocation of a yellow placard to the tenancy at 187 St Asaph Street led to a Level 2 Rapid Assessment of that damage and to a cordon being erected on the St Asaph Street frontage.

As Mr Smith noted, a Level 1 Rapid Assessment of the Colombo Street frontage would have been insufficient to determine whether there was any potential damage to the connections between the Colombo Street façade and the transverse walls. However, the initial allocation of green placards to the Colombo Street frontage meant that no Level 2 Rapid Assessment was carried out by the CCC, which was unaware of the detailed inspections by HCG. While we accept that it was not common practice for an engineer to notify the CCC of the results of an inspection carried out for an owner when the engineer was not aware of any change in placard status consequential on the report, this case raises the issue of whether in future the results of any such inspections should be notified to the relevant territorial authority. Had the CCC been advised of those inspections, the issue of a cordon in front of the Colombo Street frontage might have been reassessed.

In evidence, Mr McCarthy said that, until an owner provided a report from a CPEng as to the structural stability of a building, the CCC was not in a position to properly assess placement of a cordon. He agreed (as is the case) that only the Council can control the location of cordons. In our view, this highlights the risk with lack of communication of the results of inspections following a substantial earthquake, not only to owners and tenants who could be at risk, but also to the territorial authority responsible for ensuring public safety.

Post-earthquake building management is discussed in Volume 7 of this Report.

4.10 595 and 595A Colombo Street

4.10.1 Introduction

The building at 595 Colombo Street was a two storey unreinforced masonry building situated immediately to the north of 593 Colombo Street.

On 22 February 2011 Ms Rachel Conley had been in the Southern Ink premises (593B Colombo Street) minutes before the earthquake, to make an appointment. She left Southern Ink and walked north along Colombo Street. Her friend Ms Jessica Kinder was with her. In a written statement Ms Kinder described seeing a heavy concrete slab fall and strike Ms Conley's body during the earthquake, trapping her. Shortly after, a group of men began to dig at the pile of rubble Ms Kinder indicated. Ms Conley was found and her pulse checked but she was dead.

Ms Kinder's written statement makes it reasonably clear that Ms Conley was outside 595 Colombo Street when the earthquake struck. That evidence is supported by the written statement of Ms Denise Healy, who saw men frantically trying to remove masonry covering a person in front of the Lotus Heart (the restaurant at 595 Colombo Street).

Mr Hayato Sakaguchi, one of the owners of 595A Colombo Street, the building adjacent to 595, was summonsed to appear at the hearing but did not attend. In an email to counsel assisting the Royal Commission, Mr Sakaguchi stated that just after the February earthquake he heard a voice calling a lady's name, "Rachel", at the shop front and that about 10 people were calling her name and trying to pull debris away from her. He said that they did not find anyone. Had Mr Sakaguchi answered the summons, this observation could have been clarified. However, counsel assisting the Royal Commission investigated and called evidence about the failure of 595A Colombo Street in case there was any uncertainty as to where Ms Conley was at the time of the earthquake and which building failure caused her death.

Figure 18: 595 Colombo Street (blue frontage), pictured before the February earthquake. The Japanese restaurant is 595A

4.10.2 The buildings

Both buildings were of similar construction to 593 Colombo Street and are thought to have been built in the early 1900s.

The building at 595 Colombo Street had not had any structural strengthening before the September earthquake, while 595A had had some strengthening in 2001 to remove its earthquake-prone status under the law then in place (the Building Act 1991). However, as at 4 September 2010, that building (and 595 Colombo Street) would have been earthquake-prone in terms of the Building Act 2004.

In 2004 the tenant of 595 Colombo Street applied for a retrospective building consent for alterations that had already been started. Subsequently, the CCC determined, and advised the owners, that because there was no change of use and the alteration work was not considered to be "substantial" the CCC would not require any structural strengthening to be carried out. The building consent was granted but the tenant subsequently decided not to proceed with the work and asked for the consent to be cancelled.

As part of that building consent application, the tenant had obtained an engineering assessment of the building from Endel Lust Civil Engineering Ltd, which recommended a five-year securing programme for the building. The programme included:

- mortar work (immediate – within one year);
- installing ties to ground floor cavity brick walls (intermediate – within three years); and
- installing independent steel frames to support the first floor and roof (long-term – within five years).

4.10.3 Events following the September earthquake

After the September earthquake, both buildings were assigned green placards after a Level 1 Rapid Assessment in which minor or no damage was noted. In line with the CCC's policy at the time in relation to buildings that had been assigned a green placard after the September event, there was no further inspection following the Boxing Day earthquake, unless the CCC was aware of the need for one to be made.

Mr and Mrs Patel, the owners of 595 Colombo Street, arranged through their son Hitem Patel (who gave evidence) for an engineering inspection by a structural engineer, Mr Noel Hanham from TH Consultants Ltd. Mr Hanham gave evidence that the Patels wanted him to investigate the extent of the damage and ascertain whether there were any immediate safety concerns associated with the building. From his discussions with Hitem Patel, Mr Hanham concluded that the Patels did not want a detailed inspection.

Mr Hanham carried out a Level 2 Rapid Assessment that did not involve consideration of plans, removal of linings or inspection of the ceiling cavity. He concluded that while the building was likely to be earthquake-prone, there was no substantial structural damage and it was "essentially safe". In evidence, Mr Hanham explained that by this he meant that the building had not suffered any significant structural damage, so its condition was similar to what it was before 4 September 2010. His approach was encapsulated in the report he prepared dated 3 February 2011 in which he described the damage that he had observed, and then wrote:

> Building conclusion:
>
> - The building has not been severely damaged by the earthquake;
> - There is no evidence of significant structural damage;
> - The ground floor remains in a habitable condition;
> - The first floor requires work to restore to pre-earthquake condition; and
> - The first floor ceiling presents a potential hazard from plaster falling off the laths.

Mr Hanham gave evidence that, in hindsight, the damage-based test for occupancy (which was adopted by most if not all engineers before 22 February) was the wrong test.

Mr Peter Smith, who prepared an independent report for the Royal Commission, concluded that both buildings failed in the February earthquake by an outward rotation of their first-floor façades, including the parapets, which collapsed onto Colombo Street.

Figure 19: 595 (to the left) and 595A (adjacent to it) Colombo Street after the February earthquake

4.10.4 Issues

4.10.4.1 Application of CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

The failure of both of these buildings illustrates the risks to human life inherent in a passive approach to earthquake-prone buildings policy.

In relation to 595 Colombo Street, the tenant's engineer had recommended securing works. Yet legally the owner could not be required to carry out those works, even those said to be required in the immediate future unless the CCC considered the building was dangerous.

The experience with both of these buildings provides support for the recommendations made in section 7 of this Volume that territorial authorities should adopt active and more immediate earthquake-prone buildings policies.

4.10.4.2 Post-earthquake assessments

We are of the view that the damage-based test applied by most engineers to building assessments following the September earthquake needs further consideration. As Mr Hanham noted, the lessons from the February earthquake show the inadequacy of placing sole reliance on such a test insofar as URM buildings are concerned.

We will make a recommendation as to the approach we consider appropriate in Volume 7 of our Report.

4.10.4.3 Upgrading of unreinforced masonry buildings

The strengthening carried out at 595A Colombo Street failed to prevent the façade from collapsing, although it appears to have had some minimal effect. This underscores the urgent need for unreinforced masonry buildings to be adequately strengthened, with parapets and façades restrained, as discussed in section 6 of this Volume.

4.11 601 and 601A Colombo Street

4.11.1 Introduction

The building at 601 and 601A Colombo Street was a two storey URM building situated at the end of a block of similarly constructed buildings on the south-western corner of Mollett and Colombo Streets.

On 22 February 2011 Mr Normand Lee was a pedestrian on Colombo Street. After the earthquake, his body was found in rubble in front of 601 and 601A Colombo Street.

Figure 20: 601 (Pleasure Plus) and 601A (Longhorn Leather) Colombo Street following the September earthquake

4.11.2 The building

The building appears to have been constructed in the early 1900s with timber roof framing and a timber first floor. There was a party wall between tenancies and a party wall with the adjoining building to the south.

The building had a reasonably open façade to Colombo Street but was less heavily penetrated on the Mollett Street frontage. It had a high parapet on the Colombo Street façade, the parapet sloped downwards along the Mollett Street frontage. Before the September earthquake the building was essentially in its original condition, no earthquake strengthening having been carried out.

The building was assigned a red placard by the CCC following the September earthquake, owing to the partial collapse of the Mollett Street façade. Cordons were placed blocking off Mollett Street and the footpath adjacent to 601A Colombo Street. It appears that those cordons remained in place until 22 February 2011.

Figure 21: The damaged Mollett Street frontage of 601A Colombo Street after the September earthquake

The building was owned by Mr Simon Yee, Mr Leo Yee, Mr Donald Yee, Mr Ewan Yee and Mr Sun Nam Yee. Mr Marton Sinclair, of Eliot Sinclair & Partners, inspected the building on behalf of the owners on 15 September 2010. He concluded that it was unsafe to occupy.

On 15 October 2010 there was a further CCC Level 2 Rapid Assessment, which confirmed the red placard and noted that demolition was likely. The inspector recommended an engineer's report be obtained and accordingly the CCC wrote to the owners requesting that they provide a report from a CPEng. Mr Stephen McCarthy from the CCC gave evidence that the reason the CCC requested this was to help assess the stability of the building. It was not for the purpose of assessing the adequacy of the existing cordon, although he said it would have helped with this assessment.

Following the Boxing Day earthquake, a Level 1 Rapid Assessment was carried out on 27 December 2010. The red placard status was confirmed and either a Level 2 Rapid Assessment or a detailed structural engineering evaluation was recommended.

On 28 December 2010 the CCC served the owners a notice under section 124 of the Building Act 2004 requiring work to be done by 31 January 2011 to reduce or remove the danger posed by the building. Mr McCarthy conceded that no Level 2 Rapid Assessment was carried out as had been recommended in the Level 1 Rapid Assessment on 27 December 2010. However, he explained that was because no state of emergency was declared following the Boxing Day earthquake and the CCC was relying on Building Act notices rather than requiring Level 2 assessments.

Mr John Dallison, a principal in the Christchurch law firm Harold Smith & Dallison, acted for the building owners and effectively managed the property for them. He gave evidence that, although following receipt of Mr Sinclair's report in September 2010 consideration was initially given to demolishing the building but retaining the façade, the owners eventually decided to demolish the whole building towards the end of 2010. Mr Dallison said that he had discussions with the CCC before 24 January 2011 in which demolition had been raised but he agreed that the CCC record produced in evidence, of a telephone conversation between him and the case manager on 24 January 2011, was the first record of that issue being raised with the CCC. In that conversation, Mr Dallison advised that the owners wished to demolish the building and they would soon be going through the consent process.

Mr Sinclair carried out a brief external inspection in late January 2011 following a request from Mr Dallison. He observed significant cracking to the upper northern end of the building close to the Colombo Street façade. His evidence was that despite this cracking and the internal cracking that had been observed in September 2010 (including vertical cracking to the transverse wall between 601 and 601A, close to the Colombo Street façade), he did not believe the Colombo Street façade was at risk of collapse. Rather, he thought that at worst there was a risk of collapse of the parapet on the north-eastern corner of the building. Although he said that he did not directly turn his mind to the adequacy of the cordon, he considered that it was sufficient, given the damage observed and the similar cordons in place around the city at that time.

On 31 January 2011 Mr Paul Campbell, a structural engineer on secondment to the CCC from Opus, carried out a re-inspection of the building. This was part of a follow-up by the CCC in relation to buildings subject to Building Act notices. That inspection was external only. Mr Campbell confirmed the red placard status of the building. He requested an engineer's report on the Colombo Street façade and any temporary works required to move barriers. Mr Campbell said in evidence that from his assessment of the damage to the building he believed that the cordon was adequate. Further, he said that a CPEng's report was required to confirm whether the cordon was in the right place and whether it could be moved back closer to the building.

Mr Campbell carried out a further re-inspection on 14 February. He noted that the northern end of the building (601A) had more damage than 601 but that it was all one structure so the building as a whole was compromised. He also recorded, "Urgent CPEng report required." When asked why the report was urgent when he thought the cordon was adequate, Mr Campbell said it was because there had been no action from the owner and it was important to get some action.

It is unfortunate that, given that the building did not have heritage status, the owners did not proceed with demolition in a more timely manner or at least signal that intention to the CCC at an earlier stage. We accept, however, the explanation of Mr Dallison that there were delays as a result of having to deal with insurers, and note his assumption that because the building was unoccupied and cordoned off, the demolition was not urgent.

Mr Peter Smith said in his report to the Royal Commission that in the February earthquake the failure of the Colombo Street façade and the remainder of the Mollett Street façade was an outward rotation of the façade about the first-floor support.

Figure 22: The building at 601 and 601A Colombo Street after the February earthquake

4.11.3 Issues

4.11.3.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

This building remained in its original state and there had never been any requirement for seismic strengthening due to the CCC's passive Earthquake-Prone Dangerous and Insanitary Buildings Policy. Had the CCC adopted a more active policy, the building might have been strengthened at least to some extent before the Canterbury earthquakes (although this still may not have prevented the failure of the building). We accept the CCC's submission, however, that had its policy allowed a timeframe of 15 or more years to carry out strengthening work, it is probably unlikely that anything would have been done.

4.11.3.2 Adequacy of the cordon

Mr Smith expressed the opinion that, in hindsight, the combination of the cracking to the upper north side of 601A and to the transverse wall between 601 and 601A should have led to the cordon being placed further out in Colombo Street. Due to the height of the façade, this would have essentially meant that Colombo Street would have had to have been blocked off. Mr Sinclair's assessment of the damage, and the appropriate cordon, would appear to differ from Mr Smith's, but as Mr Sinclair noted, the purpose of his assessment was not to ascertain the adequacy of the cordon.

Mr Smith also observed that it was important that the CCC undertake Level 2 assessments in such cases to adequately assess damage to the building and ascertain the necessary extent of the cordon.
Mr Campbell said that, with hindsight, he wished he had carried out an internal inspection.

It is unfortunate that there was no Level 2 assessment after the Boxing Day earthquake as recommended in the Level 1 assessment on 27 December 2010. Such an assessment might have been informative on the issue of the adequacy of the cordon.

As Mr McCarthy noted, the engineer’s report that the CCC was seeking from the owners could have informed the CCC on the issue. However, the difficulty with that approach is that it relied on the owner to give the CCC information necessary to assess the adequacy of the cordon. The owner might not provide such a report, as was the case with this building.

This case also illustrates the shortcomings of only applying a damage-based assessment to URM buildings after a significant earthquake.

4.12 603 and 605–613 Colombo Street

The Royal Commission's hearings into the failure of the buildings at 603 Colombo Street and 605–613 Colombo Street were conducted concurrently. We consider that it is appropriate to report on the issues relating to both consecutively.

4.12.1 603 Colombo Street

4.12.1.1 603 Colombo Street: Introduction

The building at 603 Colombo Street was part of a two storey row URM building (situated at the end of the row) at the intersection of Colombo and Mollett Streets. Adjacent to 603 was the building known as 605–613 Colombo Street (and next to that 615). All were part of the same original development, known as the Austral Buildings, which were divided into separate tenancies by party walls.

According to information provided to the Royal Commission by the New Zealand Police, at the time of the February earthquake, Mr Graham Weild and Mrs Joan Weild were walking on the west side of Colombo Street near the intersection with Mollett Street. They were killed when the façades of 603 and 605–613 Colombo Street collapsed out onto the street. Their bodies were found under the rubble in front of 603 Colombo Street.
Mr Gabi Ingel and Mr Ofer Levy were also pedestrians in that vicinity. Their bodies were found in rubble in the vicinity of 603 Colombo Street.

4.12.1.2 603 Colombo Street: The building

The Austral Buildings were listed in the Christchurch City Plan as Group 4 heritage buildings. This meant that they were of "metropolitan significance" and/or made "a contribution to the heritage of the city, the protection of which is seen as desirable by the Council". A resource consent was therefore required to alter or demolish the buildings.

The CCC considered the buildings to be earthquake-prone in terms of the 1991 and 2004 Building Acts.

Figure 23: The building at 603 Colombo Street, shown in a photograph from the CCC file which appears to have been taken around 1992. Mollett Street is on the left

A seismic risk building survey of 603 Colombo Street carried out by the CCC in 1991 identified the cornice, parapet and chimney as hazards. Mortar deterioration was also noted on the corner of the parapet on the street elevations. Immediate action was recommended.

A hazardous appendage survey conducted by the CCC in 1992 identified noticeable mortar deterioration and cracking, and a cracked parapet, cornice and wall.

4.12.1.3 603 Colombo Street: Events following the September earthquake

The building was severely damaged in the September earthquake, in particular the south wall adjacent to Mollett Street. As a result, following a CCC Level 1 Rapid Assessment on 5 September 2010, a yellow placard was placed on the building. A Level 2 Rapid Assessment was recommended.

A CCC Level 2 Rapid Assessment on 11 September 2010 confirmed the yellow placard status and recommended barricades. The Level 2 Rapid Assessment form noted: “Barricades need extension to cover front of Colombo Street and entry to Mollett Street”. The form also stated: “Risk to public – structural engineers assessment critical”.

Figure 24: 603 Colombo Street following the September earthquake. The Te@ Net Internet Café occupied the ground floor of the building

Figure 25: A closer view of the barricades from the area outside 601 Colombo Street. The pedestrian is walking north towards 603 Colombo Street

Figure 26: The barricades in front of 603 Colombo Street

The Yee Brothers Syndicate (comprising Mr Simon Yee, Mr Leo Yee, Mr Donald Yee, Mr Ewan Yee and Mr Sun Nam Yee) had owned 603 Colombo Street since April 1973.

Mr John Dallison, a principal in the Christchurch law firm Harold Smith & Dallison, acted as the owners' solicitor and agent. Following the September earthquake, on 6 September 2010 Mr Dallison instructed Mr Marton Sinclair, a structural engineer of Eliot Sinclair & Partners Ltd, to inspect the building. After inspections on 16 and 19 September Mr Sinclair sent a report dated 20 September 2010 to Mr Dallison. He advised that, given the extensive cracking in the Mollett Street façade, the building was potentially unsafe and should remain unoccupied until investigation and structural strengthening could be undertaken.

A CCC Level 2 Rapid Assessment by a structural engineer on 12 October 2010 confirmed the yellow placard and recommended a detailed engineering evaluation and temporary propping of the south wall. The CCC wrote to the owners on 15 October 2010 (care of Harold Smith & Dallison) requesting a CPEng report on the building and recommending that they provide temporary support to the south wall.

The CCC served a notice under section 124 of the Building Act on the owners on 20 October 2010, once again care of Harold Smith & Dallison. The notice recorded the need to provide temporary support to the south wall and gave the owners until 31 January 2011 to complete the work required.

A CCC Level 1 Rapid Assessment after the Boxing Day earthquake resulted in the yellow placard being maintained. However, it became apparent from the evidence of Mr Stephen McCarthy of the CCC that the placard status was subsequently upgraded by a CCC officer to red, and a further Level 1 Rapid Assessment was carried out the next day, 27 December 2010. That inspection confirmed the red placard status. Under "Comments" the rapid assessment form noted: "Major cracks, south wall. Potentially more severe since September. Reassess current barricade". It also said, "Urgent Attn. Main Thoroughfare. Urgent Engineer Assessment." Under the heading "Further Action Recommended", the box marked "Barricades are needed (state location)" was ticked and the words "Mollett Lane" were written next to it. A Level 2 Rapid Assessment or detailed structural engineering evaluation was also recommended.

In a "Particulars of Building Damage" form on the CCC file that appears to relate to the Level 1 Rapid Assessment on 27 December 2011, it was noted that an internal assessment was needed but the rapid assessment form made it clear that only an exterior inspection had been carried out. The Particulars of Building Damage form also noted that protection measures (barricades) were in place but needed upgrading.

It became apparent at the hearing that there was no Level 2 or detailed engineering evaluation as recommended in the rapid assessment form of 27 December, nor was there any reassessment or upgrading of the barricades that were in place.

Ms Vincie Billante, an environmental policy consultant who worked as the team leader of the CCC's Building Recovery Office in late 2010, gave evidence at the hearing. She was asked to comment on the systems that were in place at that time and that might have contributed to a Level 2 Rapid Assessment not being obtained in this case. She said, "…we had very little guidance or framework on which to go on because no one in New Zealand had experienced anything to this degree, and it would be fair to say that there was a certain amount of chaos immediately afterwards while the systems were being put into place..." Further, she said that the CCC did not have the resources to carry out Level 2 Rapid Assessments or detailed engineering evaluations and that a recommendation to carry out such an inspection could be conveyed to the building's owner, which took place in this case by following up with a Building Act notice.

Ms Billante offered the view that the reference on the Level 1 Rapid Assessment form to "Urgent Attn. Main Thoroughfare" could be a reference to Mollett Lane. Counsel assisting the Royal Commission has unsuccessfully attempted to contact the inspector who completed that form, but we are of the view that "Main Thoroughfare" must have been a reference to Colombo Street. Hence the need for urgent attention and the request for a Level 2 assessment and a reassessment of the barricades.

Mr Sinclair undertook a further external inspection for the owners after the Boxing Day earthquake but found no obvious additional cracking. When questioned at the hearing about his inspections, Mr Sinclair said that he was not involved in the placement of the barricades. He expressed the view that, given the presence of dangerous façades on both sides of Colombo Street, the whole street should have been closed until the buildings could be made safe or demolished. However, when questioned by counsel for the CCC he agreed that, at the time, he considered the barricade was adequate and entirely consistent with barricades that had been put up around other parts of the city. Mr Sinclair also gave evidence that the damage he saw on the Mollett Street frontage did not "strongly point" him to "a potential failure of the Colombo Street façade".

On 28 December 2010 the CCC served another Building Act notice that recorded structural defects in the building, in particular cracking of the south wall. The notice required work to be carried out by 31 January 2011. A CCC file note recorded that a "walkabout" on 20 January 2011 revealed the barricade was still in place.

According to a further file note, a CCC officer spoke to Mr Dallison on 24 January 2011 who "advised that they are working through this at the moment". The CCC officer requested that he send an engineer's report in relation to the building if possible and also contact details for the engineer.

No work was carried out on the building by the owners. Mr Dallison gave evidence that, following a period of assessment, a decision was made in January 2011 to demolish the building. This does not appear to have been communicated to the CCC until a meeting on 1 February 2011. According to notes kept by Mr Sean Ward, a senior planner with the CCC, those present at the meeting on 1 February were Mr Ward, Mr Dallison, Mr Sinclair, Ms Trudi Burney (a planner from Eliot Sinclair), Mr Matthew Bushnell (of Bushnell Builders Ltd, who was working for the insurer of 605–613 Colombo Street), Mr Philip Hector (a senior building consent officer with the CCC), Mr John Barry (a CCC case manager) and Ms Amanda Ohs (a policy planner in the CCC heritage team).

Mr Dallison said that the proposed demolition of the Austral Buildings was discussed at the meeting and that the procedure to obtain consent for demolition was discussed in detail. He said it was agreed that it would be more cost-effective to have one engineer carry out a full assessment of the whole building and that on 15 February he instructed Buchanan & Fletcher Ltd to proceed with this. Mr Dallison said he left the meeting with the clear impression that public notification of the necessary application for a resource consent for demolition would be mandatory. Mr Ward gave evidence that it could take up to six months to obtain a resource consent for demolition, but he said that this was an estimate only and would depend upon whether notification was required. He said he advised those present at the meeting that a requirement for notification was a strong possibility.

On 16 February 2011 Mr Mark Ryburn, a structural engineer on secondment to the CCC from Opus, carried out a re-inspection of 603 Colombo Street. His inspection was part of the CCC's process of visiting buildings that had been assigned a yellow or red placard. He said in evidence that part of his overall purpose was to consider the position of the barricades.

As part of its report to the Royal Commission on building safety evaluation processes in the central business district following the September earthquake, the CCC produced a form entitled "Guidance for Monitoring and Reviewing Barricades". The form, which was dated 15–16 September 2010, listed factors to consider in determining where a barricade should be placed. Mr Ryburn said he was not given a copy of the form, nor was he told that a barricade should be situated at a distance of one and a half times the top storey height away from the façade of a building where failure of the top storey was a possibility.

On 16 February Mr Ryburn completed an "Engineers Re-inspection of Damaged Building" form. He noted "significant cracking to south wall which is leaning outwards – likely connection failure…" He recorded that a barricade was in place and should remain, and recommended that work be completed by 16 March 2011. In evidence Mr Ryburn said he did not expect the masonry would fail by rotating outwards but rather that any failure would probably consist of vertical crumbling, as had happened with other buildings. He also said he did not think that a failure of the Mollett Street frontage would necessarily have caused the collapse of the Colombo Street façade. However, he accepted that it could have contributed to a possible collapse of the façade or compromised it in some way.

Mr Paul Campbell, who was also seconded to the CCC from Opus, carried out another re-inspection of the building. Once again, this was part of the CCC's process of carrying out follow-up inspections of buildings with yellow and red placards. Neither Mr Ryburn nor Mr Campbell was given a copy of the CCC's complete file for the inspections. However, they were provided with some documents relating to the period following the September earthquake. Although the "Engineers Re-inspection of Damaged Building" form he completed was undated, Mr Campbell said in evidence that it would have been filled out on or about 16 February 2011. He noted bad cracking to the Mollett Street elevation and was unable to access the building because of the barricade. Mr Campbell said that the collapse of the Mollett Street frontage could have weakened the top right-hand corner of the Colombo Street frontage, although he said that at that stage he had been satisfied with the position of the barricades on Colombo Street, given the practices that were adopted at the time.

Mr Peter Smith said in his report to the Royal Commission that “The first floor façade to Mollett Street and Colombo Street failed by an outward rotation of the façade about the first-floor support in the severe shaking during the 22 February 2011 earthquake”. He expressed the view that, in terms of public safety, after an earthquake there needed to be a rapid assessment of both the exterior and interior of such buildings, especially to assess connections between facades and floor and roof diaphragms. He said it was unfortunate that no internal inspection took place with this building.

Mr Smith said that the February earthquake “demonstrated beyond question the danger of these façades and the need to cordon off in front of buildings where the building does not have integrity to restrain that façade to a reasonable strength level”.

Figure 27: 603 Colombo Street following the February earthquake

4.12.1.4 603 Colombo Street: Issues

4.12.1.4.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy to the building

This building again provides an illustration of the risks inherent in a passive approach to earthquake-prone buildings. We refer to this issue in more detail in section 7 of this Volume.

4.12.1.4.2 Assessment of the building following the September earthquake, in particular the Colombo Street façade

This building failure highlights the risk with conducting only a rapid, external inspection of a URM building following a substantial earthquake. In this case, the Level 1 Rapid Assessment following the Boxing Day earthquake recommended a Level 2 inspection or a detailed structural evaluation, but neither was carried out.

The inspections carried out by Mr Ryburn and Mr Campbell for the CCC were brief exterior inspections only, and it was apparent from their evidence that they were never intended to be otherwise. With this level of inspection, it is not possible to be confident of the structural integrity of an unreinforced masonry building. In particular, the integrity of the wall-to-floor/ceiling connections cannot be ascertained from the exterior. This can directly affect the decision as to the appropriate placement of barricades. If there is a risk of façade collapse, as opposed to the hazard of a falling parapet, this will markedly affect the appropriate location of a barricade.

In this case, all of the external inspections noted significant damage to the south wall. In our view, this had the potential to compromise the Colombo Street façade if the south wall collapsed in an aftershock. Thus it was all the more important that there be an internal inspection of the Colombo Street façade connections so that the CCC could consider whether the existing barricades needed to be extended.

We do not consider that a lack of resources to carry out a more detailed internal and external inspection is a sufficient answer to what is a public safety issue. Nor is it sufficient to rely on a Building Act notice requiring the owner to engage a structural engineer to carry out such an inspection. This would effectively be passing on to an owner the Council's responsibility to the public for barricade placement. An owner may or may not take the appropriate action.

We accept that at this time the CCC was dealing with many hundreds of damaged buildings. The scale of the CCC's task after the September earthquake was further exacerbated by the Boxing Day aftershock. We understand that at the end of December 2010 there were approximately 140 cordons within the city centre, measuring approximately 7.5 kilometres in length, and numerous Building Act notices had been issued. Two notices had been served on the owner in the present case, on 20 October and 28 December requiring action to be taken by 31 January, so the CCC had not been inactive. However, nothing was done.

In this case, Mr Sinclair clearly never carried out an internal inspection of the building. He said this was because he could not gain access due to the barricade that had been erected by the CCC. It was evident that both Mr Dallison and Mr Sinclair considered that, because the building had been barricaded off, there was no urgency to make any decisions in relation to the building and they believed that public safety concerns had been met by the CCC. As we have indicated, we are of the view that, although consideration was obviously given to the placement of barricades on Colombo Street, the fact that no internal inspection was carried out meant that the issue was not considered as fully as it should have been.

4.12.2 605–613 Colombo Street

4.12.2.1 605–613 Colombo Street: Introduction

The address designated 605–613 Colombo St was the middle portion of the two storey Austral Buildings that have been described in relation to 603 Colombo Street.

At the time of the February earthquake, Mr Andrew Craig was driving a Red Bus Company bus north along Colombo Street approximately adjacent to 605 Colombo Street. During the earthquake a large amount of masonry and bricks fell from the building onto the left side of the bus. This was witnessed by Mr Kenneth Edwards, who was driving a Leopard bus immediately behind Mr Craig's bus. The Leopard bus was partially crushed by falling bricks and masonry that brought both of the buses to an immediate stop. Mr Edwards sustained moderate injuries but went to the assistance of the occupants of the other bus.

Mr Craig was subsequently transported to Christchurch Hospital but died two days later from his injuries. The following people were found deceased on the Red Bus following the earthquake: Master Jayden Andrews-Howland, Mr Jeff Sanft, Mr Philip Coppeard, Mr Joseph Routledge, Mrs Lucy Routledge, Mr Earl Stick and Mrs Beverley Stick.

At the hearing, we heard from a survivor from the Red Bus, Ms Ann Brower, who gave evidence of her ordeal and resulting injuries.

4.12.2.2 605–613 Colombo Street: The building

According to Mr Michael Fletcher of Buchanan & Fletcher Ltd, the engineer engaged by the owner's insurer, this part of the building was about 26 metres long parallel to Colombo Street, and 12 metres deep. It was divided into five equal units, each about five metres long. The brick parapet along the Colombo Street frontage was estimated to be 1200mm high by 450mm thick.

According to a CCC seismic risk buildings survey, the building was constructed in 1906.

The building at 605–613 was owned by Benson Cheng Holdings Ltd and occupied by the Khmer Satay Noodle House and Kiwi Disposals.

Figure 28: The building comprising 603–615 Colombo Street

Figure 29: The building at 603–615 Colombo Street viewed from the northern end

Figure 30: The northern part of the building. Leather Direct occupied 615 Colombo Street

A letter from the CCC to a previous owner dated 16 December 1982 records that the CCC was concerned about the stability of the building in a moderate earthquake. A seismic risk survey in 1991 recommended that remedial action be taken within two years. A hazardous appendage survey in 1992 identified noticeable mortar deterioration and a crack along the top of a heavy parapet.

As at 4 September 2010 the CCC considered the building to be earthquake-prone in terms of the Building Act 2004.

4.12.2.3 605–613 Colombo Street: Events following the September earthquake

A CCC Level 1 Rapid Assessment was carried out on 5 September 2010 and a green placard was placed on the building. The only damage recorded on the assessment form was “minor parapet cracks in the back wall”.

Mr David Eaton, a co-director of Buchanan & Fletcher, carried out an inspection on 14 September 2010. He noted cracking in the east-west walls and recommended propping of the front edge of the veranda along the Colombo Street frontage. This work was carried out by Bushnell Builders Ltd.

Figure 31: The building viewed from the opposite footpath on Colombo Street. Propping can be seen under the awning

Mr Fletcher inspected the building on 27 October 2010 after a number of significant aftershocks. He considered that there were no new cracks in the crosswalls (walls perpendicular to the façade, to which the façade is usually attached) near the Colombo Street frontage but that existing cracks had widened. The east wall had separated from the crosswalls at each end of the building with a gap of more than 20mm but the parapet and east walls showed no signs of damage. Mr Fletcher expressed the view that the building was likely to be earthquake-prone and recommended that the Colombo Street wall and parapet be tied back to the crosswalls. These tiebacks would be "interim securing work to restore the building's structural performance to pre-4 September 2010 levels". In a letter to the insurer dated 23 November 2010, Mr Fletcher attached sketches for the tiebacks and said, "As the building is occupied, the repair work should be carried out promptly". On 13 December 2010 Bushnell Builders provided an estimate of $200,000 plus GST for this work to the owner's insurer. The work was never carried out.

A CCC Level 1 Rapid Assessment was made by Mr Anthony Raper, a CPEng volunteer, on 26 December 2010. The assessment form recorded that the front façade was leaning out and that the parapets above the roofline, which he viewed from behind on a Fire Department hoist, appeared to have separated from the crosswalls. Mr Raper assigned 605 Colombo Street a yellow placard. He recommended a structural engineering evaluation and noted on the form, "Needs check from upper floor (interior) of transverse/ outer façade".

Mr Raper gave evidence that he wanted the façade checked more thoroughly than he had been able to but that he did not consider an immediate barricade needed to be erected as there was only a moderate risk of the façade collapsing. Also, he envisaged that the inspection would take place within a short period of time, so if that inspection showed a need for a barricade, it would be put in place. It appears from the CCC's records that the yellow placard recommendation was subsequently changed to red by a CCC officer, as occurred in the case of 603 Colombo Street.

A notice under section 124 of the Building Act was served on the owner on 28 December 2010. The notice stated that the building was damaged, there were structural defects and the parapets above the roofline appeared to have separated from crosswalls. Work was required to be carried out by 31 January 2011. The covering letter from the CCC said that advice on how to remove the danger should be sought from a qualified structural engineer.

A CCC file note dated 7 January 2011 stated, "Please inspect building. Owner has called in saying that a wall has gaps over 40mm after the 4.9 shock". Despite this file note and the Level 1 Rapid Assessment form dated 26 December 2010 recommending a check of the interior of the upper floor, no such check was ever carried out by the CCC. However, on 17 January 2011 Mr Fletcher carried out an inspection, accompanied by Mr Robin Cheng, Mr Matthew Bushnell and Mr Peter McLeod (a loss adjustor from Mainland Claims Management Ltd). Mr Fletcher found that the existing cracks between the east wall and crosswalls had widened and new cracks had appeared. At the south end, where the separation was greatest, the gap was 50–60mm. The separation was worse as one moved southwards along the building and there were signs of separation at every crosswall. He said that the proposed securing could still be carried out, but that more and/or longer steel straps might be required.

Mr Fletcher told the owner's loss adjustor that the Khmer Noodle House should not be occupied until the securing work was carried out. He said that the Kiwi Disposable tenancy was "currently ok to occupy, but this should be monitored daily". He advised Mr McLeod that "It is now becoming urgent that a decision is made to either secure or demolish the building". He said in evidence that he was concerned that the Colombo Street façade could fall off in a significant aftershock. However, he was not concerned that the façade was in immediate danger of collapsing. When asked about his opinion that it was "currently ok" for the Kiwi Disposals' section of the building to be occupied, Mr Fletcher referred to the presence of a tieback in place where that unit met 615 Colombo St. He also said that he had spoken to the tenant and made it clear that he should monitor the existing cracks and contact his office if they increased in size. If they had increased to a similar size to those at the southern end, he said he would have recommended a red placard for that section of the building.

Mr McLeod said in evidence that because the securing work was difficult and would cost over $200,000, the decision was made to demolish the building. A meeting took place with the CCC on 1 February 2011 in relation to 605–613 Colombo Street. The buildings at 603 and 626 Colombo Street were also discussed at that meeting. Mr Bushnell attended the meeting on behalf of the owner of 605–613 Colombo Street. He gave evidence that he clearly remembered "saying that I thought the building was dangerous and that I believed that the most appropriate action was demolition".

The main reaction he recalled from the CCC officers present was "their advice that the building could not be demolished because of its heritage status without a resource consent and that the resource consent would be notified". He said that "Mr Sinclair put it to them that that process was likely to take about six months and they agreed that…was the likely timescale". He also said that the "…CCC officers were professional and helpful but their hands were tied by the requirements of the Resource Management Act".

Mr Sinclair also attended the meeting as the owner's engineer for the buildings at 603–615 and 626 Colombo Street. He prepared an agenda for the meeting, which was produced at the hearing. The agenda dealt with these two buildings separately and in each case included as the first item "Extent of earthquake damage – danger to public". In evidence, Mr Sinclair said that at the meeting both he and Mr Bushnell expressed their concerns over "the buildings" and the risk of failure of the walls. In response to a question from the Royal Commission, Mr Sinclair explained that he was more concerned about parts of the Austral Buildings other than 603 Colombo Street. He also said that Mr Bushnell was particularly concerned because he had been into the Benson Cheng Buildings (i.e., 605–613) and had seen "the wall opening up". Mr Sinclair's prime concern at that time was 626 Colombo Street.

Sean Ward, a senior planner in the CCC's resource consents team, who was present at the meeting on 1 February 2011, said in evidence that neither Mr Bushnell nor Mr Sinclair indicated that 605–613 Colombo Street needed to be barricaded. His notes contained no record of such comments and nor did he recall any mention that the whole of Colombo Street needed to be closed because of the danger posed by the building. He did not recall any safety concerns being raised about the Austral Buildings (605–613). When questioned by counsel assisting the Royal Commission, he accepted that Mr Bushnell could have expressed concerns about the potential failure of the façade, although he was confident he would have recorded that in his notes if it had been said. Mr Ward also acknowledged that at the time of the meeting on 1 February 2011 he was aware of the CCC's power under section 129 of the Building Act 2004 to demolish a building. The Canterbury Earthquake (Resource Management Act) Order 2010 provided an exemption from the usual Resource Management Act requirements, meaning this power could be exercised without the need for a resource consent.

Mr John Higgins, a resource consents manager from the CCC, gave evidence about the CCC's approach to resource consents for the demolition of heritage buildings after the September earthquake. He said that apart from the exemption in relation to the use of section 129, there was no change to the regulatory framework for dealing with the demolition of heritage buildings that had been in place before the September earthquake. This meant that, unless the CCC exercised its power under section 129, a resource consent would be required for demolition. An application for a resource consent could have triggered public notification, although notification was not mandatory. He said notification could mean that processing the application could take three to six months.

Mr Higgins said that "Given the need for damaged buildings to be made safe and secure pending decisions as to the future of damaged heritage buildings, the CCC was facilitating a stabilisation of heritage buildings with the requirement of lodging a retrospective resource consent application when the repair or demolition of the building was determined". He noted that no resource consent application for demolition was ever lodged in relation to this building.

Mr Paul Campbell carried out an engineer's re-inspection for the CCC on or about 2 February 2011. He said in evidence that at that time he was not aware that the CCC had received a call informing them that the wall had a gap of over 40mm following the Boxing Day earthquake. Mr Campbell was aware of the comments on the Level 1 Rapid Assessment of 26 December. He recorded that the canopy had been propped and that no other work had been carried out. He did not have access to the roof and therefore referred to the 26 December report that indicated the parapets above the roofline appeared to be leaning out. He placed a question mark next to the words "Protection fencing required".

In evidence he said he was not sure why he put a question mark there but that if he had seen "anything that needed a fence [he] would have definitely ticked yes and made some notes". In response to questions from the Royal Commission, he agreed that the question mark indicated he thought it was an issue that should be addressed. He said that in hindsight he should have written some notes on the form about this issue. Although he accepted that there would need to be an internal inspection of load paths to determine whether the building was going to collapse outwards, he did not agree that he should have recommended a barricade.

Apart from the area immediately in front of 603, there was no barricade in front of the rest of the Austral Buildings at the time of the February earthquake.

Mr Smith said in his report to the Royal Commission that “The first floor façade of the buildings failed by an outward rotation of the façade about the first floor support beams in severe shaking during the 22 February 2011 earthquake”.

Figure 32: An aerial view of the south end of the building, showing the two damaged buses on Colombo Street after the February earthquake

Figure 33: The building at right following the February earthquake

Figure 34: The damaged buses

4.12.2.4 605–613 Colombo Street: Issues

4.12.2.4.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy to the building

As with many other inherently weak unreinforced masonry buildings, no strengthening of this building had been required. As a result it remained in a relatively original condition.

The collapse emphasises the need for the façades of URM buildings to be effectively restrained, and the desirability of an active policy for earthquake-prone buildings. While significant strengthening may not have prevented the façade collapsing given the severity of the February earthquake, it would at least have given it a better chance.

4.12.2.4.2 Failure to place barricades in front of the building to ensure safety of the public

At no stage was there ever a barricade erected in front of this building apart from the section of the barricade that extended across Mollett Street and in front of 603.

We consider that there should have been such a barricade, given the nature of the damage to the building after the Boxing Day earthquake and in particular the apparent separation of the façade from the transverse walls. We consider it would have been prudent for Mr Raper to adopt a more conservative approach and to recommend a barricade pending the more detailed structural engineering evaluation that he recommended. Although he said he only considered there was a moderate risk of the façade collapsing (and recommended a yellow placard), the reason he recommended an engineering evaluation was to confirm the position. We accept he envisaged that the CCC evaluation would take place a short time later, but a significant aftershock could have occurred at any time. In any event, no structural engineering evaluation was ever carried out by the CCC as recommended by Mr Raper. We add that there can be no certainty that any barrier erected would have been effective to prevent the loss of life that occurred.

A notice under section 124 of the Building Act was served on the owner two days after Mr Raper's inspection, and reference was made to the apparent separation of the parapet from the crosswalls. However, no remedial work was carried out by the owners because by January 2011 they had decided it was not economic to repair the building and they intended to demolish it.

We are of the view that serving the Building Act notice on the owner was insufficient to deal with Mr Raper's recommendation to further evaluate the building, in particular its façade. The assessment he recommended would have provided the information upon which a decision could be made regarding the barricade. That was a matter of public safety and therefore one for the CCC to determine, whereas an owner, as in this case, might decide to take no action.

In relation to Mr Fletcher's assessment of the building following Boxing Day, we are of the view that, as with Mr Raper, it would have been prudent for Mr Fletcher to adopt a more conservative approach following his assessment of the building on 17 January 2011. In an email to the loss adjustor on that day, Mr Fletcher referred to the separation of the façade and said that the matter was becoming urgent. In evidence, he conceded that one of the reasons for that urgency was his concern about the potential danger the façade posed. However, he had formed the view that it was not in imminent danger of collapse, given that the pattern of aftershocks is normally a diminishing one. The difficulty with this is that in confirming the CCC's red placard on the Khmer Noodle House tenancy, Mr Fletcher clearly considered the building a potential danger to at least that tenancy in the south end of the building. If a tenant could be in danger inside the premises, so too could a pedestrian outside.

Mr Fletcher gave evidence that he had spoken to the tenant of Kiwi Disposals, located in the northern part of the building, and told him to advise Mr Fletcher's office if the cracks above his tenancy increased. In our view, it would be preferable for such advice of potential dangers to be in writing.

However, a more fundamental difficulty is the separate consideration of the north end of the building from the south. It appears that 605–613 Colombo Street (considered to include Leather Direct, though this is in fact at 615) was allocated a green placard on 5 September 2010. Then on 26 December 2010, following the Level 1 Rapid Assessment, a red placard was placed on 605 Colombo Street (the Khmer Satay Noodle House). In our view, it would have been better to consider all tenancies in the building. (This is an issue we have also addressed in relation to 593 Colombo Street.) As Mr Fletcher conceded, the façade above the noodle house could have come away in a significant aftershock and potentially pulled off the whole of the façade of that portion of the building up to 615.

As Mr Campbell agreed, by placing a question mark on his re-inspection form, he was indicating that he thought protection fencing was an issue that should be addressed. There is no record of that happening. In our view, it would also have been prudent for Mr Campbell to adopt a more conservative approach to the issue of a barricade based on the information he had available to him (namely, the observations of Mr Raper as set out on the Level 1 Rapid Assessment form, Mr Raper's recommendation for further evaluation, and the absence of any further inspection).

4.12.2.4.3 Heritage issues

The owners of the building were given until 31 January 2011 to carry out the work referred to in the Building Act notice. The next day, on 1 February 2011, the meeting took place between CCC representatives and representatives of the owners of 603 and 605–613.

Both Messrs Bushnell and Sinclair said that the issue of potential danger from the façade of 605–613 was raised at the meeting. Mr Ward from the CCC did not recall that issue being raised. He referred to the fact that the issue was not recorded in the notes he made, a copy of which he produced. However, he accepted the possibility that it was raised but that he could not recall it. On the balance of probabilities we find that the issue was raised at the meeting. However, it seems that, perhaps because of the particular concerns raised in relation to 626 Colombo Street, the concerns of Mr Bushnell about 605–613 Colombo Street were not fully appreciated. It appears that the case manager for the building, Mr Barry, who was at the meeting (and was presumably aware of the concerns expressed by Mr Raper in the Level 1 Rapid Assessment form on Boxing Day), also did not appreciate the extent of Mr Bushnell's concern. As with Mr Raper's recommendation, there was no follow-up by the CCC.

The heritage status of the Austral Buildings meant that, even though the owners had decided to demolish, it would not have been possible for them to do so without a resource consent. The practical effect of this was that a dangerous building would remain standing until the resource consent application had run its course. Given that the owners wanted to demolish, they had no incentive to carry out the expensive interim securing work.

The absence of such work made the CCC's decision about whether to place a barricade in front of the building even more important. If an appropriately located barricade had been in position, public safety would have been ensured pending resolution of a resource consent application. We consider that it would also have been open to the CCC to consider exercising its power under section 129 of the Building Act 2004 (as amended by the Canterbury Earthquake (Building Act) Order 2010) to demolish the building without a resource consent. We deal with this issue in section 7 of this Volume.

4.13 617–625 Colombo Street

4.13.1 Introduction

Jennifer Donaldson was a pedestrian on Colombo Street at the time of the February earthquake. Her body was found by the New Zealand Police under rubble outside 625 Colombo Street.

4.13.2 The buildings

The buildings at 617–625 Colombo Street and 143 Tuam Street were adjacent two storeyed URM buildings on the north-western corner of Tuam and Colombo Streets. Although they may not have been one building originally, they had been connected together in the past and were regarded as one structural unit. They were built with a lightweight roof on timber trusses supported on the perimeter by masonry walls. Their street frontages on Colombo and Tuam Streets were relatively open.

Figure 35: The corner of 617 Colombo Street before the September earthquake. The vehicle at left is pointing east along Tuam Street

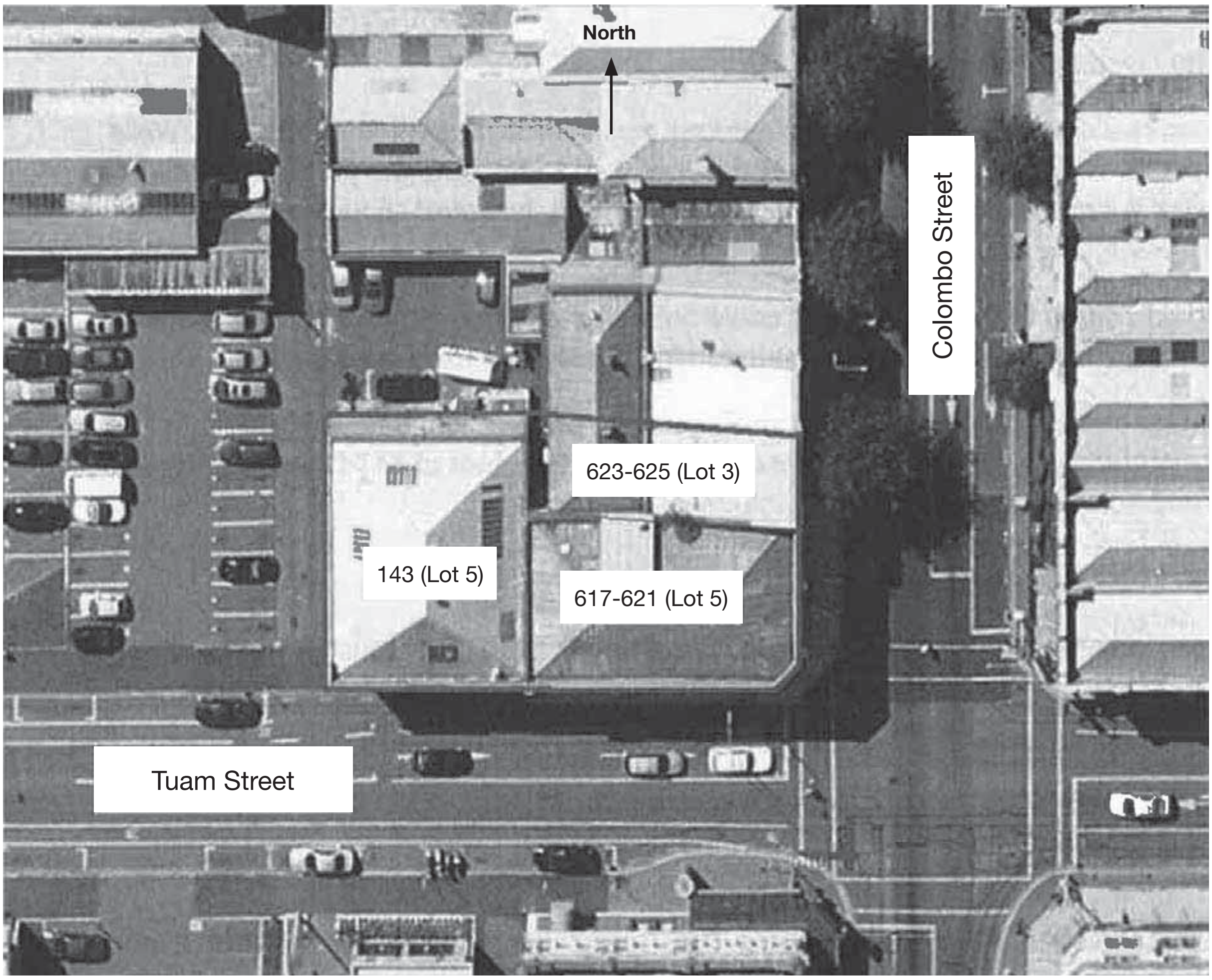


Figure 36: An aerial photograph of the locality before the February earthquake

In 1982 the CCC wrote to the owner of the building at 617 Colombo Street/143 Tuam Street suggesting that, as there was scaffolding in place, it would be an appropriate time to consider the structural stability of the building. There does not appear to have been any reply or follow-up to that letter.

A CCC seismic risk buildings survey in 1991 gave the building at 617 Colombo Street a score of 15, which resulted in a classification that meant immediate remedial action was recommended. A hazardous appendage survey in 1992 identified noticeable mortar deterioration, loose masonry and significant cracking.

Mr Peter Smith said in his report to the Royal Commission that there had been few alterations to the buildings other than strengthening work carried out in 1994 and 2000. His interpretation of CCC correspondence was that a second stage of seismic strengthening had been undertaken in September 2000. He estimated that this increased the strength of the buildings to about 20% of the level stipulated by the Building Code at the time.

When engineers from Beca Carter Hollings & Ferner Ltd (Beca) conducted a seismic evaluation after the September earthquake, they calculated the buildings to be 11% of the current new building standard (NBS). The buildings would therefore have been considered earthquake-prone in September 2010.

4.13.3 Events following the September earthquake

Level 1 Rapid Assessments were conducted on the buildings after the September earthquake. All of the buildings were allocated green placards on 5 September 2010.

On 7 September 2010 Mr Matt Cameron, a Beca engineer, conducted a visual inspection of the building at 143 Tuam Street on instructions from Colliers, the owner's property managers. As a result of this, a Level 2 Rapid Assessment form was completed and submitted to the CCC.

On 10 September 2010, following a number of large aftershocks, Mr Cameron re-inspected the building and recommended a green placard but also recommended repairs to parapets on the south-western corner of the building (in Tuam Street).

A visual inspection of 625 Colombo Street was carried out by Mr Mark Humphrey of Beca on 15 September 2010. A Level 2 Rapid Assessment form was completed, which noted cracking in the internal blockwork walls. A subsequent inspection of the party wall between 623–625 and 627 Colombo Street (from the 627 side) revealed a number of cracks in the wall that were not evident from the other side. The Level 2 Rapid Assessments were delivered to Civil Defence by Beca. However, they were not on the CCC file.

Beca was then commissioned to complete a detailed structural evaluation of the buildings. This was provided to the owner on 10 December 2010. The report concluded that the building was 11% NBS and therefore earthquake-prone but that it did not pose an immediate risk to the occupants. Various repairs and further investigations were recommended.

Mr Jonathan Barnett, a Beca structural engineer, gave evidence that while the 11% score confirmed that the building was earthquake-prone, it was not an unusual score for a very old URM building. He said the conclusion that the building did not pose an immediate risk to the occupants was based on the damage observed. The Beca report had identified the need for damage to be repaired in the short term, but had stressed that the repairs recommended would not improve the 11% score. What was required for that to happen was a detailed strengthening scheme to be fully investigated, designed and implemented. The repairs specified were to cracking of the reinforced blockwork walls and unreinforced masonry brickwork walls of 617–625 Colombo Street and the parapets of 143 Tuam Street.

Mr David Ehlers, one of the owners of the buildings, gave evidence that the parapet of 143 Tuam Street was repaired and some minor repairs at 625 Colombo Street were carried out to comply with health and safety requirements. However, the structural repairs recommended in the report had not been carried out by the time of the February earthquake. Mr Ehlers said he understood from the Beca report that although the parapet repairs had been identified as urgent, the other repairs were not. However, the owners had lodged claims with their insurer and were awaiting approval to carry out the other repairs.

In the February earthquake, the façade of the buildings at 623 and 625 Colombo Street (as well as the adjacent buildings at 627 and 629 Colombo Street) failed through an outward rotation from the first floor and parapet about the first-floor support.

Mr Smith noted that the façades of the buildings at 617–621 Colombo Street did not fail, presumably as a result of the strengthening work undertaken; and he compared this to the failure of the end buildings of a series of interconnected URM buildings of similar height (at 593, 601A and 603 Colombo Street), which had not previously been strengthened. He said that this demonstrated the potential benefit of strengthening even to such a low level as 20% of the current Code. However, the failure of the façades at 623 and 625 Colombo Street (and also 627 and 629) highlighted the fact that such minimal strengthening of URM building façades is unlikely to be effective in a severe earthquake.

Figure 37: Damage to 617–625 Colombo Street after the February earthquake (looking south along Colombo Street)

4.13.4 Issues

4.13.4.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

Earthquake strengthening was carried out on the building in 1994 and 2000. However, because of the increased strength requirements imposed under the Building Act 2004, the building was still earthquake-prone.

4.13.4.2 Structural assessment of the building after the September earthquake

In this case, the owners (through their property manager) obtained a detailed structural evaluation from Beca. Although the test applied by Beca was a damage-based one, they also carried out an initial evaluation procedure to assess the strength of the building.

Beca's conclusion that the building had a strength of about 11% NBS confirmed that the building was earthquake-prone. However, on the damage-based test it was considered that the building did not pose an immediate risk to the occupants, despite the requirement for various repairs to be carried out.

In our view, this highlights the shortcomings of a damage-based assessment after a significant earthquake. It also raises the question of whether there needs to be a minimum standard set for the capacity of a building.

4.14 738 Colombo Street

4.14.1 Introduction

The building situated at 738 Colombo Street was a two storey structure of combined URM and early reinforced concrete construction with timber roof framing and a timber first floor.

Christchurch Police records have confirmed that the body of Desley Thomson, who was a pedestrian on Colombo Street at the time of the February earthquake, was found on the road close to the footpath under collapsed building material outside the OK Gift Shop premises at 738 Colombo Street.

Figure 38: The building before the September earthquake

4.14.2 The building

The building had a concrete beam and column construction with infill brick in the north wall, concrete panels at the upper levels of the eastern and western walls and structural steel columns in the south wall. The steel columns supported steel beams which in turn supported the timber floor. Timber trusses supported the roof off the north and south walls.

The building adjacent to it at 736 Colombo Street was a four level concrete-framed building with brick infill walls including a basement. At the first-floor level, the two buildings were opened to each other in order to allow a larger space to be utilised. Seven hundred and thirty-six Colombo Street was built in the early 1900s and 738 Colombo Street in 1937.

It appears that strengthening work was completed in relation to 738 Colombo Street, designed by Buchanan & Fletcher Ltd, structural engineers, in 1991. This included securing the upper level concrete walls at ceiling and first-floor level using an epoxy bolting system and the installation of steel bracing at ceiling level and horizontal ply and steel beams at floor level. Brick parapets to the north and east were restrained in 1996. However, the building would still have been assessed as earthquake-prone under the Building Act 2004.

The owner of the building, Mr Jonathon Liu, bought the building through his company (Natural Blessings Ltd) in August 2008 from OK Gift Shop Ltd (OK Gift Shop). OK Gift Shop remained as a tenant of the building. At that time Mr Liu entered into a property management agreement with Simes Ltd, which later became Knight Frank. Mr Liu said in evidence that he essentially left all of the management of the property to Simes Ltd and later Knight Frank. At the time of the September earthquake, Mr Liu also owned 736 Colombo Street, which was also managed by Knight Frank.

4.14.3 Events following the September earthquake

Following the September earthquake, there was a Level 1 Rapid Assessment of the building on 5 September 2010, which noted minor damage. The building was assigned a green placard.

OK Gift Shop arranged for an engineer's inspection of the building by Powell Fenwick Consultants Ltd. Mr Liu said in evidence that, on being advised by the tenant that an engineering check was required, he called Mr Luke Rees-Thomas (of Knight Frank). However, this cannot have been the case. From the evidence given by Mr Rees-Thomas and Mr Andrew Bell, both of Knight Frank, it is clear that Knight Frank did not have any contact with Mr Liu following the September earthquake in relation to this inspection. Further, Mr Rees-Thomas was not involved in the management of this building until 27 October 2010. A written statement to the Royal Commission from Mr Akira Yoshikane, manager of the OK Gift Shop, advised that he had instructed Powell Fenwick because he could not contact Knight Frank or Mr Liu at the time.

Powell Fenwick conducted a 'walk-through inspection' of the building on 6 September 2010 and provided a brief written report on the same day. That report noted "preliminary indications are that this building is not in immediate danger of structural collapse" and that there was nothing requiring urgent attention to ensure the ongoing stability of the building. It was noted that these conclusions were based on a visual walk-through inspection only and it was possible there was unobserved damage that might require remedial work. The report recommended a more detailed/full structural inspection.

The Powell Fenwick report of 6 September 2010 was addressed to Mr Liu at a post office box (which it transpired was that of the OK Gift Shop) but was also emailed to Mr Liu at treasure@ihug.co.nz. In evidence Mr Liu confirmed that this was his email address but he could not recall receiving the report. Mr Liu also said that he had received correspondence from the Royal Commission addressed to the same address, although he later said that he was not sure if he did actually receive it. Michael Freeman, structural engineer from Powell Fenwick, was able to confirm that, from Powell Fenwick's records, the report had been sent by email to Mr Liu and there was no notification of non-delivery. On the basis of this evidence, we find that the report was received by Mr Liu at his email address.

Mr Bell gave evidence that he was responsible for the management of the property until 27 October 2010 when Mr Rees-Thomas took over. Mr Bell said that he became aware of the Powell Fenwick report after speaking to the tenant on 7 September 2010 and he requested a copy of it. The report was subsequently emailed to Mr Rees-Thomas on 2 November 2010.

On 9 September 2010, Mr Hamish Mackinven of Lewis Bradford (who had been instructed by Knight Frank to inspect 736 Colombo Street) emailed Mr Bell advising that he had completed a brief structural inspection of 736 Colombo Street and that it appeared that there was no structural reason that this building could not be occupied. That email was forwarded by Mr Bell to Mr Rees-Thomas, who then emailed Mr Mackinven on 24 November 2010 to "arrange a full structural engineer's report on the buildings 736–740 Colombo Street". Mr Mackinven said that, although that email referred to the buildings 736–740 Colombo Street, he was only ever involved in the one building at 736 Colombo Street and he took that email to be referring to that building.

Mr Rees-Thomas' evidence was that he intended Mr Mackinven to carry out full inspections of both buildings. There is some support for that in Mr Rees-Thomas' email of 25 November 2010 to the tenant of the OK Gift Shop advising that there would be an inspection by a structural engineer the next day "to assess the building's damage and safety in full".

On 26 November, Mr Rees-Thomas met Mr Mackinven at 736 Colombo Street. He left Mr Mackinven at that building. It appears that Mr Rees-Thomas thought that Mr Mackinven would complete his inspection of 736 and then inspect 738. However, Mr Mackinven understood that he was only to complete his inspection of 736. Mr Mackinven provided a report in relation to 736 dated 30 November 2010. Mr Rees-Thomas said in evidence that when he received that report and noticed that it only related to 736, he contacted Mr Mackinven and told him that a report was also required for 738. Mr Rees-Thomas could not recall any of the detail of that conversation. Mr Mackinven could not recall the conversation taking place.

Mr Rees-Thomas said that he subsequently had a conversation with the loss adjustor, Mr Phil Buckman, in which Mr Rees-Thomas said he conveyed the need for a report on 738 as well. Mr Buckman did not give evidence at the hearing but email correspondence received from him following the hearing confirmed that his understanding was that Lewis Bradford had only ever been engaged to carry out assessments of 736 Colombo Street.

Mr Mackinven proceeded to prepare a detailed report on 736 Colombo Street. Lewis Bradford had entered into a short-form agreement (signed by Mr Rees-Thomas on 25 November). They entered into another agreement in relation to a full structural assessment with Mr Buckman in relation to 736 on 22 January 2011. There was never any short-form agreement completed in relation to 738 Colombo Street.

Mr Mackinven had asked Mr Rees-Thomas to obtain plans from the CCC. It appears that plans for both buildings were on the same CCC file and these were eventually forwarded by Mr Rees-Thomas to Mr Mackinven on 8 February. When the 22 February earthquake occurred, Mr Mackinven was still in the process of preparing a full assessment of 736 Colombo Street. He confirmed that, even if he had understood that the same was required for 738 Colombo Street, he would not have been able to complete that before 22 February.

A CCC Level 1 Rapid Assessment of 738 took place on 27 December 2010 following the Boxing Day earthquake. This resulted in the building being allocated a green placard. There is a reference on that form to a Powell Fenwick report, although there was no report on the CCC file.

Mr Freeman gave evidence that he carried out a Level 2 assessment on 26 December following the Boxing Day earthquake, on instructions from the tenant, the OK Gift Shop. He said that the shop was open for business at the time of the inspection. He was given a limited tour of the buildings, which included access to the lower level shop, access to the rear storeroom at the lower level and access to the storeroom in the first-floor level at the rear of the building only. He was not able to access the upper level tenancy, which extended to the Colombo Street frontage of the shop. He said that his inspection involved a visual inspection only and, given the extent of the fit-out on the lower level of the shop, the inspection was very limited. He said that he was not invited during his inspection to conduct any intrusive testing or remove shop fit-out items to gain better access to the structural elements of the building.

He recalled seeing minor damage consisting of cracking to lath and plaster partition walls in the rear area of the shop only. There was no visual damage to any of the masonry walls, including the front wall of the building, which was inspected from Colombo Street. Mr Freeman said that he did not consider the observed damage to be detrimental to the structure of the building and did not consider the structural integrity of the building had been diminished by the Boxing Day earthquake. Mr Freeman confirmed in evidence that he concluded that the building remained structurally sound and fit to be occupied. He said that there was no evidence to suggest that the areas he was not able to access might be damaged. However, in retrospect, given the events in February, he conceded that the lack of access to some areas may have affected his conclusions. He added that, in retrospect, a Level 2 inspection would not have been sufficient. What was required was the removal of linings, consideration of building plans and minor preliminary calculations to work out the capacity of the building.

On 19 January 2011, Mr Rees-Thomas received an email from FHS Roofing Ltd, who had been instructed by him to inspect a roof leak at the building. It was noted in that email that the "Colombo Street parapet (3m tall) has come adrift from the walls on either side and will need refixing to the adjacent buildings to re-secure". Mr Rees-Thomas forwarded this email to Mr Buckman on 26 January 2011. Two days later Mr Buckman forwarded it to Mr Mackinven and asked him to "inspect this and report as part of your investigations into the damage".

That same day, Mr Mackinven inspected the parapet and sent Mr Buckman an email in which he gave Mr Buckman a report of the damage to 736 Colombo Street. He also noted, "As requested I have inspected the parapet of the adjacent building at 738 Colombo Street. The damage to this parapet was noted in our previous inspection and is captured in our report. It has been caused by the lack of a seismic gap between the two buildings and movement occurring between them". In evidence, Mr Mackinven conceded that he had not inspected the other end of the parapet but explained by reference to photographs that were taken at the time that the parapet of 738 was not connected to the adjacent building. He said that the observed damage was not of concern.

The building was extensively damaged in the February earthquake, including collapse of the façade onto the street. Mr Peter Smith stated in his report to the Royal Commission that "from the photographs it would appear that the front façade above first-floor window-sill level rotated outwards from the support at the window-sill level, collapsing onto the footpath as a result of the severe shaking experienced during the earthquake".

4.14.4 Issues

4.14.4.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

In this case, it appears that the earthquake strengthening that was considered necessary in 1991 and 1996 was carried out. However, because of the increased strength requirements imposed under the Building Act 2004, the building was still earthquake-prone. Even if it had been strengthened so that it was no longer earthquake-prone under the Building Act 2004, it is likely that, given the severity of the shaking in the February earthquake, the walls would still have failed.

While it is difficult to eliminate entirely the dangers posed by such buildings during a significant earthquake, this highlights the need for urgency in the retrofit of URM buildings.

4.14.4.2 Assessment of the building following the September and Boxing Day earthquakes

This building again highlights the risks of undertaking only a damage-based assessment for an URM building following a substantial earthquake.

The issues that arose in relation to this building, namely the misunderstanding and miscommunication that arose about a more detailed inspection, the delay before one could have been obtained in any event, and the reliance on brief walk-through inspections after both the September and Boxing Day earthquakes, which Mr Freeman conceded in retrospect were inadequate, require consideration.

While it is clear that a detailed report could not have been obtained before the February earthquake, it is unfortunate that there was miscommunication and misunderstanding about it. It highlights the consequences of a lack of clear communication.

Figure 39: 738 Colombo Street after the February earthquake

4.15 753–759 Colombo Street

4.15.1 Introduction

The building at 753–759 Colombo Street was a two storey URM structure on the western side of Colombo Street between Gloucester and Armagh Streets, and was divided into four tenancies. Visually it appeared to be one building together with 751 Colombo Street, but each was separated by a party wall from its neighbour.

Ms Marielle Falardeau appears to have been a pedestrian on the footpath on the western side of Colombo Street at the time of the February earthquake. Her body was found under collapsed building material outside 753 Colombo Street, which housed a shop called Colombo Souvenirs.

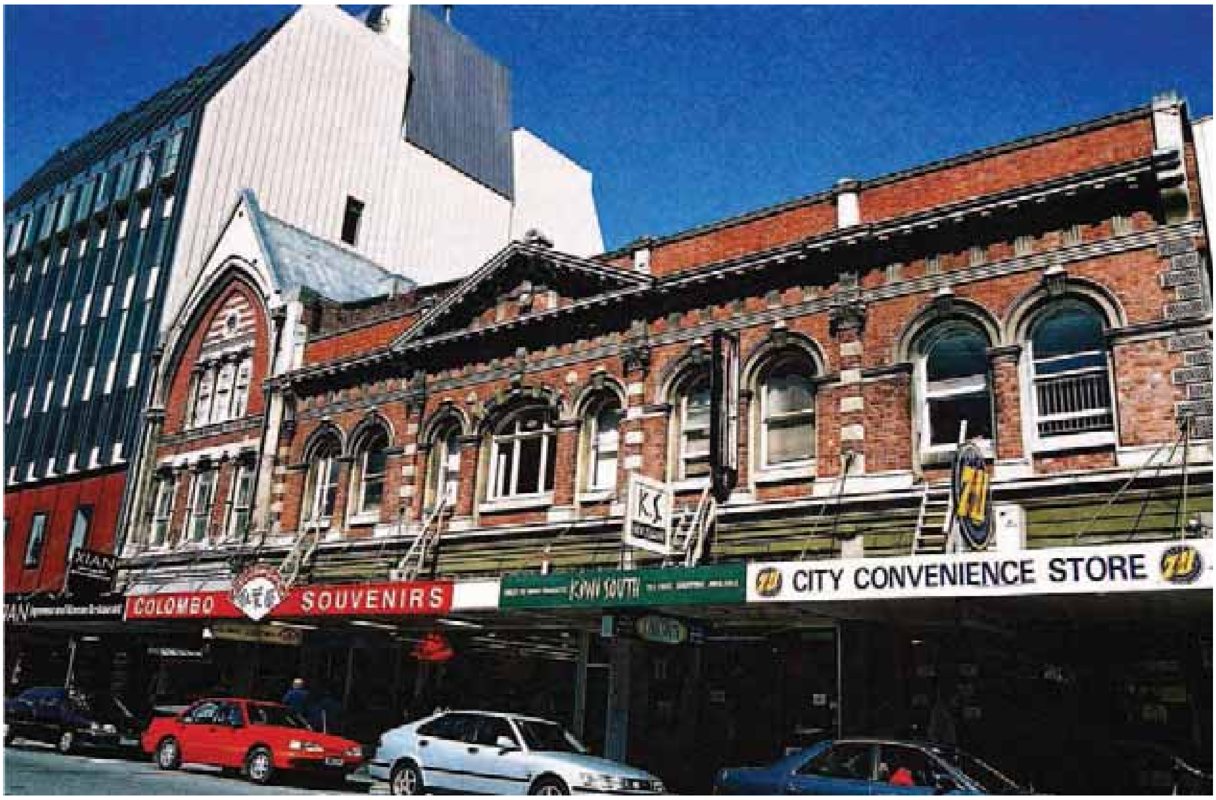


Figure 40: The buildings at 751–759 Colombo Street before the September earthquake. The taller URM building at left bearing the sign "Xian" is 751 Colombo Street. Colombo Souvenirs was a tenant at 753 Colombo Street

4.15.2 The building

The building was listed as a heritage building in the CCC District Plan and was registered as an historic building by the Historic Places Trust.

A CCC seismic risk buildings survey in 1991 noted "seemingly complete mortar deterioration on feature parapet" and gave the building a score of 16, which resulted in its being classified as A, meaning immediate remedial action was recommended. A hazardous appendage survey carried out around the same time on 751–757 Colombo Street referred to:

- significant loose masonry, mortar deterioration and cracking;
- "One of the worst examples in Christchurch"; and
- "Probably an area of the heaviest pedestrian traffic in central Christchurch".

The building was jointly owned by the Church Property Trustees and the Jason Richards Trust. Ms Elizabeth Clarke, an employee of Church Property Trustees, was the property manager. She gave evidence that, as a result of a change of tenancy of 753 Colombo Street and resulting work required, a building consent was applied for in 1994. In April 1994 the CCC advised that it believed the building as a whole was earthquake-prone in terms of section 66 of the Building Act 1991, and that no building consent would be given until this issue was addressed.

Strengthening work was carried out on 753 Colombo Street in 1994. Mr Stephen McCarthy of the CCC gave evidence that this work appeared to include the installation of two concrete frames and a diaphragm on the first floor, and steel members to strengthen the walls. The walls and roof were also tied to the structures with steel members and Chemset™ (chemically anchored) bolts.

Mr McCarthy was asked when giving evidence why the CCC would not have insisted on the building as a whole being strengthened, rather than just 753 Colombo Street. He said that often with these types of buildings the CCC treated each tenancy or each part of the building as a separate building, and this was a way to get at least some strengthening done.

Mr McCarthy's evidence was that 755 Colombo Street appeared to have been strengthened in 1994 by the installation of two concrete frames. This work only affected the ground floor. CCC records show that 757 Colombo Street appeared not to have been strengthened. The building at 759 Colombo Street was strengthened in 1999 in a similar manner to 753.

All the strengthening work had been carried out before the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy was introduced in 2006. It is likely that all of the tenancies would have been regarded as earthquake-prone for the purposes of the policy. No applications for building consents to make significant alterations were submitted after the introduction of the policy, so the requirement to consider strengthening in terms of the policy had not been triggered.

4.15.3 Events following the September earthquake

Following the September earthquake, a CCC Level 1 Rapid Assessment of 751–759 Colombo Street was carried out on 5 September 2010. Minor damage was noted and the building was allocated a green placard. A further Level 1 Rapid Assessment was conducted on 7 September 2010 for 751–759 Colombo Street. This recorded a detailed inspection of parapets and corbels and also resulted in a green placard.

A brief structural inspection was carried out on behalf of the owners by Mr Hamish Mackinven of Lewis Bradford, consulting engineers, on 8 September 2010. In relation to the tenancies at 753, 755 and 759 Colombo Street, nothing was noted to indicate that the building was structurally compromised. There did not appear to be any reason why the building could not be occupied. In relation to 753 and 755, Mr Mackinven noted chimneys that were not in immediate danger of falling but recommended that they should be removed in the near future. Ms Clarke gave evidence that this work was completed.

In relation to 757 Colombo Street, Mr Mackinven noted some damage to a concrete wall at the rear of the building, which required strengthening. The wall had also pulled away from the masonry wall and needed to be structurally tied to it. He noted that this tenancy was then unoccupied but that the work would need to be completed before it was re-tenanted.

Mr Mackinven gave evidence that he considered his inspection of the building to be more thorough than a normal Level 2 inspection. He inspected both the interior and exterior of the building, went out onto the canopy to inspect the front façade, twice climbed up onto the roof to inspect the roof structure and front façade, and inspected the front façade from the opposite side of the street with a pair of binoculars. He confirmed that his assessment was a damage-based assessment and that because the damage he observed was minor, he did not believe it had diminished the capacity of the building.

Mr Mackinven gave evidence that the remedial work required at 757 Colombo Street was carried out under his supervision between 18 and 21 October 2010.

There were no inspections, either by the CCC or on behalf of the owners, following the Boxing Day earthquake. Ms Clarke said that she relied on advice from their property managers, Knight Frank, previously Simes Ltd, who did not advise of any structural damage.

Mr Mackinven had no further involvement with the building after 21 October 2010. In evidence he was asked whether his assumptions in relation to aftershocks changed after the Boxing Day earthquake. He said that they had indeed changed, because that earthquake had been on a different fault to the Greendale fault and was close to the central city. He said that the way that he assessed buildings following Boxing Day changed, in that he had become more aware of the potential for another fault to appear close to the city.

The Royal Commission heard evidence from Mr Craig Lewis, a structural engineer with 25 years' experience and Director of Lewis Bradford Consulting Engineers. He spoke of the damage-based test applied after the September earthquake, and how his firm and other colleagues he spoke to took a decidedly more cautious approach to the assessment of buildings after the Boxing Day earthquake for the same reasons given by Mr Mackinven. He said that he thought that if his firm had been inspecting this building post-Boxing Day, they would have taken a slightly different approach. They would have conducted a more risk-based assessment and recommended that drawings be accessed. Although original drawings might not have been available for this building owing to its age, the Council did hold drawings for alteration and strengthening work carried out to parts of the building.

In the February earthquake the building suffered severe structural damage, including collapse of the upper storey façade onto the street. Mr Peter Smith said in his report to the Royal Commission that the front façades rotated outwards at the point of connection above the windows and collapsed onto the footpath on Colombo Street.

Figure 41: Two views of the building after the February earthquake

4.15.4 Issues

4.15.4.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

The CCC building surveys in 1991 identified significant mortar deterioration and described this building as "one of the worst examples in Christchurch". Some strengthening work was carried out but the building was likely to have still been earthquake-prone under the Building Act 2004.

We note that when 759 Colombo Street was strengthened in 1999 the CCC contributed $35,000 to the cost of this work, which it secured by way of a conservation covenant with the owners. Mr McCarthy was asked in evidence whether this type of assistance was a realistic way to deal with the economic difficulties of upgrading URM buildings. He replied, "I think realistically it is and I think local government generally accepts that they have a part to play in making it easier to upgrade unreinforced masonry buildings, indeed any earthquake-prone buildings". He said that before the September earthquake the CCC was contemplating establishing a fund to help facilitate building upgrades.

4.15.4.2 Assessments of the building following the September earthquake

The engineers who assessed this building following the September earthquake adopted a damage-based test to determine fitness for occupancy.

URM buildings are susceptible to sudden failure in earthquakes because of the materials and methods used in their construction. Even when the danger is reduced by seismic strengthening they continue to have a higher risk of collapse than other structures. Therefore, consideration needs to be given to whether these buildings should be occupied after a significant earthquake. The level of strength and degree of improvement necessary to make URM buildings safer in the event of a moderate earthquake is discussed in sections 6 and 7 of this Volume.

4.16 309 Durham Street North

4.16.1 Introduction

The Durham Street Methodist Church at 309 Durham Street North was a URM building constructed of stone in Gothic style. The building was divided into three parts: the church proper, the annex (adjacent to the western end of the church) and the hall (adjacent to the south side of the annex and south-western corner of the church). The church and the annex were classified as Category I by the Historic Places Trust (i.e., they were considered to be of special or outstanding historical or cultural heritage significance or value).

When the February earthquake struck, a group of eight workmen from the South Island Organ Company Ltd was removing the pipe organ from the church. The building suffered a catastrophic collapse in the earthquake.

Police information provided to the Royal Commission indicated that six workmen including Mr Scott Lucy, Mr Paul Dunlop and Mr Neil Stocker were working inside the church, dismantling and moving the organ. Two of their other colleagues were on the outside of the building. After the earthquake hit and the church collapsed, Mr Lucy, Mr Dunlop and Mr Stocker were trapped under rubble, but the other three managed to get out. Mr Lucy was last seen running down the stairs inside the church during the earthquake. Mr Dunlop was last seen about four metres from the altar, and Mr Stocker was last seen standing on scaffolding. Their bodies were found by Urban Search and Rescue (USAR) on 23 February 2011.

4.16.2 The building

The church was built in 1864, the annex constructed as an addition in 1869, and the hall as a further addition in 1873. In the church, ornate tied timber trusses spanned buttress columns supporting the roof structure. There was a gallery at first floor level encircling the central ground floor seating. The first floor was supported by the external walls and internal columns. Both the annex and the hall also had timber trusses supporting their roofs.

On the southern side of the church (and in front of the hall) was a more modern building known as Aldersgate, which housed the Methodist City Mission and church administration.

It appears that no structural strengthening had been carried out on the church in the past. A structural report by an R. D. Sullivan structural engineer in September 2009 noted that the three parts of the building were earthquake-prone and would collapse in a moderate earthquake. Various strengthening options were proposed but none adopted. A proposal was made by Mr Sullivan in May 2010 to provide design details for strengthening the building. Mr Gregory Wright, Executive Officer of the Methodist Connexional Property Committee, gave evidence that before the September earthquake the Methodist Church was waiting to see what the CCC's strengthening requirements would be.

4.16.3 Events following the September earthquake

In the September earthquake some parts of the building suffered significant damage that would have required extensive reconstruction of the eastern towers of the church, the hall and (to a lesser extent) the annex. The building was allocated a red placard on 5 September 2010 and a full cordon recommended.

Figure 42: The eastern façade of the Durham Street Church after the September earthquake

After the September earthquake, the owner engaged Arrow International Ltd (Arrow) in relation to the building. Arrow engaged Mr Sullivan to prepare an initial damage assessment because of his prior knowledge of the building. Mr Sullivan noted that the church had been very extensively cracked and he designed steel frames to provide temporary support. He also noted that the organ in the church would have to be removed to storage while repairs were undertaken.

Figure 43: The organ in the Durham Street Methodist Church

The pipe organ had been inspected by the South Island Organ Company Ltd on 22 September 2010 and found to have sustained little damage. The decision was made to remove the organ from the church. Mr Wright explained that he understood this was necessary for remedial work to be carried out on the western wall of the church and he was advised that it could be done safely.

As the building had a heritage classification, it was necessary to involve the CCC in any repair work or removal of items such as the organ. Although the CCC Environmental Policy and Approvals Unit gave approval for the organ to be removed, this was based on a consideration of heritage issues rather than safety.

As the building had been allocated a red placard after the September earthquake and a full cordon had been erected, a notice under section 124 of the Building Act 2004 was never issued. By the time the CCC approval to remove the organ was sought early in 2011, the red placard status had expired. Therefore, although CCC approval still had to be obtained because of the heritage status of the building, Mr McCarthy of the CCC said any safety issues regarding the removal of the organ or access to the church were for the owner to address.

It was apparent that although a resource consent was required to remove the organ, the CCC approved its removal on the basis that a retrospective application would be filed. In submissions filed after the hearing, the CCC accepted that although there was no legal basis for allowing this, it had taken a pragmatic approach to Resource Management Act compliance in respect of listed heritage buildings requiring urgent minor works such as temporary securing and repair.

As Mr Sullivan was busy in the weeks that followed, Mr Gary Haverland of Structex Metro Ltd (Structex) was engaged to prepare a report on the damage and review temporary propping details prepared by Mr Sullivan. Mr Haverland said that he was asked to provide a second opinion on the appropriateness of the proposed propping but not the design calculations for that propping. Mr Haverland completed a structural assessment report on the building dated 4 October 2010, noting that the church and hall had suffered significant damage.

In a further report dated 21 October 2010, Mr Haverland commented on the temporary propping that had been designed by Mr Sullivan. He concluded that the proposed propping system and details were appropriate to provide temporary medium-term support to the eastern wall and north-eastern tower. Mr Haverland recorded that, based on Structex's inspection and report dated 4 October 2010, Structex believed that the main church auditorium had not had significant structural damage and was therefore "unlikely to collapse as a result of significant aftershocks".

He did not consider that additional temporary propping of the north-eastern tower was necessary to enable the organ to be removed. He recommended that "building occupancy be minimised to assist in reducing risks to persons carrying out the removal work". In evidence, Mr Haverland said he considered that the building had performed well in the September earthquake and that the aftershocks being experienced at the time were of a shorter duration and lesser magnitude. Further, he said that the organ was situated at the western end of the church, where the degree of damage was low, and it was distant from the area of greatest damage (the eastern wall of the church and the north-eastern tower).

In relation to his recommendation that "building occupancy be minimised", Mr Haverland said that in considering this he had regard to Structural Design Actions Part 0: General Principles, Standards Australia/ Standards New Zealand (AS/NZS 1170.0:2002), which incorporates risk factors. He said the risk factor was lower for temporary propping and construction works in which a small number of persons worked on site for a shorter period. That risk factor, he said, recognised the reduced likelihood of a large earthquake occurring during a shorter period of time when construction work or removal work was being carried out.

Structex had been engaged by Arrow to ascertain whether it was safe to remove the organ, and further advice was received by Arrow from Structex following the Boxing Day earthquake. Details were provided of a safe access via the Aldersgate building next to the church and safety measures were put in place.

Mr Timothy Fahy, project manager employed by Arrow, dealt with Mr Haverland. Mr Fahy also liaised with the CCC Heritage and Planning sections in relation to the proposed removal of the organ. The South Island Organ Company Ltd was engaged to enter the church and remove the organ.

On 19 January 2011 Mr Haverland carried out a further inspection to observe any additional damage as a result of the Boxing Day earthquake and subsequent aftershocks, and also to determine any safety issues associated with removing the organ. He noted significant further damage. In a later inspection he also noted that there was a bow in the western gable wall of the church. While it appeared to be mainly historical, as a precaution he recommended that brackets be installed to that wall to provide additional stability while the organ and other chattels were removed.

Mr Haverland said that by then it was becoming less likely that the building would be able to be repaired and retained, but that he was proceeding with a detailed assessment for repair. Although there had been further damage, Mr Haverland did not consider that the church was in a state that would prevent the organ from being removed because:

- the deterioration was gradual and most additional damage was likely to be the result of the Boxing Day event, which was considered to be a very significant aftershock in itself;
- stonework generally fell out from the building and all work was being carried out inside;
- the roof and gallery structure would normally prevent the walls falling in;
- a safe protected path had been constructed through Aldersgate;
- the roof trusses were tied together with a steel rod providing a good tie between the stone sidewall buttresses; and
- the main risk identified at that stage was associated with individual stones falling from the exterior of the building.

On 1 February 2011 Mr Haverland inspected the site with Mr Fahy to consider the possibility of providing access through the northern door of the annex. Mr Haverland said that if access were to be provided through this area, protective scaffolding should be placed over the door.

Mr Haverland gave evidence that at each stage he undertook a risk assessment having regard to the damage to the building. Given the damage sustained, he said that it was not possible to eliminate the risk during the organ removal process, but it could be minimised by limiting access to a short period of time, holding safety briefings (by Arrow) to highlight the risk, providing protective scaffolding and safe paths, and installing additional brackets to stabilise the annex wall behind the organ.

Mr Haverland completed a seismic assessment report on the church dated 17 February 2011, which recorded that "the building has been assessed as having a longitudinal (along the building) strength of 15 per cent of current code, and a transverse (across the building) strength of 10 per cent current code". In evidence, Mr Haverland said that the lateral load capacity would have been improved by the propping installed at the eastern end and the significant additional strength the gallery provided to the church building.

In a letter to Mr Fahy dated 16 February 2011 Mr Haverland said:

> The weakest area of the building is the Auditorium of the main church which has a transverse lateral load capacity of 10 per cent of current code. This assessment and strength is based on the building in its pre-earthquake condition, with no cracks. The building in its current state will have a strength less than its assessed value.
>
> Following our recent visits to the building, which have been carried out after the Boxing Day earthquakes, there has been noticeable additional damage, particularly to the north wall annex. Cracking of the side wall buttresses also appears to have increased.
>
> Further damage will continue to occur as a result of on-going aftershocks, which could result in the building becoming unsafe.
>
> We understand that the building, as well as its contents are of significant historical value. It is therefore necessary that additional temporary bracing be installed to the north wall of the auditorium, as well as the west wall of the hall to provide longer term protection to the building and its contents in the event of significant ongoing aftershocks.

In evidence, Mr Haverland explained that this work related to longer-term protection of the building. He did not consider it was unsafe for short-term access. He thought that it still had a low probability of collapse during an aftershock, particularly given the nature of the aftershocks that were being experienced. He did not consider that additional propping would be required before the organ could be removed. The proposed bracing of the western wall of the hall was outside the area of occupancy and the northern wall was not considered to be at high risk of collapse in the aftershocks being experienced at the time.

Mr Fahy contacted Mr Haverland after receiving a draft copy of Mr Haverland's report of 17 February and asked whether it was appropriate for the organ removal to proceed. Mr Haverland told him that he considered that it was. In evidence, Mr Haverland said he pointed out that the building had performed well and beyond expectations during the September and Boxing Day earthquakes: apart from the eastern wall and the towers, which were braced, it did not show significant signs of collapse under lateral loads associated with the aftershocks that were being experienced. He also said that assessments at this level of analysis were typically conservative: the calculations used for the building assessment were for a 50-year design life with crowd loading. Furthermore, there were other redundancies in the structure that were not taken into account in the analysis, which would have provided significant improvement in stability, such as the gallery floor at mid-height and the steel roof ties.

Mr Haverland stated in evidence:

> My view remained that it was appropriate to use a risk factor of 0.5 for construction loads as these were appropriate for short term access. This would also be consistent with the propping design carried out by Dick Sullivan. A risk factor of 1.3 would have assumed full use with full occupancy for a 50 year life. In assessing the risk involved with contractors being on site at this stage it was appropriate, in my view, to scale these figures to take into account the factors referred to in AS/NZS 1170.0:2002 such as the limited access. In that sense it would have been possible to scale the figures in relation to contractor short term access from 10 per cent to 26 per cent or in the case of the west wall adjacent to the organ from 87 per cent to 226 per cent.

Mr Haverland was questioned at some length on this issue by counsel assisting the Royal Commission and by the Commissioners. He explained that the risk factor (and the scaling-up of the strength assessment of the building) was used as part of the qualitative assessment to allow people to go into the building for short periods of time, but was not used as a tool to assess the strength of the building. Further, he emphasised that it was based on AS/NZS 1170.0:2002[8], which he understood took into account the elevated risk during an earthquake.

Figure 44: The interior of the church, showing scaffolding erected as part of the removal process

Mr John Hargraves, director of the South Island Organ Company Ltd, dealt with Arrow and relied on the assurances Mr Fahy gave that Mr Haverland had assessed the building and the risks involved.
Mr Hargraves gave evidence that he was not aware of the report from Mr Haverland dated 17 February 2011.

The company began removing the organ on 14 February 2011. The work was expected to take two weeks but was almost complete on 22 February. When the earthquake struck the church suffered a catastrophic collapse.

Figure 45: An aerial view of the Durham Street Methodist Church site after the February earthquake

Figure 46: The eastern side of the Durham Street Methodist Church after the February earthquake

Mr Peter Smith, who conducted an independent assessment of the failure of the building for the Royal Commission, said in evidence that the building effectively disintegrated in the high level of shaking, particularly the vertical acceleration that occurred during the February earthquake.

In relation to the propping, while Mr Smith considered that Mr Sullivan's interpretation of what was needed was more conservative than Mr Haverland's, he was of the opinion that even if the propping designed by Mr Sullivan had been installed, it would still not have prevented the collapse of the building.

Mr Smith considered that the performance of the building in the Boxing Day earthquake would have afforded some confidence to Mr Haverland in his assessment, but he noted that the connections between the various components of the building had not been investigated as part of that assessment. That would have required exposure of the connections to enable them to be examined, whereas Mr Haverland had inferred they were in good condition because he observed little movement between the roof trusses, mezzanine floor beams and the side walls. Mr Smith also commented that the latest thinking in terms of propping of such buildings was that it could actually be detrimental rather than helpful, and that in Italy the current thinking is to wrap the building and try to tie it together as a unit.

In relation to the assessment of risk in entering such a building, Mr Smith did not consider that the New Zealand Standards addressed this issue. As there were no clear guidelines for an engineer in making such an assessment, Mr Smith thought that risk factors in AS/NZS 1170.0:2002[8] were often used as a reference point by engineers to assess risk. He considered that there was scope for the development of guidelines that might assist engineers in assessing such risks.

4.16.4 Issues

4.16.4.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

The failure of this very old building provides a striking illustration of the problem that results from a passive approach to earthquake-prone buildings. This was a building where the owner knew before 4 September 2010 that it would likely collapse in a moderate earthquake and that it therefore required strengthening. The owner was waiting to see what the CCC's policy on strengthening would be, rather than having the work done at its own initiative.

4.16.4.2 Assessment of the risk associated with removing the organ

While we accept that hindsight can colour this issue, we are of the view that it would have been prudent to adopt a more conservative approach to the assessment of the risk involved in removing the organ. We say this for the following reasons:

1. This was clearly an earthquake-prone building.
2. It had suffered substantial damage in the September and Boxing Day earthquakes.
3. Mr Haverland's evidence was that by mid-January 2011 he considered it was becoming less likely that the building would be able to be repaired and retained. Although Mr Fahy expressed the view that to his knowledge deconstruction of buildings was not occurring at that time and that the CCC was unlikely to have agreed to the building not being retained, he said that this possibility had only been considered very briefly.
4. Mr Haverland considered that it would be necessary to fit additional temporary bracing to the northern wall of the church. While Mr Haverland explained that this related to longer-term protection of the building and its contents in the event of significant ongoing aftershocks, there could of course have been a significant aftershock at any stage.
5. Mr Haverland did not examine connections.
6. In regard to the risk factor of 0.5 applied by Mr Haverland and the theoretical scaling-up of the assessed strength of the building for the purposes of considering the risk, we doubt that this was the appropriate way to assess the risk. It could have artificially increased confidence in the building's structural integrity. Further, we have reservations about applying this methodology to a building at a time when there is an active ongoing sequence of earthquakes

We agree with the comments of Mr Smith (and Mr Haverland) that there is a lack of clear guidelines for engineers and others in assessing the risk of entering what is essentially a dangerous building. Such guidelines could stipulate the methodology and safety measures that would be put in place where access is to be permitted. This is a matter that we address in Volume 7 of our Report.

In this case it was apparent that no notice under section 124 of the Building Act 2004 was issued after the allocation of a red placard because a full cordon was in place and the owner was restricting access. This meant that, while the heritage section of the CCC was involved in the decision to remove the organ, the CCC was not involved in the safety assessment as it had no role under the Building Act.

We discuss dealing with dangerous buildings and the consideration of heritage concerns in section 7 of this Volume.

4.17 194 Gloucester Street

4.17.1 Introduction

The three-storey URM building that was situated at 194 Gloucester Street (known as Wave House) housed Winnie Bagoes, a pizzeria. The building was listed as a Group 3 heritage building in the CCC District Plan and registered as a Category II historic building by the Historic Places Trust.

When the February earthquake struck, Mr Ofer Mizrahi, an Israeli tourist, was in a white Mitsubishi van parked outside the building. The van was crushed by falling rubble from the collapse of the northern wall of the building. Mr Mizrahi died as a result of the injuries he sustained.

Figure 47: The front (northern) side of 194 Gloucester Street before the February earthquake

4.17.2 The building

The building was constructed in 1906 as the Trades and Labour Hall and originally comprised two floors fronting Gloucester Street and a single storey hall to the rear. In 1916 a second floor was added to the hall. Third-floor offices were added to the front section in 1924. A reinforced concrete liftshaft was added to the front side of the internal masonry wall in 1960.

It appears that a structural assessment by Holmes Wood Poole & Johnstone, structural engineers, in 1975–76 led to structural strengthening being undertaken to meet a seismic load level of 0.05g.

Mr Peter Smith, who carried out an independent assessment of the building for the Royal Commission, gave evidence that from his perusal of the CCC records there had been some strengthening work completed in 1975–76 but there was some uncertainty as to its extent.

A seismic report was prepared by Holmes Consulting Group (HCG) in 2002 for Mr Christopher James, a prospective purchaser who wanted to convert the ground floor into a restaurant. The report concluded that significant strengthening involving the introduction of new shear wall elements and concrete facing was likely to be required to satisfy section 46 of the Building Act 1991, which related to change of use of buildings. The HCG report was provided to the CCC by Mr James, who submitted to the CCC that café-style dining on the ground floor and office space on the first and second floors did not constitute a change of use. Further, he said that the cost of "significant strengthening" referred to in the report would make future renovations of the property unfeasible and would therefore probably result in the termination of the purchase agreement.

In a facsimile dated 21 February 2002, the CCC advised Mr James, "We have taken appropriate advice based on your amended proposal based on café-style dining on the ground floor and office space on the upper floor. We are now of the opinion that your amended proposal is not a change of use in terms of section 46 of the Building Act 1991". In January 2003 the CCC confirmed that the establishment of a bar/restaurant in the building did not constitute a change of use so no engineering report was required.

Mr Stephen McCarthy, from the CCC, gave evidence that the proposal for café-style dining on the ground floor in 2002 would not have constituted a change of use because there had previously been a kitchen servicing an assembly hall and this would have been considered part of the hospitality industry even though it had not been in use for some nine years. He said that there were no written records of this and he was relying on the knowledge of people who worked for the CCC at the time, in particular the legal section, which would have provided the advice referred to in the CCC facsimile of 21 February 2002.

Mr David Wallace of Devonia Realty Ltd (Devonia), who managed the building for the building's overseas owner, gave evidence that when the building was purchased in 2008 the vendor's agent advised that earthquake strengthening had been done in 2003 during refurbishment. However, after the September earthquake they were told by Beca Carter Hollings and Ferner Ltd (Beca), who Devonia had instructed to inspect the building, that it could not see any indication of this.

Mr Samir Govind, a Beca structural engineer, designed and supervised remedial work on the building after the 4 September and Boxing Day earthquakes. He gave evidence that his firm obtained CCC records to try and ascertain whether any seismic strengthening work had been carried out in 2003 but could not find any evidence of such work.

It appears therefore that, although work was completed when the fit-out for Winnie Bagoes was carried out in 2003, no seismic upgrade was required or carried out as it was not considered a change of use of the building.

4.17.3 Events following the September earthquake

After the September earthquake, a CCC Level 1 Rapid Assessment on 5 September 2010 noted that the parapet on the south side (at the rear of the building) had fallen into a courtyard. The building was allocated a green placard.

However, a Level 2 Rapid Assessment carried out by Mr Govind on behalf of the owner the next day resulted in the building being assigned a yellow placard. He noted the collapsed parapet at the rear and also cracking to upper-level brick walls.

A CCC Level 2 Rapid Assessment on 5 October 2010 noted cracking to the rear parapet and the yellow placard was confirmed. Then on 12 October 2010 the CCC served a notice on the owner under section 124 of the Building Act, requiring work to be completed by 31 January 2011.

Devonia instructed Beca to complete a preliminary structural engineering evaluation, which was completed on 14 December 2010. That evaluation assessed the building's capacity as 5% NBS but was supplemented by further assessment calculations that indicated a capacity range of 15–25% NBS if some reliable diaphragm connection was available. Mr Govind noted that in a building such as this there was potentially very little reliable diaphragm connection.

The day after the Boxing Day earthquake the building was inspected by USAR. Severe parapet damage was noted and damage to the northern and north-western parts of the building. A second Building Act notice was served on the owners, care of Devonia, on 27 December 2010, requiring make-safe work to be completed by 31 January 2011.

Mr Wallace gave evidence that on 6 January 2011 Devonia advised the CCC that Beca had carried out a closer inspection of the upper parts of the building with a crane and concluded that the level 3 western wall was precarious and needed to be taken down immediately, both to make the building safe and to enable an internal inspection for further damage.

Devonia sent another email to the CCC later that day reiterating the danger to persons and property and advising that the building contractor was starting on site that week. The make-safe work was approved by the CCC by email that same day, subject to a retrospective application being made for a resource consent in due course.

Devonia engaged contractors to be briefed by Beca and then carry out the make-safe work under Beca's supervision. On 3 February 2011 a CCC engineer's re-inspection form recorded that this repair work was in progress and that the protective fencing around the building was adequate. Mr Wallace said in evidence that Beca was subsequently instructed to inspect the work that was carried out by the contractor. The make-safe work was completed by 14 February 2011. Mr Govind of Beca sent an email to Mr Wallace (with a copy to the CCC) stating: "As promised the works at 194 Gloucester are now complete – refer letter to remove fences. I presume with this letter the adjacent buildings can be opened up as well as the concern with 194 Gloucester is closed out".

That email attached a letter from Mr Govind to the owner of the building, which stated:

> On the basis of a visual inspection of the building conducted on 14 February 2011, we are satisfied, on reasonable grounds, that any potentially dangerous features have been removed or secured, and that the stability of the structure is sufficient that it does not pose a threat to adjacent buildings or the public that is significantly greater than prior to the earthquake.
>
> Notwithstanding the above, the building has suffered damage from the recent earthquake and is potentially earthquake prone. The inherent risks due to being a potentially earthquake prone building still exist. We are currently undertaking further investigations and assessment work to develop appropriate remedial/strengthening works (if required) for the building.

The CCC relied on the email and letter from Mr Govind and subsequently removed the barriers that had been in place in front of the building, positioned about halfway into the traffic lane on Gloucester Street nearest to the building.

On 15 February 2011, Ms Sharon Weir of the CCC sent an email to other CCC officers stating:

> We have a[n] urgent requirement to remove the cordons of the 192–194 Gloucester Street block. This has been signed off by the engineer to remove, Neville Higgs.
>
> We have loaded a[n] RFS number 91246304 marked urgent, this does need to be completed today as the property owners have been in contact with Chris Kerr and the Media is a threat to us…

Mr Wallace gave evidence that neither the building owner nor Devonia had any involvement in the removal of the cordons. Although he confirmed that the same owner also owned 192 Gloucester Street and that Devonia managed that building as well, he said that as far as he was aware neither the owner nor Devonia had made any request to the CCC or Beca to remove the cordons. Mr Wallace said that 194 Gloucester Street was empty and that there was no reason to remove the cordon in front of the building. The only reason to remove any fences would have been to provide parking for customers of a pharmacist, Mr Phil Berry, who was seeking to reoccupy his premises at the western end of 192 Gloucester Street. Mr Wallace said he suspected that the email from Ms Weir might have mistakenly referred to the building owner when she had meant to refer to Mr Berry, who operated the pharmacy and to whom a subsequent email sent by Ms Weir that same day referred.

While Mr McCarthy disapproved of the terms of the email Ms Weir had sent, he presumed that there was pressure from a nearby business owner to remove the cordon, as was not uncommon. He said that although a decision to remove a cordon would normally be recorded on the CCC file, there was no written record of it in this case. Mr McCarthy said he believed that the file was sufficiently complete to satisfy Mr Higgs, the CCC engineer, that he could make the decision. He conceded in cross-examination that the letter from Mr Govind dated 14 February 2011 did not confirm that the building was "safe to occupy", and that this was a requirement in the CCC's procedure for removal of temporary fencing/barricades from buildings with yellow or red placards.

In cross-examination, Mr Govind maintained that, despite the reference to fences in his email, he was not intending to advise the removal of the fences, but rather was addressing the Building Act notice requirements. However, Mr McCarthy was of the view that, although the CCC relied on Mr Govind's letter to remove the fences, the Building Act notice remained in place as there were more permanent works required to the building before it could have been reoccupied. In fact it remained unoccupied.

Mr Smith gave evidence that in the February earthquake the building suffered a substantial collapse of the eastern and western walls, and of the northern wall above second floor level.

Figure 48: The building after the February earthquake

Figure 49: The front of the building after the February earthquake, showing the damaged van to the left

4.17.4 Issues

4.17.4.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

Again, the history of this building provides an illustration of the passive approach of the CCC to earthquake-prone buildings. In this case, an engineer considered in 2002 that a proposal to convert the ground floor into a restaurant might constitute a change of use that would entail substantial earthquake strengthening. However, although there are no written records, it appears that a change to café-style dining and then to a restaurant and bar was not considered to be a change of use, presumably on the basis that there had been a kitchen in operation on the ground floor some nine years previously. This may have been a permissible application of the legislation at the time, as Mr McCarthy maintained, although there is insufficient information available to the Royal Commission about the historic use of the building for us to confirm that. Nevertheless, we are of the view that this approach was inconsistent with ensuring public safety in relation to a URM building.

4.17.4.2 Removal of the cordons in front of the building

In providing the letter of 14 February 2011, Mr Govind was clearly applying the same test that almost all engineers were applying at that time, namely a damage-based test. In fact, he did qualify his conclusions by saying that the building was potentially earthquake-prone. On the basis of the test he applied, his conclusions cannot necessarily be faulted, but we consider that relying solely on a damage-based test for determining whether it is safe to occupy a URM building after a substantial earthquake is problematic.

The CCC appears to have relied solely on Mr Govind's letter in deciding to remove the cordons. Although there was reference to Mr Higgs, the CCC engineer who signed off the removal, there was no evidence before us to show that any independent CCC assessment had been made of the building or cordons.

There does seem to have been pressure on the CCC from a business owner in a nearby property to remove the cordon quickly. This may have had some effect on the CCC's processes but it was clear, as Mr McCarthy said, that the CCC effectively relied on Mr Govind's letter in arriving at its decision. The terms of the letter of 14 February did not completely comply with the CCC's procedure for removal of a cordon, in that there was no engineer's report stating that the building was safe to occupy. In fact, according to Mr McCarthy, the Building Act notice would have remained in effect because there was other, more permanent work required before reoccupation. While that omission may not have had any practical effect, it may reflect the apparent pressure on the CCC to remove the cordon quickly.

In our view, this case highlights the issues presented by lack of clear cordon management after a significant earthquake. Post-earthquake building management is discussed in Volume 7 of this Report.

4.18 194 Hereford Street

4.18.1 Introduction

The structure at 194 Hereford Street was a two storey URM building on the corner of Hereford and Liverpool Streets. Mr Gregory Tobin worked as a chef at Joe's Garage, a café on the ground floor. He was in the kitchen at the time of the February earthquake and was seen by one of the business owners, Ms Christine Watson, running out the front door onto Hereford Street, where he was hit by falling masonry. After the earthquake, USAR searched the rubble outside the building and located Mr Tobin, who was deceased.

Figure 50: The western side of 194 Hereford Street (viewed from Liverpool Street) before 22 February 2011

4.18.2 The building

The building was likely to have been built in the 1930s with lime-based mortar. It was strengthened and rebuilt internally in 2005–06 under the supervision of O'Loughlin Taylor Spence Ltd, consulting engineers, when the external walls and associated foundations were the only original structural elements retained. The external walls were a combination of double, triple and cavity brick construction. The northern and western façades had reinforced concrete bond beams over the window and door openings at ground and first-floor levels. The ground floor had a new reinforced concrete slab.

Previously the external walls had been laterally strengthened in the east-to-west direction using steel portal frames, which also supported the new floors and roof. The existing parapets had been tied back to the new roof with steel channels anchored into the back of them. The perimeter walls had been tied into the timber floor diaphragms at the first and second floor.

4.18.3 Events following the September earthquake

After the September earthquake, a CCC Level 1 Rapid Assessment recorded damage as “minor/none” and a green placard was allocated to the building. As the building had a green placard and the CCC was unaware of any damage, there was no further inspection or assessment by the CCC, including after the Boxing Day earthquake.

After the September earthquake the owners of the building arranged for an inspection by O’Loughlin Taylor Spence. Mr Rhys Smith of that firm carried out numerous inspections between September and February, and designed and oversaw remedial work to the building.

The building sustained significant structural damage in the February earthquake, including collapse of the URM parapets on the northern, western and southern elevations, collapse of the northern façade at first-floor level (including two thirds of a reinforced concrete roof-level bond beam) and collapse of the east parapet and firewall at first-floor level.

Figure 51: The northern frontage of 194 Hereford Street after the February earthquake

Figure 52: The western and southern walls of 194 Hereford Street after the February earthquake

Mr Peter Smith commented in his report to the Royal Commission that it was possible that workmanship may have contributed to the failure of the connection between the external walls and the strengthening works, because good workmanship was an important factor in the use of epoxy-based fixings to secure the brick walls to the structure of the building. Further, he noted that "heightened industry awareness of the importance of workmanship and temperature in the use of epoxy fixing systems is required and increased construction monitoring or proof testing for quality assurance of these fixings seems justified".

Mr John O'Loughlin from O'Loughlin Taylor Spence gave evidence of the structural strengthening carried out and in particular commented on the issue raised by Mr Smith in relation to the epoxy fixing. In Mr O'Loughlin's view, while the quality of workmanship was a factor, "the fact that the bricks are separating during a vertical acceleration far higher than the Code has ever allowed for means that no matter how well or poorly the connections are made they are going to fail under those circumstances".

Mr O'Loughlin said that although he oversaw the strengthening work, he was only periodically at the site, possibly once a week. Although he observed that the epoxy fixing had been carried out by the contractor, he said that engineers relied on the contractor to do the work correctly and it was "an observation process the engineer goes through rather than a supervision process".

Mr Phil Wilby gave evidence that the epoxy fixing work was carried out by staff employed by New Zealand Civil and Construction Ltd, of which he was general manager and a director. Mr Wilby gave evidence that, in his opinion, the work was carried out in a workmanlike manner and in accordance with the manufacturer's specification. He carried out an analysis of the strength of the fixing rods. In his view, due to the apparent lack of damage to the rods and the fact that they appeared to be well epoxied into the brickwork, it was the bricks and mortar themselves that had failed as they were the weakest building element. Mr Wilby conceded that on this particular contract there was no proof testing or quality-assurance checking.

Mr O'Loughlin and Mr Rhys Smith were both questioned about steel channels on the southern wall in photos taken by the latter, which showed two bolts missing. We accept from their evidence that these would not have made any difference to the structural strength of the building. However, it transpired that an inspection of the building by them after the February earthquake showed that all of the bolts in similar steel channels on the northern side had been missing, so that the channel had effectively not been attached to the purlins. When asked what that indicated to him as an engineer, Mr Smith replied, "That whoever put that in there didn't finish their job". Mr O'Loughlin said that during the strengthening works he was not able to inspect the channels at the northern end of the building as the roof had already been covered at that end when he came to inspect it.

After an inspection of the building on 14 October 2010, Mr Smith had designed a bracket to address cracking of the eastern end of the northern parapet. By that date he had access to the original strengthening drawings, which indicated that brackets should have been fixed from the roof-level framing to the back of the walls to restrain them. At that stage he had not been into the roof space, but he concluded that, given the damage, either the brackets had not been fitted on the north façade, or if they had been, they were ineffective.

Mr O'Loughlin made the point that, although the northern façade collapsed and (as it transpired later) bolts were missing from that side, so too did the western wall, which appeared to have been properly secured.

After the hearing, counsel assisting the Royal Commission wrote to Armitage Williams Construction Ltd, the contractors who had carried out the strengthening work, asking for comment on this issue. Unfortunately the company could not contact the site manager who had been responsible for the project at the time. However, Armitage Williams noted that there had been a CCC inspection of the roof space before the linings were installed. We are aware from the CCC file that there was a ceiling inspection but this appears to have focused on timber framing, ceiling lining fixings and insulation. Our understanding of the inspection regime at that time is that the CCC would have relied on the design engineer to ensure the strengthening work was installed as designed.

4.18.4 Issues

4.18.4.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

Despite extensive strengthening works carried out in 2005–06, because of the increase in the strength threshold of an earthquake-prone building, this building would still have been potentially earthquake-prone as at September 2010.

Under the CCC's 2006 Earthquake-Prone Dangerous and Insanitary Buildings Policy, if an owner applied for a building consent for a significant alteration (as was the case here), there was no requirement to strengthen the building if it was already more than 10% NBS. In this case, the CCC had been satisfied from the information available that the building exceeded 10% NBS.

In our view, this made a passive policy even more passive. It effectively meant that a building owner would not have to strengthen a building unless it was less than 10% of NBS (unless there was a change of use). We note that fortunately this has not been replicated in the CCC's 2010 policy.

4.18.4.2 Efficacy of the previous structural strengthening

The previous strengthening carried out apparently prevented the collapse of the building apart from the upper levels of external walls and the parapet. Despite the violent shaking to which the building was subjected, much of the interior remained intact and apparently suffered little damage. The problem was with the attachment of the brick walls to the strengthened structure.

4.18.4.2.1 Epoxy fittings

While Mr Peter Smith raised the possibility that workmanship was a factor in the failure of the brick façades, it appears from Mr Wilby's evidence that the standard of workmanship was unlikely to have been a factor. Nevertheless we are of the view that, consistent with Mr Smith's opinion, more research is needed into the retrofitting of URM buildings, including the epoxy fixing of masonry walls to the structural elements of a building.

We also agree that there needs to be heightened industry awareness of the importance of workmanship and temperature in the use of such systems, and increased construction monitoring or proof testing for quality assurance.

4.18.4.2.2 Missing bolts

It is a concern that there appear to have been no bolts fixing the steel channel to the purlins on the northern end of the building. This might well have been identified during the strengthening works if the roof had not been covered over at that end of the building before Mr O'Loughlin was able to inspect it. It is unfortunate that Armitage Williams could not make contact with the person who was the site manager at the time, to enable this issue to be explored more fully. In the circumstances we cannot take this issue any further.

While we are not aware that issues of this nature are a widespread problem, they highlight the need for industry awareness and continuing education. We note Mr O'Loughlin's comments that the western wall, though properly secured, collapsed in the February earthquake.

4.18.4.3 Vertical accelerations

Mr Smith noted that the vertical accelerations in the February earthquake would have significantly reduced the out-of-plane strength of the lime mortar URM northern and southern wall façades. He also noted that the axial load in upper-floor URM walls was relatively low, so these walls were more susceptible to vertical acceleration effects under out-of-plane failure. Mr O'Loughlin agreed with this.

We agree with Mr Smith's suggestion that, in the interests of public safety, more consideration should be given to the effects of vertical acceleration on the upper storeys of URM buildings. This is an issue that the Ministry of Building, Innovation and Employment and the New Zealand Society for Earthquake Engineering should consider.

4.19 246 High Street

4.19.1 Introduction

The building at 246 High Street was a three storey URM building. Immediately to the north was 248 High Street, which was known as the Link Centre and ran through diagonally to 152 Hereford Street.

Mr Joseph Pohio, who had been a member of USAR for 23 years, was in the Link Centre at the time of the February earthquake. As he bent over to help a woman on the ground about five metres inside the High Street entrance, the north wall of the building collapsed through the roof and he was struck by rubble. He was dragged clear by members of the public and CPR was performed but he could not be revived and died at the scene. On 22 February 2012 Mr Pohio was posthumously awarded a Christchurch Earthquake Award for heroism for going to the aid of the woman in the Link Centre.

4.19.2 The building

4.19.2.1 The Link Centre

The Link Centre was a modern building comprising a concrete column-and-wall main tower on Hereford Street, linked to High Street by a two-level concrete floor-and-column structure. A large void in the first-floor level allowed light from roof-mounted lightwells into the ground-floor retail area.

Figure 53: 246 High Street before the February earthquake, viewed from the north-west. The iron-clad mustard-coloured party wall can be seen at top centre

It appears that the Link Centre was built in about 1978 after the demolition of the building that previously occupied the site. The southern wall of the Link Centre was built abutting a brick wall that is likely to have originally been a party wall between 246 and 248 High Street. As the Link Centre was only a two storey building, the upper storey of the northern brick party wall of 246 and 248 High Street was left exposed. It was then covered in a mustard-coloured iron cladding, presumably for aesthetic and weatherproofing reasons. A building survey carried out on 246 High Street in 1975 noted that the northern and southern walls “may be party walls for adjacent buildings”.

4.19.2.2 246 High Street

A CCC seismic risk building survey in 1975 gave the building a score of 15, which resulted in a classification of A, meaning that immediate remedial action under section 301A of the Municipal Corporations Act was recommended.

A letter from the CCC to the owner of the building in 1976 noted that the building would not comply with the provisions of that section (i.e., it would not have sufficient strength to resist a moderate earthquake). In particular, the CCC was concerned about the façade construction and sought advice as to the owner’s future intentions for the building. There does not appear to have been any reply or follow up by the CCC.

A further CCC seismic risk building survey in January 1990 gave the building a score of 14, which resulted in a classification of B, meaning that remedial action within two years was recommended. Earthquake strengthening was also required to be carried out in 1990 as a result of a building permit application by the then owner. The CCC sought to ensure that the strengthening work was completed by requiring the owner to enter into a memorandum of agreement (accompanied by a caveat on the title to the land) that appears to have treated the permit for strengthening and refurbishment work as a permit to erect a temporary building, which the owner agreed would be removed or made to comply with the CCC’s building by-laws by 31 May 2005. During strengthening it was discovered that there were steel columns in the front façade area that appeared to have been installed in about 1960. The then owner’s engineers proposed to the CCC that for this reason there could be a revised seismic strengthening scheme that took into account the existence of the steelwork. The CCC agreed to this, subject to the understanding that the occupancy of the upper floors would not be significantly increased.

The CCC noted that the question of the long-term future of the building remained to be answered but that the present intent to address the problem was covered by the memorandum of agreement.

In 1991 the CCC conducted a hazardous appendage survey that noted five hazardous chimneys on the eastern elevation and significant cracking, although no cracking was visible on the street façade.

On 19 March 2003 the CCC, "in recognition of the substantial strengthening work already completed to the ground floor", extended the period allowed in the memorandum of agreement for completion of the strengthening work to 31 May 2008. That concession was conditional on the building not undergoing any change of use or significant alterations before that date.

In 2006 the solicitor for a prospective purchaser of the building asked the CCC whether there was still a requirement for strengthening work to be done on the building by 31 May 2008. The CCC replied in August 2006 that it was currently reviewing its policy on earthquake-prone buildings, with the long-term aim of progressively issuing notices requiring structural improvement, and that high-risk buildings were first in line. In the meantime the policy was the same as it had been previously, with buildings being addressed when a building consent application was received.

The CCC advised that generally buildings with a caveat on the title were those in the worst risk category (A), which would mean it was likely that improvement would be required as part of any building consent application. The CCC also noted that the likely requirement for this building was a structural report and that improvement work would probably be required with any future building consent applications. If no such applications were made, it was likely that the owner would be put on notice to carry out improvements within 10–15 years.

Figure 54: The roof of 246 High Street. The top of the mustard-coloured party wall can be seen on the right

4.19.3 Events following the September earthquake

It appears that after the September earthquake the building was allocated a green placard following a Level 1 Rapid Assessment.

Mr Christopher Chapman, of Grenadier Real Estate Ltd, trading as NAI (Harcourts), managed the building for its owners, Shugborough Properties Ltd. Harcourts arranged for Holmes Consulting Group Ltd (HCG) to carry out an assessment of the building. A Level 2 Rapid Assessment was conducted by HCG on 10 September 2010. That inspection noted damage to the parapet and chimneys on the south-eastern side and changed the existing green placard to yellow. The CCC was advised.

After a further inspection by Mr Alistair Boys of HCG on 15 September 2010, it was recommended that all loose masonry be removed from the chimney and parapets and that a temporary restraint detail for the parapet on the south-western corner of the building be provided. Mr Boys inspected the northern parapet, which did not show any evidence of damage. In evidence Mr Boys said that he was not able to view the masonry of the top of the north wall/parapet owing to the cladding and capping. He did have a limited view of the portion of the inside of the wall that was visible from the roof area, but was unable to see the exterior of the northern wall as it was covered in metal cladding. Mr Boys carried out an interior inspection but this was limited to the accessible areas and he could not be certain that he had looked at the interior of the northern wall. However, in the areas of the building that he did see, he did not observe any evidence of structural separation of the walls.

Mr Boys conducted a further site inspection on 21 September when make-safe work had been completed. He completed a Level 2 Rapid Assessment form, assigning a green placard to the building.

A CCC Level 1 Rapid Assessment carried out on 26 December 2010 after the Boxing Day earthquake recorded damage as “minor/none” and assigned the building a green placard. However, a Level 2 Rapid Assessment or detailed engineering evaluation and structural inspection was recommended, with a note to “check rear walls given age”. The CCC did not follow up this recommendation. Harcourts did not arrange for any further inspection to be carried out after the Boxing Day earthquake, but Mr Chapman said they relied on the CCC’s inspections.

The building was severely damaged in the February 2011 earthquake. In particular, the northern wall collapsed down to first-floor level, and rubble and building material collapsed onto the roof of the adjacent Link Centre atrium and into the area used by pedestrians.

Figure 55: The roof of the Link Centre after the February earthquake, with 246 High Street on the left

Figure 56: 246 High Street after the February earthquake

At the hearing, Mr Peter Smith, who prepared an independent report for the Royal Commission, raised a significant issue in relation to the northern wall of the building. By referring to a 1978 foundation plan for the Link Centre and a photograph, he was able to explain that the northern brick wall of 246 appeared to have been a party wall shared with the building that formerly occupied the Link Centre site before the Link Centre development. When that former building was demolished and the northern wall of 246 left exposed, the southern block wall of the Link Centre was built 25mm from the party wall. The portion of the third storey of the party wall that was exposed (the Link Centre being only two storeys) must subsequently have been covered in metal cladding to provide weatherproofing.

Mr Smith said the concern was that once the adjoining building had been demolished, the masonry party wall no longer had the adjoining building for support and had only the connections to the building at 246 to restrain it. Many URM buildings had an ineffective restraint at floor level, rendering their walls potentially dangerous. Here the wall had failed above the first-floor level.

A further feature of concern that became apparent after the failure of the building was that the rear portion of the northern wall appeared to cover a corrugated iron portion, raising doubts about any significant fixing at roof level.

Mr Smith expressed the view that consideration needed to be given to the potential danger to public safety from such walls after the demolition of an adjoining property.

4.19.4 Issues

4.19.4.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

As early as 1975 the building had been identified as not having sufficient strength to resist a moderate earthquake. However, nothing was done until 1990 when the then owner applied for a building permit. Even at this point the owner was able to minimise the structural strengthening carried out, by revising occupancy requirements and relying on the steel columns that appeared to have been installed in 1960. Apparently the longer-term future of the building was still unresolved but the CCC sought to enforce future upgrading by the terms of a memorandum of agreement and caveat. Just how that agreement was ever going to be effective escapes us, as it did counsel for the CCC, Mr Laing. We suspect that such a mechanism would not be used again in the future.

4.19.4.2 Assessment of the building after the September earthquake

We endorse the views of Mr Smith in relation to the matter of a party wall exposed by demolition of an adjacent building. Mr Boys was not asked to comment on whether, in inspecting the building following the September earthquake, he gave consideration to the issue of the party wall that had been exposed by the demolition of the adjoining building.

However, a difficulty with the damage-based assessment of this building was that the northern wall/parapet was to a large extent obscured by exterior cladding/capping and interior wall linings. Mr Boys accepted in evidence that there could have been obscured damage, but he considered that, from the lack of evidence of damage to other representative areas of the building that he was able to view, it was unlikely that an invasive inspection would have yielded more information. While that might have been the case, it highlights the problems with the inspection of URM buildings using a damage-based assessment after a substantial earthquake.

The Royal Commission considers that when granting permission to demolish a structure it should be normal practice to consider the safety of remaining portions. Further, conditions attached to a building consent for a new building should include a requirement to replace the support that the former building provided to the party wall.

In this case it appears likely that 246 and 248 had a common party wall that subsequently collapsed onto 248. An error of omission occurred when the support previously offered by the former 248 building was not replaced when the Link Centre was built. The loss of support to a party wall when a portion of a row building is demolished is discussed in section 7 of this Volume.

4.20 43 Lichfield Street

4.20.1 Introduction

The building at 43 Lichfield Street (known as the Anderson building) was part of a complex of four buildings owned by the retail company, J. Ballantyne & Co. Ltd (Ballantynes). There were three rows of precast concrete spandrel panels above the Lichfield Street frontage, some of which fell from the building in the February earthquake.

Ms Linda Arnold was sitting in her motor vehicle near 43 Lichfield Street when the earthquake struck. One of the spandrel panels crushed the car, killing her.

Figure 57: The southern frontage of the building at 43 Lichfield Street is shown at left in this photograph. The three rows of precast concrete façade panels can be seen above the frontage and along the eastern side of the building

4.20.2 The building

The building at 43 Lichfield Street was a seven-level ductile frame building with precast, prestressed floors supported on transverse frames with seismic beams. The building comprised two levels of retail space above ground and a further four levels of parking above (numbered in levels higher than seven in sequence with the neighbouring car park building). There was also one basement level below ground. Three rows of precast concrete spandrel panels were attached to the upper three levels of the southern and eastern sides of the building.

The head contractor for the construction of the building was C.S. Luney Ltd (Luneys). It engaged LSC Consulting Ltd (LSC Consulting) as structural engineers for the project. Mr Dick Cusiel, a structural engineer and director of LSC Consulting, oversaw the design of the structural elements of the building, including the spandrel panels.

The building plans set out the mechanism of attachment of the spandrel panels to the eastern and southern sides of the building. However, there was a difference between the design of the spandrels panels on each side. On the eastern side, the plans provided for L-shaped steel cast-in ties. These were to be cast into the precast spandrel panels and run into the concrete topping on site. The floor topping was to be poured over the ties, locking the spandrel panels into the structure.

The drawings of the spandrel panels on the southern (Lichfield Street) side did not show steel cast-in ties. However, they did provide for each panel to have four steel bolts connected to weld plates on the columns of the building. Those bolts were not included in the design of the spandrel panels on the eastern side.

4.20.3 Events following the September earthquake

After the September earthquake, a CCC Level 1 Rapid Assessment of the building on 5 September noted minor damage and resulted in a green placard.

Ms Hannah Clarke, a structural engineer with Powell Fenwick Consultants Ltd, inspected the building on 5 September and 19 November 2010, on the instructions of the owner. In evidence, she said the brief to Powell Fenwick excluded the parking areas in the building. She said that consequently her inspections did not include the spandrel panels. Ms Mary Devine, managing director of Ballantynes, agreed that Powell Fenwick was not instructed to inspect the car park. Mr Cusiel's firm was asked to inspect this area, as it had been involved in the original design.

Ms Clarke also said in evidence that she was not asked to and did not inspect the exterior of the Anderson building fronting on to Lichfield Street. On this matter, she said that although Ballantynes did not specify what the engineers should inspect, they relied on the engineers' expertise as to whether the building could be reoccupied. She pointed out that Powell Fenwick carried out inspections of the exterior of at least some of Ballantynes' buildings.

After an inspection of the parking areas of the building by a CCC officer, LSC Consulting was asked to inspect some concrete columns on each side of a ramp to level 10A. Mr Matt Cusiel of LSC Consulting carried out an inspection on 23 September 2010. In an email to Ballantynes that day, he reported that some work should be carried out but that the ramp could still be used safely. Mr Dick Cusiel conducted a "walkover" of the building on 20 October 2010. He said in evidence that he did not note any damage to the spandrel panels during this.

Ms Clarke prepared a report to the owner dated 14 December 2010. The report noted that although there was some damage to the building, its short-term structural integrity was not affected.

Ballantynes asked LSC Consulting to advise on the repairs required to the Anderson building. Mr Dick Cusiel provided a report to Ballantynes dated 22 December 2010 setting out repair procedures. He said, "We are confident the building will continue to comply with the required Building Codes". Ballantynes proceeded to have the required repairs carried out.

Mr Dick Cusiel carried out an inspection of the Anderson building on 23 December 2010, in which he noted some cracking to a wall and a ground-floor slab. He did not consider the cracks to be significant and did not think they compromised the structural integrity of the building. After the Boxing Day earthquake the CCC carried out a further Level 1 Rapid Assessment. Again this noted minor damage and resulted in a green placard.

At the request of Ballantynes, Mr Dick Cusiel carried out further inspections of the Anderson building on 19 January and 2 February 2011. Once again he did not have any concerns about its structural integrity. In evidence, he said he did not carry out any inspection of the Lichfield Street exterior of the building, nor any interior inspection of potential damage to the connections between the spandrel panels and the columns on the southern side. His assessment of the building did not include an examination of the plans, as there was no damage evident.

The building suffered widespread and significant damage in the February earthquake, indicating that it had been pushed close to its capacity for seismic loading. The damage included failure of transfer beams, column connection and column beam hinging, as well as shear displacement of beams and beam elongation. In addition, some of the spandrel panels on the southern side fell from the building.

Figure 58: The building after the February earthquake

In evidence, Mr Dick Cusiel candidly acknowledged that the absence of the L-shaped cast-in ties on the spandrel panels on the southern side "contributed with the significant force of the earthquake to the spandrel falling away from the structure". He described the absence of the ties as an omission. He said that the weld plates and angle cleats "were primarily there for the purpose of construction, to put the panels in place while the floor topping was poured. They were unlikely to have been sufficient to keep the panels in place in the event of a major earthquake".

Mr Dick Cusiel explained that although a draughtsman in his office had drawn the plans, he had reviewed them prior to their submission to the CCC for consent and he took responsibility for the omission.

In a report to the Royal Commission, Mr Peter Smith said that the spandrel panel fixings for the southern side of the building did not comply with the Building Code that was current at the time. In evidence, Mr Dick Cusiel agreed with this. Mr Smith also said that, as the connections were significantly under strength and the earthquake shaking was in excess of the building code design requirements, failure of the spandrel panels was almost inevitable. Mr Cusiel also agreed with this.

Figure 59: A spandrel panel on Ms Arnold's car (left), and the site after removal of the spandrel panel

4.20.4 Issues

4.20.4.1 Non-compliance with Code

Mr Smith identified that the connections of the spandrels on the southern side of the building did not comply with the Building Code and were significantly under strength. Mr Smith said that failure was almost inevitable in an earthquake as strong as that experienced on 22 February 2011. We note however that, although two of the three large spandrel panels on the southern side fell, one remained attached, notwithstanding the inadequacy of the connections.

As Mr Dick Cusiel acknowledged, the absence of cast-in ties to the spandrel panels in this section of the building contributed to their falling.

4.20.4.2 Identification of non-compliance by the local authority

Mr Stephen McCarthy from the CCC gave evidence that the CCC agreed with Mr Smith that the spandrel panel fixings as detailed in the drawings did not comply with the Building Code current at the time. He gave evidence that, before issuing the building consent for the work, the CCC received a design features report and a producer statement. There would have been inspections as the work progressed, and once the project was complete, the CCC required a construction review producer statement.

Counsel for Mr Dick Cusiel cross-examined Mr McCarthy about the fact that the CCC had issued a building consent for drawings that it now accepted did not comply with the applicable Building Code. Asked whether he agreed that the engineers in the CCC's consenting team did not identify the absence of tie-ins for the southern spandrel panels, Mr McCarthy said, "We certainly would have liked to have picked that up. It wasn't obvious to our engineers, otherwise they would have picked it up".

Mr McCarthy agreed that "the second line of the checks at the CCC end effectively failed". He explained this by saying that, with very competent engineers such as Mr Dick Cusiel, "the level of checking will vary according to the risk profile of the job". When asked what could happen to avoid a repeat of this type of problem, Mr McCarthy replied, "We will put more emphasis on receiving a second tier of engineering review."

4.20.4.3 Identification of non-compliance by contractor

At the request of counsel assisting the Royal Commission, Luneys arranged for an affidavit to be provided by Mr Jay Anderson, the foreman on the site at the time the Anderson building was constructed.

Mr Anderson said that he had a set of plans on site at the time of construction. He said he noticed that the plans had different detailing for connection on the eastern side than those for the southern side. When the spandrel panels were delivered to the site he also noted that there was a difference between them. Mr Anderson said that he regarded the plans as being detailed and clear and they left no doubt as to the method of fixing. As the plans were so clear, he saw no reason to question them. When he saw the spandrel panels he also saw no reason to question the different fixings because they had been manufactured in accordance with the plans.

In his submission to the Royal Commission after the hearing, counsel for Mr Dick Cusiel submitted that Luneys should have identified the potential deficiency in the plans and raised it at the time. On this issue, Mr Smith gave evidence that, although he agreed the form of connection used on the south was a common method of construction, "I would have hoped that an experienced contractor would have looked at the 10 metre-long panel in particular and questioned whether there wasn't some further fixing required".

We would like to think that an experienced contractor (and an experienced CCC inspector) would have identified the problem with the spandrel panels on the southern side. However, we accept the evidence that considerable reliance was placed on Mr Dick Cusiel's undoubted experience.

This highlights issues that can arise from reliance on one engineer's structural designs during the consent process. We address this in Volume 7 of this Report.

4.21 116 Lichfield Street

4.21.1 Introduction

When the February earthquake struck, Ms Kelsey Moore was carrying her five-week-old daughter, Teneysha Prattley, as she walked with her partner, Glenn Prattley, along Manchester Street outside the Reuben Blades Hair Academy at 116 Lichfield Street. The building was on the corner of Lichfield and Manchester Streets. The Manchester Street façade of the building collapsed in the earthquake and Ms Moore and her daughter were trapped under rubble. Their bodies were found by USAR on 26 February 2011.

Mr Owen McKenna was in his car, the middle one of three vehicles stationary at the traffic lights in the northbound lane of Manchester Street at the intersection with Lichfield Street. When the earthquake struck, a large amount of building debris fell from 116 Lichfield Street onto the three cars, trapping the occupants. Rescuers removed rubble and found the deceased Mr McKenna in the driver's seat of his vehicle. Mrs Lisa Willems was also in her car at the time of the earthquake, the third of the three vehicles referred to above. She was rescued and carried across the road but did not respond to first aid and died at the scene.

4.21.2 The building

The building at 116 Lichfield Street was a three storey URM building on the south-western corner of Lichfield and Manchester Streets. It was adjacent to URM buildings on either side. The building was listed as a heritage building in the CCC District Plan.

Figure 60: 116 Lichfield Street before the September earthquake

Figure 61: 116 Lichfield Street after the February earthquake

A CCC seismic risk buildings survey in December 1991 gave the building a score of 15, which resulted in a classification of A, meaning that immediate remedial action was recommended. However, no remedial work was carried out. Mr Stephen McCarthy of the CCC explained in evidence that in his view the reason for this was that the Building Act 1991 changed the test the CCC was required to satisfy to require strengthening. This meant that a full assessment was necessary before the CCC could require owners to strengthen buildings. He said this was not possible, given the number of buildings in Christchurch. For this reason, notification was placed on the CCC's property record for future owners that strengthening would be likely to be required at some stage in the future. In fact, as discussed in section 4.2 of this Volume, the CCC's ability to require strengthening under the Building Act 1991 would have been dependent on there being a change in the use of the building.

Mr Eelco Wiersma, a representative of the trust that owned the building, gave evidence that he was not aware of any structural strengthening having been carried out in the past. He was also unaware of the CCC's policy in relation to earthquake-prone buildings. As was the case with many other building owners, Mr Wiersma did not know the structural strength of the building.

4.21.3 Events following the September earthquake

A CCC Level 1 Rapid Assessment on 7 September 2010 resulted in the building being allocated a green placard.

On 20 September 2010 the building was inspected by Mr R.D. Sullivan, structural engineer, on behalf of the owner. Mr Sullivan found that the parapets around an internal central area of the roof had been damaged. He recommended repair work.

Mr Wiersma was then contacted by Mr Sean Gardiner, a structural engineer then with Structex Metro Ltd, who was carrying out some repairs on the adjacent building at 114 Lichfield Street. Mr Gardiner suggested that he could repair 116 Lichfield Street at the same time. From that point on Mr Gardiner took over the assessment of the building at 116 Lichfield Street on behalf of the owner and insurer. On 7 December 2010 he completed an earthquake damage assessment and concluded that the building had suffered moderate damage. His view was that the parapets around the internal central area remained a fall hazard to the area below, but that there were no apparent structural hazards in the rest of the building. In relation to the building's strength, he concluded that it was possibly earthquake-prone (i.e., it had a strength of less than 33% of current requirements for new buildings, or 'NBS') and that if requested, a detailed engineering strength assessment could be completed. Mr Wiersma gave evidence that although he was made aware of this and knew that work would have to be carried out to improve the strength of the building, he was waiting until the CCC required that work to be completed.

After the Boxing Day earthquake a Level 1 Rapid Assessment of 110–116 Lichfield Street was completed by the CCC on 27 December 2010. This noted minor damage, including rear parapet wall damage to 110 Lichfield Street. Although the green placard was maintained, the inspector recommended a Level 2 or detailed structural engineering evaluation. A USAR report of the same date noted severe damage to the parapet of 114 Lichfield Street, which required a cordon into the street. This assessment resulted in a cordon being erected outside the frontages of 112, 114 and 116 Lichfield Street. It appears that the cordon was to protect pedestrians from potential parapet fall hazards from 112 and 114 Lichfield Street.

On 29 December 2010 the CCC served a notice under section 124 of the Building Act on the owner of the building. This noted structural defects including damage to the parapets and gave the owner until 31 January 2011 to complete make-safe work.

Mr Gardiner went to 112–114 Lichfield Street on Boxing Day as there had been a partial collapse of the western wall onto the neighbouring building at 110 Lichfield Street. He viewed the buildings at 110–116 Lichfield Street, inspecting the central stair area and the northern and southern sections of the roof of 116 Lichfield Street from the adjacent roof. He observed further damage to the stair area parapets. Mr Gardiner's evidence was that the principal damage to 116 Lichfield Street, to which he presumed the Building Act notice referred, was in the fire escape area. After discussing the matter with Mr Gardiner, Mr Wiersma sought an extension from the CCC of the time to complete the works to 31 May 2011.

On 18 January 2011 Mr Gardiner prepared an engineer's instruction relating to 112–114 Lichfield Street and 116 Lichfield Street. The instruction primarily related to 112–114 Lichfield Street but some of the works affected the parapets around the fire escape shared with 116 Lichfield Street.

On 21 January 2011 Mr Gardiner again inspected 116 Lichfield Street. This was a visual inspection of the exterior (excluding the roof) and the interior. Mr Gardiner's evidence was that he had been on the roof on Boxing Day and had not noted any change to the condition of the roof compared to Mr Sullivan's assessment and his own assessment after the September earthquake. He also inspected the underside of the roof in the areas where there was no ceiling, and lifted ceiling tiles in selected areas.

Mr Gardiner's observations from that inspection were contained in a report dated 26 January 2011. In his opinion, while there were changes to the internal courtyard parapets, cracking within the building was relatively minor throughout the primary walls and had not significantly reduced the seismic capacity of the building. The walls around the fire escape remained a hazard to the area below and he therefore advised that the fire escape should not be used. There were also areas of loose bricks in the perimeter of the level 2 ceiling and for that reason he advised that level 2 should not be used.

Mr Gardiner noted in the report that there were no apparent structural hazards in the remaining areas of the building. In relation to level 2 he noted, "the crack at the SE corner of the building has increased in size and inspection above the ceiling has revealed the crack extends up towards the parapet. The crack also extends down through L1" and "the eastern façade may have moved away from the L2 ceiling and floor slightly (up to 10mm?) in the middle of the building".

In evidence, Mr Gardiner said that, having regard to the construction of the building, he did not consider this was a significant concern and that it did not significantly affect "the global structural stability of the building as the physical offsets were minor". Further, he said that:

> …when completing a detailed assessment to determine the face load capacity of the wall one would generally not consider the benefit the connection to the return wall would provide, in that it is limited by the capacity remote from the return walls. This section of the wall was no worse than other sections of the wall along Manchester Street, without return walls.

He remained of the view that no cordon was required on the Manchester Street side of the building. Mr Gardiner stated in his report of 26 January that it was not a detailed structural strength assessment, and suggested that such an assessment be undertaken to progress the reinstatement of the building. However, he was not instructed to proceed with that.

On 2 February 2011 Mr Gardiner signed off repair works that had been completed to the parapet at 112–114 Lichfield Street and confirmed that the CCC could remove the cordon on the Lichfield Street frontage.

The next day, on 3 February, Glen McConnell, who was then working for Fortis (the contractors who were engaged to complete the repair work) sent an email to Mr Gardiner advising:

> On inspection of 116 it should have a cordon on Manchester Street. The parapet and corbel are dislodged, the south-east corner on Manchester Street is fractured from the floor to ceiling in multiple case [sic] on the top floor. The parapet over the south wall is cracked, broken and dislodged. This would fall on the building next door from two storeys above.

In a written reply to an information request from counsel assisting the Royal Commission, Mr McConnell said that he considered the building was “in imminent danger of collapse in any significant seismic event”. However, it became clear at the hearing that this was not the case and the danger Mr McConnell anticipated was partial collapse of bricks, parapets or walls.

On 4 February Mr Gardiner conducted a further site inspection to consider the matters Mr McConnell had raised in his email. He inspected the crack in the south-eastern corner of the building. He said in evidence that he did not consider there had been any significant movement since his last inspection and that he did not think it was a structural concern. He did identify high-level bricks along the southern wall as potential fall hazards, and a loose corbel stone on the Manchester Street side. He considered that the strength of these elements had not been significantly compromised but that they were a risk and should be secured or cordoned off.

Figure 62: Cracking of the interior wall of the south-eastern corner on level two of the building

Mr Gardiner completed an engineer’s instruction form dated 4 February 2011 on which he recorded the damage he had observed. He noted, “These high-level bricks and stone blocks are potential fall hazards to areas directly adjacent and should be secured as soon as possible, (or the fall areas cordoned off)”. He emailed a copy of that engineer’s instruction to Mr John Barry, the CCC case manager for the building. After referring to the section 124 notice that had been served on the owner and the fact that his firm was involved in the assessment and securing work, Mr Gardiner said in that email, “I have also attached our latest report and securing work proposal (which is in the process of getting insurance authorization to proceed)”.

In evidence, Mr Gardiner said that in the days that followed he was liaising with the building insurer’s loss adjustor in an attempt to obtain authorisation for the securing work. He said that he had not received final authorisation for that work as of 22 February.

On 16 February 2011 Mr Gardiner attended a meeting at the building with a representative of the loss adjustor. In evidence he confirmed that he was aware that there was no cordon on the Manchester Street frontage at that time. Mr Gardiner said that after he had given the instruction of 4 February 2011, he did not subsequently follow up the matter of a cordon with the CCC, as he expected that the CCC would attend to it.

He also thought that the securing works could be completed imminently. In any event, Mr Gardiner said that, if erected, the cordon he had recommended on the Manchester Street side of the building would not have protected against the total failure of the building that occurred in the February earthquake, as the cordon would only have given protection from potential fall hazards on the footpath.

Mr Gardiner was questioned at some length by various counsel and Commissioner Fenwick in relation to the crack in the south-eastern corner of the building. Despite the size and extent of the crack and the fact that, as he accepted, the only viable load transfer mechanism would have been the friction of the bricks (which would have decreased higher up the building), he maintained that it did not lead him to conclude that the Manchester Street façade might be compromised.

He agreed that the maximum width of the crack in the wall was of the order of 15mm decreasing to about half this width at the floor level. He agreed that with this level of movement between the floor and wall, the only viable tie force was friction between the wall and the floor beams in the timber floor. He still maintained that it did not lead him to conclude that the Manchester Street façade might be compromised.

Mr Paul Campbell, a structural engineer on secondment to the CCC from Opus, carried out an engineer's re-inspection of the building. The exact date of the re-inspection is unclear as the form was undated, but it would appear to have been a day or two before Mr Gardiner's sign-off of the Lichfield Street cordon.

Mr Campbell said, by reference to his re-inspection form, that it appeared he was there to check on the securing works on 112–114 Lichfield Street. As appears to have been the case with all such re-inspections, it was a brief external inspection.

Mr Campbell was asked by Commissioner Fenwick for his views on the crack to the south-eastern corner of the building. Mr Campbell's opinion was that the cracking was evidence (at least on the face of it) that the wall had moved out towards Manchester Street and he would have wanted to do a more detailed examination to confirm whether that was the case.

Mr Peter Smith, who prepared an independent report on the building for the Royal Commission, said that the failure of the building in the February earthquake was caused by an outward rotation of the Manchester Street façade.

4.21.4 Issues

4.21.4.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

We do not know whether strengthening of the building, had it been carried out before 4 September 2010, would have prevented its collapse in the February earthquake. However, as Associate Professor Jason Ingham's reports[7] to the Royal Commission showed, any significant strengthening gives a building a better chance of withstanding an earthquake.

This highlights the problem inherent in a passive approach by a territorial authority to earthquake-prone buildings, particularly where a building owner is not inclined to carry out any strengthening without being required to do so by the territorial authority.

4.21.4.2 Assessment of the building after the September earthquake

4.21.4.2.1 Mr Gardiner's assessment of the building as at 4 February 2011

In common with most engineers, Mr Gardiner's assessment was damage-based. He assessed the crack in the south-eastern corner of the building. He did not consider that the nature of the damage seen meant that the building was structurally compromised or in danger of collapse. However, we think that the damage he observed should have led him to investigate the building's structural stability more fully. Mr Campbell expressed the opinion that the presence of the crack should have led to further investigation, in particular the removal of linings to examine the state of connections between the façade and return walls. Depending on the result of that further investigation, the conclusion might have been reached that the Manchester Street façade had been compromised and that a cordon, extensive enough to take into account the potential for total collapse of the façade, should be erected on the Manchester Street frontage. However, we must also accept such a conclusion may not have been reached.

The Royal Commission has heard on a number of occasions from Mr Smith and other structural engineers of the need for URM buildings to be inspected by skilled structural engineers with relevant expertise. This building highlights this matter. We address this issue in sections 6 and 7 of this Volume, and in Volume 7.

4.21.4.2.2 Communication of the need for a cordon

Even though the cordon contemplated by Mr Gardiner would not have provided protection from the potential collapse of the façade onto the street, no cordon was established at all. It appears that despite Mr McCarthy accepting that the engineer's instruction conveyed the potential need for a cordon, the CCC took no action to follow this up. As Mr McCarthy said, had this been properly followed up it would have involved an inspection by an engineer and an assessment of the cordon required. It may be that it would have assisted if Mr Gardiner had drawn attention to the issue, rather than simply mentioning it in the attachment to his email of 9 February. If an inspection of the type suggested by Mr Campbell had been carried out, it may have resulted in the identification of a risk of the collapse of the façade and establishment of a cordon onto Manchester Street, perhaps resulting in the closure of the street.

We note that Mr McCarthy gave an absolute assurance that the lack of a cordon across Manchester Street was not brought about by any desire on the CCC's part to get the city back to business as usual by keeping Manchester Street open.

4.21.4.2.3 Failure to follow up erection of a cordon

Although Mr Gardiner said he had given an instruction and expected it to be acted upon, he did not follow up the matter of the cordon, even after his visit to the building on 16 February when it was obvious that the cordon he had recommended was not in place. Since he had identified the risk to the public on 4 February, we are of the view that it would have been preferable for him to have contacted the CCC on 16 February to follow this up. We also accept that the cordon he envisaged, which was to protect against failure of the parapet corbel and not against failure of the whole Manchester Street façade, would not have prevented these four deaths.

4.22 200–204 Manchester Street

4.22.1 Introduction

The building at 200–204 Manchester Street was a two storey URM structure on the south-eastern side of the intersection of Manchester and Gloucester Streets. The building housed a business called the Iconic Bar.

A one storey building was adjacent, to the east. There were openings between the two buildings so that they could be used as one.

Ms Amy Cooney gave evidence that her brother, Mr Jaime Gilbert, was working as a barman at the Iconic Bar on 22 February 2011. He had only been in that job some two weeks and she was also working there that day in her role as assistant to the manager. She said that when the earthquake struck they both ran from the building but were hit by falling masonry blocks. Both were covered in rubble as they lay on the footpath outside the building. Rescuers uncovered Ms Cooney and then Mr Gilbert. He was severely injured and was taken to Christchurch Hospital in a van. CPR was performed on him en route but a short time after arrival he was pronounced dead.

Figure 63: The building at the corner of 200–204 Manchester Street before the February earthquake

Figure 64: The western side of 200–204 Manchester Street after the Boxing Day earthquake

4.22.2 The building

The two storey URM building had a plaster finish and walls that were about 400mm thick. It had timber ground and first floors and a lightweight corrugated roof with timber sarking. The bottom cords of the trusses were scarfed onto the brick walls. Structural strengthening had been carried out in 1993 by Holmes Consulting Group (HCG) and in 2004 by Lewis & Barrow Ltd.

Mr Peter Smith carried out an independent assessment of the earthquake performance of the building for the Royal Commission. He gave evidence that, although the strengthening work in 1993 was designed to 67% of the then applicable requirements for new buildings, because of subsequent increases in building requirements, the building would have been about 56% of current building standards at the time of the September earthquake.

The Royal Commission heard evidence from Mr Warren Lewis of Lewis & Barrow that the 2004 strengthening work did not materially add to the building's strength.

Mr Stephen McCarthy, from the CCC, gave evidence that because of the previous strengthening work, the building was not considered to be earthquake-prone in terms of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy when the policy was introduced in 2006.

4.22.3 Events following the September earthquake

The day after the 4 September 2010 earthquake a CCC Level 1 Rapid Assessment was carried out, resulting in a green placard being assigned to the building. That green placard was confirmed by another Level 1 Rapid Assessment carried out by HCG on behalf of the owners on 8 September 2010.

A further Level 1 Rapid Assessment by the CCC on 10 September 2010 noted cracking in a parapet. The building was again allocated a green placard. That assessment also recommended a Level 2 Rapid Assessment. Mr McCarthy referred to a notation on the form that appeared to relate to an interior inspection, although it was unclear. However, he conceded that the CCC records did not show that any Level 2 assessment had been carried out. Mr McCarthy explained why this might have been the case by saying that the pressure of having to organise the many engineers and volunteers required at that time "was just overwhelming" for the CCC.

On 22 November 2010 a proposal and plans drawn up by Lewis & Barrow to add a new structural first floor and strengthen the roof was filed with the CCC. This proposal was filed on the instructions of the Iconic Bar's manager at the time, Mr Darryl Fraser, who was considering purchasing the business. However, CCC records show that eight days later, on 30 November 2010, the applicant requested a hold on this proposal and subsequently withdrew it. Mr Lewis gave evidence of his opinion that the structural work shown on those plans would have helped in some small way to prevent collapse in the south-eastern corner of the building but would have had minimal effect elsewhere.

On 26 December 2010 a CCC Level 2 Rapid Assessment took place after the earthquake on that day. It was noted that the eastern gable wall was badly damaged. On the second page of the assessment form it was also noted that the western wall was damaged, especially at the apex. The building was allocated a red placard. However, on receiving the briefs of evidence for the Lewis & Barrow witnesses, counsel assisting the Royal Commission made further enquiries that confirmed the reference on the second page of that form to damage to the west wall was incorrect. The only damage that had in fact been observed during that inspection was to the eastern wall.

The Rapid Assessment form recommended a detailed structural assessment. A further Level 1 Rapid Assessment the next day, on 27 December 2010, noted "stress fractures on plastered brick walls – upper areas mainly above where the roof trusses connect – parapets". The building was again assigned a red placard. An Urban Search and Rescue (USAR) damaged building reconnaissance report, also dated 27 December 2011, noted that an "engineering assessment" was required.

On the same day the CCC served the owner a notice under section 124 of the Building Act 2004. That notice referred to the eastern gable wall damage and, although it was based on the rapid assessment of 26 December 2010, it did not refer to damage to the western wall. Mr Gary Looker, a representative of the owner, Symphony Projects Ltd, gave evidence that although the notice appeared to have been sent to the company's post office box, he had never received it. Mr Looker gave evidence that Mr Fraser was attending to all matters relating to the assessment and repair of the building after the September earthquake. In a written reply to questions from counsel assisting the Royal Commission, Mr Fraser advised that he did not receive a Building Act notice from the CCC and was only aware of the damage ascertained by the Council from the red placard on the front door of the building. He instructed Lewis & Barrow in relation to that damage.

In the days that followed, Mr Christopher Gordon of Lewis & Barrow designed and oversaw make-safe work on the building. Mr Gordon gave evidence that he did not see a Building Act notice affixed to the building or to the barricade fencing. However, he did recall seeing the red placard that noted the observed damage.

Mr Gordon inspected the building on 28 December 2010 and prepared a site report detailing interim repair work required, including plywood bracing on the outside of the eastern wall. In evidence he said that such repairs would provide temporary support of the wall so the building could be reoccupied. He left the site report with Mr Fraser for him to arrange a builder to complete the work. Mr Gordon said that before designing the repair works he conducted a visual inspection of the interior and exterior of the building to see if there was any damage requiring repair other than that noted on the red placard. He did not observe any damage other than some cracking to the northern and western faces that appeared to be historic.

The next day Mr Gordon spoke by telephone to Mr Lewis, who had had previous involvement with the building in relation to the work carried out in 2004. As a result of that discussion they decided to add further strengthening by way of vertical steel angles over the plywood bracing.

On 29 December Mr Gordon inspected the building again. The repair work he had recommended had been started. He recorded the additional details he had agreed on with Mr Lewis, in a further site report dated 29 December 2010.

The next day Mr Gordon visited the site again and saw that the work was proceeding as detailed in his site reports and that it was almost complete (he said all that remained was to affix one or two vertical steel angles to the plywood bracing). On the same day he prepared a Chartered Professional Engineer (CPEng) sign-off statement and sent it by email to the CCC, asking them to remove the red sticker from the site. He also noted that a building consent application had been made (this was a reference to the application filed by Lewis & Barrow on the instructions of Mr Fraser in November 2010) and that "an amendment to the building consent will be made in January to include the removal of the damaged area of the eastern gable end wall and reinstatement with a suitable structure". He said in evidence that he was anticipating that the building owner or its insurer would engage Lewis & Barrow to design a permanent repair. Mr Gordon noted in the email that he was not a CPEng but did have 16 years' experience with Lewis & Barrow.

On the same day Mr Gordon was advised by the CCC that the certificate had to be signed by a CPEng engineer. Mr Gordon spoke to Mr Simon Gifford, a CPEng engineer with Lewis & Barrow, who reviewed the file and discussed the damage and repair works with Mr Gordon. Mr Gifford had not had any previous involvement with the building and did not inspect it himself. Mr Gordon told Mr Gifford that, based on his inspection of the building and the repair works done, he believed the structural integrity of the building had been restored to the state it had been in prior to 4 September. Mr Gifford signed the CPEng certificate, which was dated 31 December 2010. He said it was the first time he had signed off another engineer's work so he took the matter seriously.

Mr Gordon accepted that the CPEng certificate had been delivered to the CCC without his having inspected the completed works. However, when asked if that was "the norm", he said it would depend on whether all the material was on site and whether the builder was thorough. He said that in this case all the steel work was on site and the builder was doing a very good job. Further, he said he had gone to the site the next day, and delivered a copy of the CPEng certificate to Mr Fraser. He had taken some photographs of the building and was able to see that all the steel works were in place.

Mr Peter Smith was asked for his view on the CPEng certificate being completed and forwarded to the CCC before Mr Gordon had inspected the completed repair work. Mr Smith was of the view that this was not appropriate and that a CPEng certificate should not have been completed without the engineer involved having ensured that all of the required work had been completed to his satisfaction. Mr Smith was also asked to comment on the appropriateness of a CPEng engineer completing a CPEng certificate when he had not been involved in the building at all, nor inspected the repair works. Mr Smith considered that this was appropriate and often acted as a quality assurance in that some engineering practices required such certificates to be signed only by a director of the practice. This view was echoed by Mr McCarthy.

The CCC relied on the CPEng certificate and removed the red placard from the building on 31 December 2010, which allowed the business to re-open for New Year's Eve.

There was subsequent discussion by email between Mr Lewis and the loss adjuster over permanent repairs.

On 9 February 2011 Mr Mark Ryburn, an Opus International Consultants Ltd structural engineer on secondment to the CCC, carried out an inspection of the building. This was part of a series of re-inspections at the time of buildings that had received yellow or red placards.

The Engineer's Re-inspection of Damaged Buildings form Mr Ryburn completed noted: "Recommend contacting the engineer for a confirmation of the works as lateral load capacity may not exist. Also get comments on the cracking (likely just in the paint)". The form he completed also noted that protection fencing was required to "cover parapet on Gloucester Street".

Mr Ryburn said in evidence that when he conducted his re-inspection on 9 February 2011 he was unaware that repairs had been completed and signed off and that the red placard had been removed by the CCC. Rather, he thought he was carrying out a re-inspection of a red-placarded building. At the building that day he spoke to a woman who it transpired was the new owner of the business (having taken possession at the beginning of February 2011). In his evidence-in-chief, Mr Ryburn said the new owner told him that an engineer's report had been obtained as part of the sale and purchase agreement. He said he told her that this did not appear to be on the CCC file he had been given and that a formal sign-off was needed before the building could be reoccupied. He said that he told her to submit the report within seven days so it could be reviewed and processed.

In cross-examination it was put to Mr Ryburn that the new owner, Ms Leanna Christie, had written to counsel assisting the Royal Commission stating that she did not recall speaking to Mr Ryburn that day. Mr Ryburn maintained that he had spoken to her. However, he did not recall whether she specifically said an engineer's inspection had taken place, although he understood that there had been an engineer involved. Mr Ryburn conceded that he had not recorded his requirement to have the engineer's report forwarded to the CCC within seven days. When asked how the CCC would then have followed that matter up, he noted that he had recommended on the form that the CCC contact the engineer. He also said it was possible that he had later mentioned it to the administrator of the Building Review Office team, but he could not recall whether this was the case.

Mr Ryburn had concerns in relation to the building, as evidenced by the comments he made on the report, and he wanted these issues to be followed up with the engineer who had been involved with it. That was the purpose of his comments on the form and his request to the new owner to forward information to the CCC. Mr Ryburn said in evidence that when he returned to the CCC he probably would have separated the form from the usual process "so it didn't just sit in the queue", because there were people in what he had presumed to be a building with a red placard.

There appears to be some support for this in that someone (not Mr Ryburn) had placed a Post-it note on the re-inspection form and written the words: "Neville, please view and make a decision". This was a reference to Mr Neville Higgs, an engineer working at the CCC's Building Recovery Office at that time. Mr Ryburn had no further dealings in relation to the building, but expected the matters referred to in his form to be followed up.

Owing to a backlog of work, Mr Higgs did not deal with the formal process for closing off the CCC's file in relation to this building until the morning of 22 February 2011. Mr Higgs gave evidence that it was apparent from the CCC file that he had seen and checked the CPEng certificate signed by Mr Gifford. However, there is no record on the CCC file that he saw Mr Ryburn's re-inspection form. Further, Mr Higgs could not recall whether he saw the re-inspection form, and therefore whether he took any account of it. However, he said in evidence that if he had seen it, he believed he would still have closed the file, given the fact that there was a CPEng certificate and that Mr Ryburn's inspection would have been "a rapid external inspection from street level" only.

Mr Higgs was able to say from inquiries he had made just before the hearing that the re-inspection form with the Post-it note on it had either been put on his desk or in his in-tray by an employee in the Building Recovery Office, but he was still not able to say whether he had seen it.

Mr Ryburn had also noted on the re-inspection form that protection fencing was required on Gloucester Street. This was not actioned either.

The building sustained substantial damage in the February earthquake. Mr Smith gave evidence that the external walls above the first-floor level of the northern and western façades fell outward onto the street. They appeared to have disintegrated under the severity of the shaking, leaving epoxy fixings projecting from the steelwork above road level.

Figure 65: The north-western corner of 200–204 Manchester Street after the February earthquake

Figure 66: The western wall of 200–204 Manchester Street after the February earthquake

In his assessment of the building's failure in the February earthquake, Mr Smith raised the possibility that workmanship in the epoxy fixing of dowels through the brick façades might have been a factor in the failure of the connection between the external walls and the strengthening works. He accepted that he could not be certain why those fixings failed, but was of the view that high vertical accelerations certainly played a large part.

Mr Lewis gave evidence that he oversaw the retrofit work completed by Contract Construction in 2004. He carried out site inspections that included random testing of the fixing of the dowels through the brick walls. Mr Mark McKenzie, a carpenter who had been employed by Contract Construction as site foreman for the works in 2004, gave evidence that the steel dowels used to fix the steel angle floor-and-truss braces to the external masonry were installed correctly and in accordance with the manufacturer's specifications and instructions.

In relation to the similar fixings that had been installed in 1993 under the supervision of HCG, Mr Lewis said that although he had not tested any of the fixings they appeared to be in good condition. Mr McKenzie confirmed that when the work was being completed in 2004, if they had noticed anything in relation to the 1993 work they would have notified the engineer. In a written communication to the Royal Commission, Mr Craig Lewis, a director of Lewis Bradford Ltd, consulting engineers (who in 1993 had been an engineer with HCG), said that, to the best of his knowledge and recall there were no matters of concern in relation to workmanship during the 1993 works and that he had found the work and quality processes of the contractor, Mr Luney, to be very good.

In relation to the dowels that were epoxy fixed through the bricks, Mr Warren Lewis's evidence was that the holes for them were drilled horizontally in the 2004 strengthening work but appeared to have been at an angle in the 1993 work. In his view, whether they were drilled at an angle or horizontally should not have affected their strength, and the different method adopted in 2004 would have been related to the thickness of the epoxy.

Mr Warren Lewis did not agree with Mr Smith that there had been a general failure of the epoxy fittings. He referred to photographs that showed some brick or Oamaru stone adhering to the fixing, pointing more, he said, to the disintegration of the wall masonry. He suggested that in the last 20 years there had been a move away from the use of a "boss" – a large washer on the outside of the masonry wall with the bolt going right through the wall.

Mr Smith gave evidence that the current thinking was that it was preferable to fix the bolts at an angle to ensure better penetration of the masonry (as opposed to the mortar joint), and therefore provide a better fixing. However, he accepted that there was debate within the industry about this issue and that it required more research. As he had also done in relation to the failure of the building at 194 Hereford Street, Mr Smith expressed the view that there needed to be heightened industry awareness of the required temperature in the use of epoxy fixing systems and increased construction monitoring and proof testing for quality assurance.

4.22.4 Issues

4.22.4.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

The strengthening works carried out in 1993 and 2004 meant that the building was not considered earthquake-prone in terms of the CCC's earthquake-prone buildings policy introduced in 2006. Despite that, the building (and, in particular, the northern and western upper-level walls) still failed in the February earthquake, highlighting the fact that even a building that is strengthened above the earthquake-prone threshold can still be vulnerable.

This highlights the problem with URM buildings, which despite strengthening are still inherently weak structures because of the materials used in construction (bricks and mortar) and construction methods.

4.22.4.2 Assessment of the building following the Boxing Day earthquake

This building failure highlights a problem that has been apparent in a number of cases, namely the difficulties that can arise when relying solely on a damage-based assessment to determine whether occupancy is safe.

In this case, there was a Level 1 Rapid Assessment after the September earthquake, following which the building was assigned a green placard. This was confirmed after a Level 1 Rapid Assessment by HCG on behalf of the owner on 8 September 2010. Then on 10 September 2010 there was a further Level 1 Rapid Assessment that recommended a Level 2 Rapid Assessment, which, as noted earlier, did not take place.

After the Boxing Day earthquake there was a Level 2 assessment that noted the eastern gable wall damage and recommended a detailed structural engineering evaluation. The Building Act notice procedure followed. Repair work was carried out, overseen by Mr Gordon. At that time Mr Gordon completed what appears to us to have been effectively a Level 2 assessment (a visual inspection of the interior and exterior). On the basis of that and the subsequent repair works, Mr Gifford was able to certify in the CPEng certificate that the structural integrity of the building had been returned to the state it was in before the September earthquake.

While we accept that the CPEng form is not clear about the nature of the inspection required, it could not be said that Mr Gordon's inspection was a detailed structural engineering evaluation, as recommended in the Level 2 Rapid Assessment form dated 26 December 2010. Mr McCarthy said in evidence that the CCC's expectation was that engineers would do a full assessment of the building (of the kind that Mr Gordon did in relation to this building) but not a detailed engineering evaluation because "that mechanism wasn't really in place at that time". This however, appears to be at odds with the wording of the Level 2 assessment form, which stated "Detailed engineering evaluation recommended". It is possible that Mr McCarthy was referring to a "strength-based" assessment such as has been required by the Canterbury Earthquakes Recovery Authority since the February earthquake.

It appears that the "damage-based" level of inspection carried out by Mr Gordon was one commonly carried out by engineers who were preparing to certify remedial works. In fact, the approach is set out in the guidelines prepared by the New Zealand Society for Earthquake Engineering. This approach is problematic when applied to URM buildings after a significant earthquake, and will be addressed in Volume 7.

4.22.4.3 CPEng certificate

Clearly, a CPEng certificate should only be signed when all of the required remedial work has been completed and inspected. However, although that did not happen here, the work was completed on the same day the certificate was signed and then observed by Mr Gordon the following day.

The CPEng certificate was accepted by the CCC and the red placard removed. The Iconic Bar was open for New Year's Eve. Mr McCarthy gave evidence that returning the city to normality was important in the final days of 2010. However, he also gave an assurance that this did not outweigh safety considerations in relation to this building. The evidence does not justify a conclusion to the contrary.

4.22.4.4 Lack of follow-up of the problems highlighted in the engineer's re-inspection on 9 February 2011

Mr Ryburn raised potential concerns on 9 February 2011. He expected these to be followed up by the CCC but that did not happen. The reason for this was unclear. It may have been an oversight on Mr Higgs's part, but in our view it also reflects the pressure that the September and Boxing Day earthquakes brought to bear on the CCC systems.

Mr Higgs did comment that there was "no doubt that some mistakes were made under the pressures the earthquake events was [sic] putting on the people involved and that the systems can and will be improved". Mr McCarthy also raised concerns as to the systems in place and about communications. In relation to Mr Higgs not seeing the Ryburn re-inspection form, he referred to it as an "overload situation".

Mr Higgs gave evidence that even if he had considered Mr Ryburn's form, he would still have decided to close the file. This evidence reflects the CCC's practice of applying a damage-based assessment as the basis for allowing occupancy. Although Mr Ryburn raised concerns, the CPEng certificate that had been provided satisfied the damage-based requirement set by the CCC for occupancy.

We deal generally with the nature of engineering assessments to determine occupancy in Volume 7 of this Report.

4.22.4.5 Epoxy fixing

As we have noted in relation to the building at 194 Hereford Street, we agree with the views expressed by Mr Smith on the need for further research into epoxy fixing systems and the need for more construction monitoring or proof testing for quality assurance. How this is best achieved needs to be examined by the Ministry of Business, Innovation and Employment. It may be that the technology of 20 years ago referred to by Mr Warren Lewis requires reconsideration.

4.23 265–271 Manchester Street (also 173 Gloucester Street)

4.23.1 Introduction

The building at 265–271 Manchester Street was a two storey unreinforced masonry (URM) structure on the corner of Manchester and Gloucester Streets. The address of the Gloucester Street frontage was 173 Gloucester Street.

When the 22 February 2011 earthquake struck, Mr Christopher Smith was in his vehicle parked outside 269 Manchester Street, approximately in the position occupied by the car second from the right in Figure 68. The vehicle was severely damaged by rubble falling from the building. Police inquiries established that Mr Smith was rescued by the New Zealand Fire Service and taken across the road to the Orion building at 218 Manchester Street. Despite medical treatment and CPR, Mr Smith died as a result of his injuries.

Figure 67: The south-eastern section of 265–271 Manchester Street

Figure 68: The Manchester Street frontage of the building

4.23.2 The building

According to a letter from the CCC in the early 1980s:

> The building was secured in 1976 under two building permits, which included the removal of the street wall parapets and construction of a reinforced concrete bond beam at roof level; the attachment of the first floor and roof trusses to the load bearing walls; the introduction of one laterally placed reinforced concrete frame on the ground floor; re-roofing of the entire building.
>
> In its current condition, the building is regarded as having been adequately secured under the terms of section 624 of the Local Government Act, to prevent sudden collapse in a moderate earthquake. It is not regarded as having been fully strengthened sufficient to preclude damage to the building in a moderate earthquake.

In his report to the Royal Commission, Mr Peter Smith stated that he could not be sure that all of the work described in the CCC letter had actually been carried out.

In 1991 a CCC seismic risk building survey gave the building a score of 13, which resulted in its being classified as B. This meant that remedial action within two years was recommended. The survey noted that interim securing had been carried out in 1976 and that strengthening was due in 1997. Mr Stephen McCarthy of the CCC explained in evidence that this would have been a guide to the building owners that the CCC would like them to consider further strengthening 20 years after the interim strengthening. No further work was completed in 1997.

The building would have been considered earthquake-prone in terms of the CCC's 2006 Earthquake-Prone Buildings Policy.

4.23.3 Events after the September earthquake

After the September earthquake, a CCC Level 1 Rapid Assessment on 5 September recorded no noticeable damage to the building and assigned it a green placard.

Mr Monty Claxton, a trustee of the family trust that owned the building, gave evidence that the owner relied on the fact that the building had been assigned a green placard by the CCC and did not initiate any engineering inspection of the building. However, the trust did have the services of a very efficient insurance broker who, soon after the earthquake, arranged for the building to be inspected by structural engineers employed by Opus International Consultants Ltd (Opus).

A Level 2 Rapid Assessment was completed by Mr Mohanaraj of Opus on 14 September 2010. He noted cracking in the brick walls on the southern and eastern sides, cracking in a window lintel on the southern side and minor internal cracking. Consistent with many other inspections by engineers at the time, this did not involve inspection of connections or removal of linings. The building was assigned a green placard (G2 – occupiable, repairs required).

Mr Mohanaraj recommended:

- repair to the crack in the arch window lintel as soon as possible and repair of the other cracks;
- a check above the dairy (269 Manchester Street) for any loose bricks; and
- the provision of a support arrangement such as steel bands (to external arch lintels) to prevent sudden failure of lintel blocks.

He recommended that a structural engineer's assistance be obtained to check and provide appropriate crack repair details. He also recommended a support arrangement for the external arch lintels to prevent sudden failure of lintel blocks – not for the purpose of repairing damage, but to make the building more robust for the future. He recommended that the owner consult with a structural engineer about this recommendation.

It became apparent when Mr Mohanaraj gave evidence that his inspection was a damage-based assessment with a focus on any repair work required. He did not recommend any follow-up or detailed assessment but was of the view that if any such assessment was required, that would be the responsibility of the CCC or the owners. It was not within the scope of his work to recommend such an assessment.

Maxim Projects Ltd (Maxim), a contractor, was engaged to carry out the repairs identified by Opus. A further assessment of the building was carried out on 20 September 2010 by Mr Roy Hamilton, a structural engineer employed by Maxim. The purpose of this was to ensure the safety of Maxim staff when completing the work. This assessment was consistent with the Opus assessment. Although the assessment by Mr Hamilton considered the safety of people in the building, it was still a damage-based assessment. As with Mr Mohanaraj's inspection, Mr Hamilton's inspection did not include any assessment of how the façade was connected to the floor/ceiling or how the bond beam was connected to the roof. However, Mr Hamilton did not observe any apparent separation of the façade that might have indicated a potential problem.

The works recommended by Opus were all carried out by Maxim except a support arrangement to the external arch lintels. Mr Hamilton said that Opus had been asked by Runacres, the loss adjustor, to provide a quote for that work and had assumed that Opus would be providing a design. Maxim also removed the western end portion of the parapet that had not been reduced in 1976, and a water tank in that location.

There was no inspection of the building by either the owner or the CCC following the Boxing Day earthquake.

In the February earthquake the wall on the upper floor of the Manchester Street frontage almost entirely collapsed outwards into the street, including a large section of concrete bond beam on the top of that façade. The wall to the south façade on Gloucester Street suffered less damage, although there was more damage at its western end.

Figure 69: The building after the February earthquake

Figure 70: The area outside 269 Manchester Street after the earthquake

Mr Peter Smith expressed the view that, from his observations of the photographs taken after the February earthquake, it appeared that the façades had been very poorly secured and the concrete bond beam was effectively only restrained by gravity. It was also off centre, which would have increased the risk of its falling from its position on top of the brick façade.

4.23.2 Issues

4.23.2.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

Although some earthquake strengthening was completed in 1976 (the extent of which is unclear), there was no follow-up strengthening as envisaged by the CCC in 1997 and the building would clearly have been earthquake-prone before the September earthquake. This building illustrates the risks inherent in a passive approach to earthquake-prone buildings.

4.23.2.2 Assessment of the building following the September earthquake

In this case the owner of the building effectively relied on the CCC's green placard and did not consider obtaining any assessment. The owner's insurance broker or loss adjustor did, however, arrange for what was effectively a Level 2 inspection. The brief was understandably focused on a damage assessment and necessary repair work. Therefore, there was not the level of assessment that would have examined matters such as the connections between the façades and floors/ceilings and considered the connection of the bond beam. The further inspection by Maxim was essentially of the same kind and was only to facilitate the repair work.

As we have commented in relation to the failure of other URM buildings, this case demonstrates the risk of undertaking and relying solely on a damage-based assessment of these buildings after a substantial earthquake. A more detailed assessment would have established the weakness of the building, including the integrity of the connections of the façade and beam bond to the building. This was never ascertained because of the limited nature of the type of inspection being made at the time.

4.24 7 Riccarton Road

4.24.1 Introduction

Mr Henry Ross Bush (known as Ross Bush) was killed in the February earthquake as he sat in his motor vehicle parked outside 7 Riccarton Road. The façade of the building collapsed onto his vehicle.

4.24.2 The building

The building was a stand-alone two storey URM building with timber roof framing and a timber first floor. The building had a relatively high parapet on the street frontage that returned and reduced in height around the side walls. It had a very open ground-floor façade and significant openings in the first-floor façade to Riccarton Road. The return walls had fewer penetrations.

A second-hand book store occupied the ground floor. The first floor, which was in a dilapidated state, was unoccupied.

It appears that the building was in its original condition and no earthquake strengthening had ever been carried out or required by the CCC.

Seismic risk and hazardous appendage surveys in 1991 and 1993 respectively had noted cracking to the parapet, the former recommending remedial action within two years. No action was taken by the owner or the CCC at that time or subsequently.

In evidence, Mr Stephen McCarthy from the CCC tried to explain the reason why nothing had been done about the parapet identified as a hazard in the 1991 survey. He speculated that the cracks might not have affected the structural integrity of the building and said the primary responsibility to identify the cracked parapet as a hazard rested with the owner, not the CCC.

Figure 71: The building at 7 Riccarton Road before the September earthquake

4.24.3 Events following the September earthquake

Mr Nigel Harwood, a chartered professional engineer (CPEng) volunteer, conducted a Level 1 Rapid Assessment on behalf of the CCC on 6 September 2010. He recorded damage as “minor/none” and assigned a green placard to the building. In evidence he confirmed that he was applying a damage-based test and that there appeared to be a mixture of old and new cracks. When referred to photographs taken the next day, he said he did not recall seeing a crack behind the parapet on the western wall. This crack assumed importance as the hearing proceeded.

The next day a Level 2 Rapid Assessment was carried out by Mr David Elliott, a CPEng with Aurecon New Zealand Ltd, who was engaged by Mr Morris North as manager of the St Christopher’s Community Trust, which managed the bookshop on the ground floor. Mr Elliott noted cracks to lintel areas and near the parapets but no major lean or distortion. He also noted that the building was more than 100 years old and in a very poor state of repair before the September earthquake.

In evidence, Mr Elliott said that the majority of the cracks existed before the September earthquake. He knew this because of their appearance, which he said he was able to see when viewing the building from the outside, even without binoculars. He also relied on Mr North telling him that they had been there before the earthquake. However, Mr North said in evidence that he could not recall telling Mr Elliott that the cracks were pre-existing. He said he could not be sure which cracks were pre-existing and that he could not have told Mr Elliott which ones were pre-existing. Regarding the crack on the western wall, which Mr Elliott said they had looked at in detail, Mr North said he had not noticed it before the earthquake. We have not been able to resolve these differences.

The green placard was maintained. The next day, on 8 September, Mr North rang the CCC to advise that the brick-and-concrete façade was badly cracked and he was concerned that it could fall down on pedestrians. He said that a “…structural engineer says with another significant tremor it could come down”. Mr North explained that he had a number of volunteers working in the bookshop who were raising concerns with him and one had commented that a structural engineer had said the building could come down in a significant tremor. He said that, although Mr Elliott had inspected the building the day before, he felt that a second opinion from the CCC was called for. Mr North also contacted Mr Elliott to carry out a further inspection.

Mr Elliott carried out an exterior inspection of the building on 9 September and confirmed the green placard. He noted on the rapid assessment form he completed that he had checked the front parapet and western wall but could not observe much change and that the parapet still looked vertical and stable.

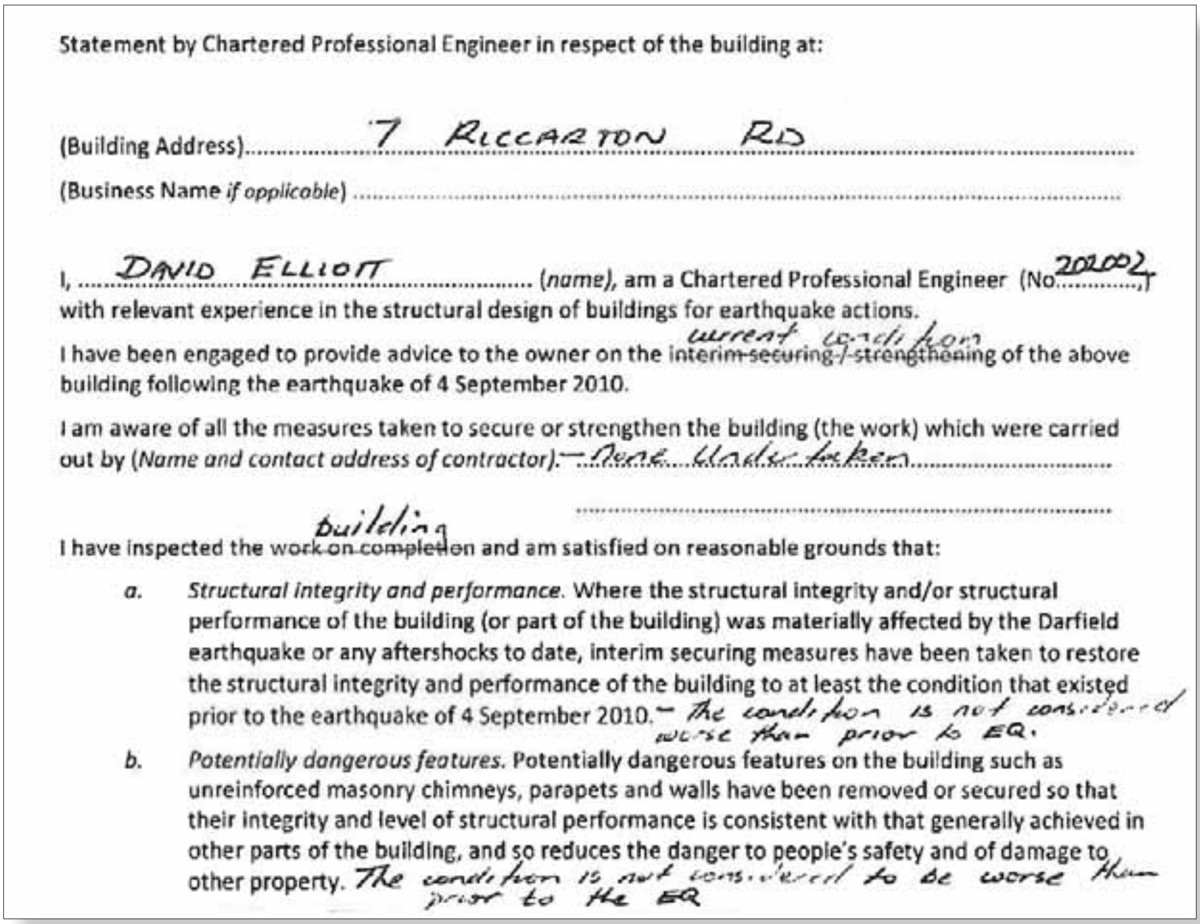
On 11 September 2010 a further Level 1 Rapid Assessment was conducted on behalf of the CCC as a result of the call by Mr North on 8 September. This inspection was carried out by Mr Vaughan McMillan, a CPEng engineer, and Mr Russell Officer, who at that time was a CCC building inspector. They concluded that the cracking in the front façade and parapet needed to be inspected by an engineer. The building was assigned a yellow placard and a Level 2 Rapid Assessment was recommended. Mr McMillan explained that the cracking to the central area of the façade indicated the possibility of some outward movement of that area. He also said that a weathering pattern was evident below the roof profile, which raised a concern about the state of the façade ties. He believed that it was prudent to assign the building a yellow placard so there could be an internal inspection and the ties could be checked by accessing the ceiling area. The yellow placard was confirmed in a further inspection by a CCC building inspector on 19 October 2010, which noted that the cracking in the parapet needed to be checked by an engineer.

On 15 and 16 September Mr North was in contact with the CCC. He was advised that to have the placard changed from yellow to green, his engineer would have to conduct a Level 2 assessment. Mr North said in evidence that he contacted Mr Elliott and passed on the CCC’s requirements. Mr North said that Mr Elliott told him he was aware of the CCC’s requirements.

Mr Elliott carried out a further inspection of the building on or about 17 September. This inspection was of the exterior only. No documentation of this inspection was completed but Mr Elliott said his view was that there had been no change to the building since his last inspection on 9 September. He said in evidence that he did not carry out an interior inspection because the cracking to the building was visible from the exterior and would not have been visible from the interior. He also said that he expected to be able to see whether the façade had moved outwards by conducting an exterior inspection. Mr Elliott agreed Mr North told him that the CCC required a Level 2 assessment but said he was told this after he had already carried out his inspection. He agreed that he could have gone back and inspected the interior. He also agreed that it was a "big step" to change a building's status from yellow to green and that the CCC wanted a Level 2 assessment before a placard could be changed, because of the public safety risk.

In order to change a yellow placard to a green one, the CCC's policy at that time required a CPEng engineer to complete a prescribed certificate to the effect that interim securing measures had been undertaken and potentially dangerous features removed or secured to restore the structural integrity and performance of the building to at least that which existed prior to the September earthquake. Whilst the certificate does not contain any reference to a Level 2 inspection before the placard can be changed, it was clearly envisaged that there would be an inspection of at least that standard before there could be such a change. We note that Appendix 24 to the CCC's *Report into Building Safety Evaluation Processes in the Central Business District Following the 4 September 2010 Earthquake*[1] refers to a structural engineering assessment of the building.

Mr Elliott spoke to and had email contact with a then CCC employee, Ms Laura Bronner, who we understand was an administrative clerk with no engineering training. Mr Elliott said in evidence he was concerned that it was inappropriate for him to sign the form because no securing work had been done. Although he could not recall the details of their discussion, he did recall that she had said he should modify the form as he saw fit. He said there was no persuasion or negotiation on his part. Mr Elliott then amended the certificate, in particular by adding the statement: "The condition is not considered to be worse than prior to EQ". The relevant portion of that form is shown below.



Statement by Chartered Professional Engineer in respect of the building at:

(Building Address) 7 RICCARTON RD

(Business Name *if applicable*)

I, DAVID ELLIOTT (*name*), am a Chartered Professional Engineer (No 202002) with relevant experience in the structural design of buildings for earthquake actions.

I have been engaged to provide advice to the owner on the ~~interim securing / strengthening~~ current condition of the above building following the earthquake of 4 September 2010.

I am aware of all the measures taken to secure or strengthen the building (the work) which were carried out by (*Name and contact address of contractor*). — None Undertaken

I have inspected the ~~work on completion~~ building and am satisfied on reasonable grounds that:

a. *Structural integrity and performance.* Where the structural integrity and/or structural performance of the building (or part of the building) was materially affected by the Darfield earthquake or any aftershocks to date, interim securing measures have been taken to restore the structural integrity and performance of the building to at least the condition that existed prior to the earthquake of 4 September 2010. — The condition is not considered worse than prior to EQ.

b. *Potentially dangerous features.* Potentially dangerous features on the building such as unreinforced masonry chimneys, parapets and walls have been removed or secured so that their integrity and level of structural performance is consistent with that generally achieved in other parts of the building, and so reduces the danger to people's safety and of damage to other property. The condition is not considered to be worse than prior to the EQ

Figure 72: CPEng Certification Form for 7 Riccarton Road

The amended certificate was accepted by the CCC and the status of the placard changed to green on that basis.

The CCC file records that a CCC structural engineer had reviewed the report and agreed with the information supplied. Enquiries by the CCC for the purposes of the Royal Commission's inquiry could not establish who that engineer was, what report he reviewed or with what information there was agreement. However, it is clear from the terms of the amended certificate and the only report supplied to the CCC (which was Mr Elliott's letter incorrectly dated 6 September 2010 but which reported on his inspections of 7 and 9 September 2010) that the CCC could not have agreed with the information supplied. That is because the only statement in those documents to which the CCC could have been agreeing was the handwritten assertion that "the condition is not considered to be worse than prior to the earthquake".

Given that the building had been yellow-placarded and that status confirmed in a subsequent inspection, it was not acceptable for the CCC to accept that statement by Mr Elliott without carrying out any further inspection.

In evidence, Mr McCarthy said he accepted that the CCC process could have been done better and that, in accepting the CPEng form, the CCC was effectively accepting that the yellow placard should never have been issued. Mr Elliott said in evidence that he was never contacted by a CCC engineer, although he was expecting that to happen because he had modified the form. When asked why he did not contact the CCC to speak to an engineer, Mr Elliott said that it was not up to him to advise the CCC how to proceed.

In late December 2010 Mr David Yan, one of the owners of the building, inspected the building with his friend and engineer, Mr Robert Ling, in the company of a loss adjustor, Mr Fritz Muller. Mr Muller's evidence was that he saw a separation between the front façade and the side wall but that he believed this and the other cracking existed before the September earthquake, although it might well have been exacerbated by it. Mr Ling appears not to have agreed with this assessment. The inspection was left on the basis that Mr Ling would prepare a report to support a claim that the cracking to the building was sustained in the September earthquake. That report was never completed.

After the Boxing Day earthquake Mr Yan and Mr Ling inspected the building. Mr Ling's evidence was that he was not overly concerned with its structural condition. However, he was concerned with the general state of the building and advised Mr Yan to remove the ceiling and wall linings in preparation for re-development plans he was going to prepare for Mr Yan. Mr Ling was asked in evidence whether he gave any thought to the effect that removing the wall and ceiling linings might have had on the building's strength. He said that the walls were dilapidated and the ceilings had holes and cracks in them so the strength would not be reduced.

Mr Peter Smith, who carried out an independent assessment for the Royal Commission of the performance of the building in the February earthquake, said that the failure mechanism was an outward rotation of the entire Riccarton Road façade about its first-floor wall support, primarily caused by inadequate restraint at roof level.

Figure 73: The building after collapse (following removal of rubble)

4.24.4 Issues

4.24.4.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

The failure of the building in the February earthquake illustrates the risk to human life inherent in a passive approach in relation to earthquake-prone buildings.

In relation to the lack of follow-up of the 1991 and 1993 CCC surveys, we accept Mr McCarthy's statement that the primary responsibility for a building rests with the owner. However, the CCC also had responsibilities in relation to earthquake-prone buildings under the Building Act 2004 (and its antecedents), particularly in respect of public safety. As this hearing and others have shown, the potential issues relating to URM buildings, and their external walls and parapets, include matters of public safety and cannot be left solely to the owner. We consider that territorial authorities need to have active earthquake-prone buildings policies that ensure appropriate actions are taken within a reasonable timeframe. This is an issue we discuss in section 7 of this Volume.

4.24.4.2 Assessment of the building after the September earthquake

It was apparent that different views were held by engineers and building inspectors who saw what must have been the same cracking to the façade of this building. Mr Smith expressed the view that this might have been because of a different approach to the assessment of post-earthquake damage by engineers, namely a damage-based approach, whereas the approach by Mr Russell Officer and Mr Vaughan McMillan, who is a CPEng engineer, on 11 September appeared to have been more of a risk-based approach.

Further, this case highlights the need for URM buildings to be treated with caution after a substantial earthquake. It also highlights the skill and experience required to inspect and assess URM buildings. As Mr McMillan noted, when he graduated he had to deal with URM buildings, but engineers currently graduating may not know much about them.

We discuss the assessment and strengthening of existing buildings in section 6 of this Volume.

4.24.4.3 Assessment by Mr Elliott after allocation of yellow placard

Mr Elliott's inspection of the building on or about 17 September after it had been allocated a yellow placard was insufficient. As he accepted, the CCC requirement was for a Level 2 assessment to be carried out before there could be a placard change. As he also accepted, the reason for this was that it was a significant step involving risk to public safety.

Although Mr Elliott claimed that an internal inspection would not have made any difference to his conclusion, the type of inspection that Mr McMillan referred to was clearly called for. If an internal inspection had been carried out, there would have been a proper basis on which to determine whether the yellow placard should have been maintained.

4.24.4.4 Amendment of the CPEng certificate

The CCC should not have accepted the amended CPEng certificate. The CCC's file note that records that its engineer had agreed with the information provided made a nonsense of the application of the CCC's policy in relation to the change of placard status. The only report from Mr Elliott that was provided pre-dated the yellow placard. At best, the modification of the form created an ambiguity about the issues that the CCC had to decide.

In effect, the yellow placard was simply put to one side as a result of the combined actions of Mr Elliott and the CCC, without the relevant matters being given proper consideration.

4.24.4.5 Removal of linings

We accept Mr Smith's evidence that the wall and ceiling linings would not have prevented the façade collapsing. However, removal of the linings by Mr Yan under Mr Ling's directions could have had the effect of decreasing the strength of the building at a time when the city was vulnerable to aftershocks and was unwise.

4.25 391 and 391A Worcester Street

4.25.1 Introduction

Wicks Fish Shop was located at 389A Worcester Street. Natasha Hadfield, the co-owner of the business, and Betty Dickson, a customer in the shop, were killed when the western wall of the adjoining property at 391 and 391A collapsed onto and through the shop roof in the 22 February 2011 earthquake.

Figure 74: The building at 391 and 391A Worcester Street, with tarpaulins on its roof after the September earthquake

4.25.2 The building

The structure at 391 and 391A Worcester Street was a two storey unreinforced masonry (URM) building housing a pizzeria on the ground floor and a residential flat upstairs. It had timber roofing and a timber ground floor.

It appears that the building had remained in relatively original condition since it was constructed, with no earthquake strengthening. No upgrade of the building was ever required by the CCC, presumably because there was never any significant alteration or change of use.

4.25.3 Events following the September earthquake

As the building was outside the CBD, there was no CCC rapid assessment after the September earthquake. However, the building was damaged when the parapet on the Worcester Street frontage collapsed back onto the roof, damaging the roof framing. Make-safe works were carried out and tarpaulins placed over the roof and the western wall to make the building weathertight. An assessment of the western wall at that time by the contractor, Contract Construction, concluded that it did not appear damaged, but the eastern wall was damaged and was propped with timber bracing against the roof of the adjoining building.

An inspection by TM Consultants, engineers, on behalf of the owner's insurer, on 11 October 2010 confirmed this damage and that the western wall did not appear to have been damaged.

There was no inspection of the building after the Boxing Day earthquake by either the CCC or any engineer on behalf of the owner.

The building was inspected by an Earthquake Commission (EQC) assessor and estimator in early February 2011 as a result of the owner's EQC claim for damage to the residential apartment on the first floor. The notes of the assessor, Mr Lindsay Attrill, and the estimator, Mr Bruce Glasgow, record that there was substantial damage to the building. In particular:

- the building was structurally unstable and had suffered a significant collapse of the roof into the building;
- during inspection of the upstairs residential bedroom it became evident that in windy conditions the tarpaulin was being lifted and in turn dramatically lifting the upper-level floors, making the building unsafe and in danger of collapse;
- the roof was unstable and severely damaged, with a major section having collapsed internally so it required a rebuild and replacement of the corrugated iron;
- the east parapet had collapsed and the wall had emergency timber bracing on the roof of the adjoining property. Both brick walls had multiple cracks and were unstable; and
- there was severe damage to all exterior walls and chimneys (potentially dangerous).

Counsel assisting the Royal Commission wrote to Mr Attrill, who resides in Australia, on 12 September 2011. His reply dated 3 October 2011 said that at the time of the inspection the assessor and estimator briefly discussed the state of the building with the owner. However, no details of that discussion were given. The owner of the building, Mr Pak Loke, gave evidence that he was given little information by the assessors at that time and was not told of the danger of collapse.

Mr Loke received a letter from EQC dated 15 February 2011 enclosing documents that described the walls of the building as severely damaged and moving and potentially dangerous. Mr Loke conceded that he had done nothing about this letter. However, he said that, although he could not be exact about the date, he received the letter just before 22 February. His evidence was that when he read that description he had doubts as to its accuracy, given what he had been told by EQC at the time of the inspection. He claimed that he was considering contacting the EQC to clarify the position when the earthquake occurred.

Mr Attrill's written reply to the Royal Commission stated that he and Mr Glasgow had informed the occupier of the extent of the damage at the time of their inspection. However, the Royal Commission did not hear evidence from the occupier because he had not replied to a written request for information and could not be located by counsel assisting the Royal Commission.

Mr Attrill also said that during the inspection he went into the neighbouring property and spoke to a person behind the counter, and it was most likely that, given the circumstances, the conversation would have been about the state of the adjoining building. In a statutory declaration, Mr Geoffrey Hadfield, who owned Wicks Fish Shop with his wife, recalled a man who was obviously inspecting the adjoining building coming into Wicks Fish Shop but said that there was little or no conversation between them. Mr Hadfield's statutory declaration is very clear in its terms. He stated that he was not told anything of the state of the adjoining building.

After his inspection Mr Attrill recorded on the EQC file that EQC should appoint an engineer as a matter of urgency. No engineer was ever appointed. EQC could not adequately explain the reason for that, although it appears that it may have been because it was recommended that the claim be declined on the basis of an initial view that the premises were predominantly commercial and not residential.

EQC did not advise the CCC or the owners of the neighbouring properties (including the Hadfields) of its concerns in relation to the building. This was because of EQC's then understanding of the application of section 32 of the Earthquake Commission Act 1993 and the Privacy Act 1993. Mr Ian Simpson, Chief Executive Officer of EQC, gave evidence that as a result of the Royal Commission's inquiry into this building failure his organisation had reconsidered that position and developed a new policy that required notifying territorial authorities and neighbours when such a situation arose.

The policy was set out in the evidence of Mr Bruce Emson of EQC, as follows:

> 6.1 EQC staff and contractors must advise their supervisor or manager and complete a notification of a dangerous building form where they consider that:
>
> a) a building may pose a serious and imminent risk to health or safety; or
>
> b) residents/neighbours are not complying with a red or yellow sticker and are therefore placing themselves or others at serious risk.
>
> 6.2 In the case of an urgent danger to health and safety, staff and contractors can immediately notify emergency services and any persons at risk, which might include the building owner, occupants and neighbours. Staff and contractors must then inform their supervisor or manager.
>
> 6.3 The notification of a dangerous building form is sent to EQC's Field Operations Manager. The Field Operations Manager checks the details of the form to ensure they are correct and that personal information is not disclosed, and then sends the form to the respective local authority, for example the CCC or CERA.
>
> 6.4 The details of each notification and actions taken are recorded by EQC in a Dangerous Buildings Register.

The policy was implemented in October 2011. Mr Simpson gave evidence that 17 such notifications had been made as of 15 December 2011.

After a request from the Royal Commission at the hearing, counsel for EQC provided a memorandum about whether EQC considered that section 32 of the Earthquake Commission Act 1993 restricted EQC's ability to advise persons such as local authorities or neighbours of buildings that EQC considered were potentially dangerous.

Section 32 gives EQC the power to inspect property, obtain information and enter land "for the purpose of obtaining any information that may be reasonably required by the Commission for the purposes of the EQC Act". However, section 32(4) limits the circumstances in which such information can be divulged to third parties.

According to the memorandum, EQC does not consider that section 32(4) precludes the disclosure of information "in the ordinary course" because EQC does not usually obtain such information by exercising its powers under section 32. Typically it obtains its information by consent. However, as counsel for EQC pointed out, it is conceivable that information about a dangerous building could be obtained by exercising the powers under section 32. In such a case it would be subject to the restriction on disclosure stated in section 32(4).

However, EQC says that, if such a situation arose, it would still be entitled to disclose the information. One of the exceptions to the limitation in section 32(4) allows information to be disclosed "for such purposes as may be specified in any other Act". EQC's view was that such information could be disclosed because one of the purposes stated in the Privacy Act relates to the prevention or lessening of a serious and imminent threat to an individual or the public.

Notwithstanding this, EQC invited the Royal Commission to recommend a further exception in section 32(4) of the EQC Act as follows:

> (e) For the purpose of preventing or lessening a serious and imminent threat to public health or public safety, or the life or health of any person.

Figure 75: Collapse of the western wall of the building into 389A Worcester Street

4.25.4 Issues

4.25.4.1 Application of the CCC's Earthquake-Prone Dangerous and Insanitary Buildings Policy

This building failure, as with most others in this category, illustrates the risk to human life inherent in a passive approach in relation to earthquake-prone buildings. The building, which was likely to have been earthquake-prone, remained in a relatively original condition at the time of the Canterbury earthquakes. We address earthquake-prone building policies in section 7 of this Volume.

4.25.4.2 Assessment and occupation of unreinforced masonry buildings following a substantial earthquake

The failure of this building, in common with the failure of other URM buildings, demonstrates the fact that sole reliance on damage-based assessments of URM buildings may be inadequate after a substantial earthquake. Post-earthquake building inspections are discussed in Volume 7 of this Report.

4.25.4.3 Lack of communication of potential danger

We accept the evidence in Mr Hadfield's statutory declaration that he was not told of the potential danger posed by the building. It is clear that if he had been told of the potential danger the wall posed, he would not have continued to occupy the Wicks Fish Shop premises. It therefore follows that, if the EQC's new policy had been instituted before the February earthquake, these two lives might well have been saved. We would have recommended that EQC's policy should be changed but EQC has recognised the need for that and, as a result of these events, adopted what we view to be a sensible and pragmatic policy.

We do, however, recommend that an amendment be made to section 32(4) of the Earthquake Commission Act 1993. It is clearly appropriate and sensible to remove any doubt about the ability to disclose information that might affect personal safety. Our recommended amendment is wider in its terms than that proposed by EQC. We do not think the exception should be limited to cases of "serious and imminent" threats to health and safety. Any threat would be sufficient to justify disclosure. We therefore recommend that section 32(4) should be amended with the change highlighted here in bold, to read, in full:

> (4) A person authorised by the Commission for the purposes of subsection (1) shall not make a record of, divulge, or communicate to any person, any information acquired in exercising the powers conferred by that subsection except—
>
> (a) to the Commission; or
>
> (b) for the purposes of this Act; or
>
> (c) for the purposes of any court proceedings; or
>
> (d) for such purposes as may be specified in any other Act; or
>
> **(e) for the purpose of preventing or lessening a threat to public health or public safety or to the life or health of any person.**

Further, we believe that statutory bodies, engineers and other professionals, tradespersons and building owners should all have a duty to disclose to the relevant territorial authority and any affected neighbour any information of which they have become aware to the effect that a building is in a dangerous or potentially dangerous condition. We discuss this further in section 7 of this Volume, where we make an appropriate recommendation.

As we have indicated, we are of the view that a building owner in Mr Loke's position who is advised of any potential danger his building poses should advise neighbouring owners or tenants of that danger. In this case, it is not clear exactly what Mr Loke was told by EQC on 1 or 2 February 2011. However, he did receive notification in writing from EQC that the wall was potentially dangerous, in the letter dated 15 February 2011. It is unfortunate that Mr Loke did not take some immediate action in relation to this information. In explanation, he said he did not receive this letter until some days after the date of the letter.

While the evidence from the EQC assessor was that the occupier had been advised of the danger, we would not consider that notification to an occupier (or even an owner) of this type of information would be sufficient to ensure that the appropriate action was taken (as the new EQC policy recognises). Notification must be to the territorial authority, an independent statutory body that has the power to address the danger.

References

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7. Ingham, J.M. and Griffith, M.C. (August 2011). *The Performance of Unreinforced Masonry Buildings in the 2010/2011 Canterbury Earthquake Swarm: Report to the Royal Commission of Inquiry*. Christchurch, New Zealand: Canterbury Earthquakes Royal Commission. And Ingham, J.M. and Griffith, M.C. (October 2011). *The Performance of Earthquake Strengthened URM Buildings in the Christchurch CBD in the 22 February 2011 Earthquake: Addendum Report to the Royal Commission of Inquiry*. Christchurch, New Zealand: Canterbury Earthquakes Royal Commission.

8. AS/NZS 1170.0:2002. *Structural Design Actions: Part 0 – General Principles*, Standards New Zealand/ Standards Australia.

Note: Standards New Zealand was previously known as the Standards Institute of New Zealand.

Section 5: Unreinforced masonry buildings and their performance in earthquakes

5.1 Unreinforced masonry buildings and their characteristics

Unreinforced masonry (URM) buildings were built in New Zealand primarily between 1880 and 1935. This 55-year period gives a relatively homogeneous stock of URM buildings compared to other parts of the world.

They make up a comparatively large number of large structures in New Zealand's buildings. They are unable to resist seismic actions in contrast to more recent structures using steel and reinforced concrete as an integral part of the building fabric. They are predominantly one, two and three storey brick buildings built for commercial purposes. Also included in this category are stone masonry buildings, churches and some important public buildings. Many URM buildings are treasured as valued records of our history and some continue to be used for the purposes for which they were built. Many others are now used as small-scale commercial premises; some are much valued for their traditional character.

These buildings were designed to resist gravity and wind loads and incorporate materials that are subject to deterioration with age: timber (subject to decay from water damage) and lime mortar. Metal fastenings are also subject to corrosion. The buildings are more than 75 years old and some more than 100 years. Many have been poorly maintained. In general, they are rigid structures with little capacity to flex when subjected to the high accelerations imparted by earthquake-induced ground motions. Unlike buildings designed with modern materials to current codes, they can change from acceptable performance to collapse with only a slight increase in the intensity of ground shaking. Collapse can occur in moderate earthquakes. The structural elements of these buildings are frequently poorly interconnected and detach from each other, resulting in catastrophic collapse under earthquake forces.

If they have not been strengthened, URM buildings are particularly dangerous as they may fail in moderate earthquakes. Because they are constructed from heavy materials, they may inflict injury, serious damage, or even death when they collapse.

It has been estimated that prior to the recent Canterbury earthquakes, there were approximately 4,000 such buildings in New Zealand. Due to the effects of the Canterbury earthquakes, there may now be about 500 fewer.

5.2 Earthquake performance

The collapses of URM buildings that have occurred as a result of the Canterbury earthquakes were mostly within the Christchurch Central Business District (CBD). As discussed in section 4 of this Volume, 39 people lost their lives due to the failure or partial failure of URM buildings in Christchurch[1]. Their collapse caused the death of pedestrians passing by, motorists, passengers on buses adjacent to a collapsing building, and of people inside buildings that fell. In at least three instances, failed buildings collapsed onto neighbouring buildings killing people inside. As also discussed in section 4, some of these buildings had been strengthened to varying degrees.

5.2.1 The Ingham and Griffith reports

The Royal Commission sought advice from Associate Professor Jason Ingham of The University of Auckland and Professor Michael Griffith of the University of Adelaide on the performance of URM buildings in the earthquakes. The first report that they prepared for the Royal Commission was provided in August 2011: *The Performance of Unreinforced Masonry Buildings in the 2010/2011 Canterbury Earthquake Swarm*[2], covered the damage that resulted from the 4 September 2010 earthquake, and was considered in the Royal Commission's Interim Report dated 11 October 2011. We sought a further report from Ingham and Griffith on the performance of URM buildings in the 22 February 2011 earthquake. That report, *The Performance of Earthquake Strengthened URM Buildings in the Christchurch CBD in the 22 February 2011 Earthquake*[3], was dated October 2011. Both reports were published on the Royal Commission's website.

In their August 2011 report, Ingham and Griffith explained the impact of the Canterbury earthquakes on URM buildings in the following passage:

> Unreinforced masonry buildings are comparatively stiff structures, with a fundamental period typically in the range of 0.3–0.5 seconds…for this period range many URM buildings were subjected on 4 September 2010 to earthquake loads that were between 67–100% of NBS…and that the same buildings were subjected on 22 February 2011 to earthquake loads that were between 150–200% of NBS…It is well established that URM buildings perform poorly in large earthquakes and consequently the level of earthquake damage in the Christchurch CBD is consistent with expectations for loading of this magnitude.

Although the September earthquake subjected many URM buildings to a level of shaking of the order of a 500-year return period earthquake, no lives were lost. The time of the shaking, at 4.35am on 4 September 2010, meant that commercial buildings – as most URM buildings were – were unoccupied, and there were no passers-by. However subsequent superficial examination of URM buildings resulted in many being classified as having minimal obvious damage and reoccupation was permitted. Several of those buildings were further damaged in February 2011, and the failure of some caused death. There is a discussion of each of those buildings in section 4 of this Volume. Many of the persons who were killed or injured were in public spaces alongside the failed structure.

The evidence[4] is that the September 2010 earthquake created ground motions approximately *at* the design level for the ultimate limit state under the current design Standard (NZS 1170.5: 2004[5]). This means that the shaking was appreciably greater than that of a moderate earthquake, the concept used to assess whether a building is earthquake-prone under section 122 of the Building Act 2004. Yet many URM buildings were intact after the September earthquake and may not have caused loss of life even if they had been occupied.

Over several years prior to the September earthquake, a number of buildings in the Christchurch CBD had been strengthened to varying degrees through additional structures designed to support the building fabric. This strengthening varied from building to building and included connections of walls and parapets to floors and roof, and internal frames to support brick walls. In some cases additional moment resisting structures were provided to absorb earthquake forces.

Both of the Ingham and Griffith reports, but in particular the October 2011 report, addressed the effectiveness of various levels of strengthening on the performance of structures in the earthquakes. In their October 2011 report, Ingham and Griffith analysed the performance of URM buildings that had some degree of retrofit and compared these with buildings which had no improvement. Data was collected from around 370 CBD buildings that had been subjected to the September, Boxing Day and February earthquakes. Section 6 of the October report gave an analysis of the performance of 94 buildings (taken from the 370 CBD buildings) to which they were able to assign a percentage of NBS, based on material in CCC files, information provided by building owners and engineers, or their own estimates. These 94 buildings included 31 unstrengthened URM buildings. Although the report does not set out their detailed factual basis, the conclusions about the effectiveness of retrofit are worth noting. Figures 75–82 summarise their findings in terms of the general effectiveness of the level of seismic retrofit, measured in terms of the percentage of NBS, on the level of damage that was sustained. In interpreting these figures it should be noted that the percentage of NBS was based on the then current Z factor of 0.22, which was appropriate for the near design level shaking of the September earthquake. However the shaking in the February earthquake was 1.5–2 times the design level. Hence, for this earthquake, 67% NBS as recorded in the figures corresponds to a range of 33–45%, when allowance is made for the shaking being 1.5–2 times the design level.

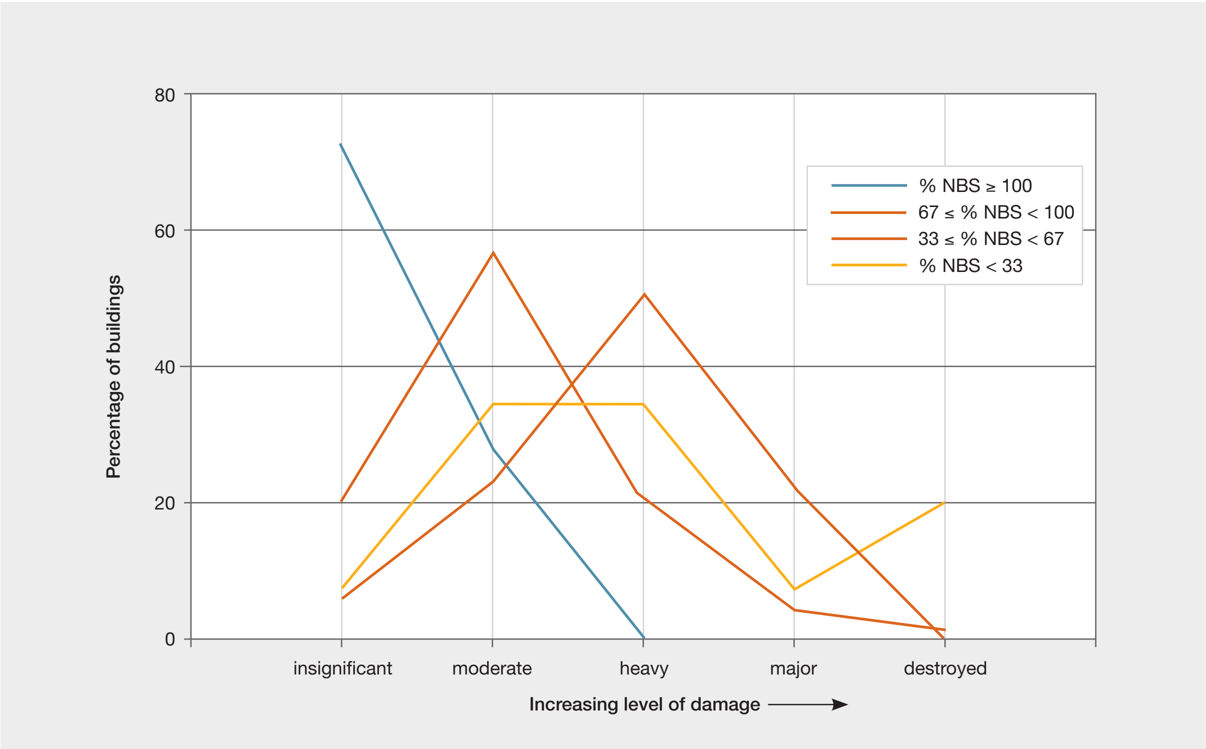


Figure 76: Plot of overall building damage level for different levels of percentage of NBS earthquake strengthening (source: Ingham and Griffith[3])

The data represented in Figure 76 indicate that, in the February earthquake, the URM buildings strengthened to 100% NBS performed well, those strengthened to 67% NBS performed moderately well, and the performance of those strengthened to less than 33% NBS was not significantly better than those that had not been strengthened. (In section 6 of this Volume we address various issues that we see arising from use of the 'percentage of NBS concept' but for present purposes we adopt it, because it is in general use, and is used in the Ingham and Griffith reports.)

The damage levels were also divided into a range of severities. The level of damage observed in buildings that had been strengthened to various percentages of NBS was compared with those buildings that had not been strengthened. The results are shown below in Figures 77, 78 and 79.

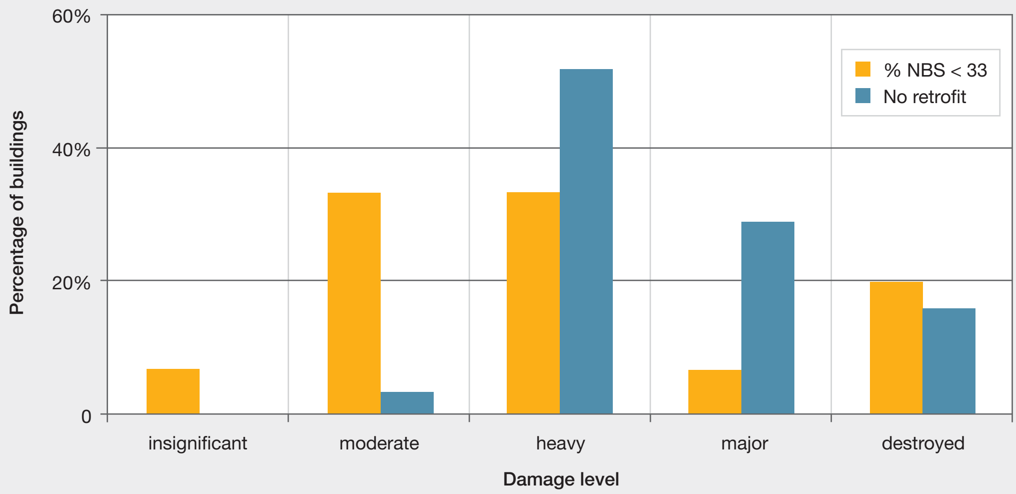


Figure 77: Damage comparison between URM buildings strengthened to 33% NBS and no retrofit (source: Ingham and Griffith[3])

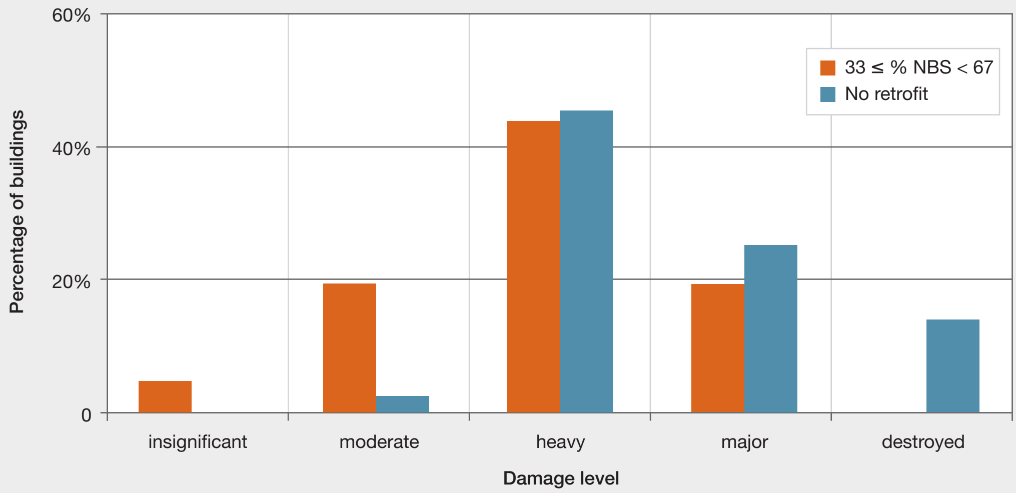


Figure 78: Damage comparison between URM strengthened to 33–67% NBS and no retrofit (source: Ingham and Griffith[3])

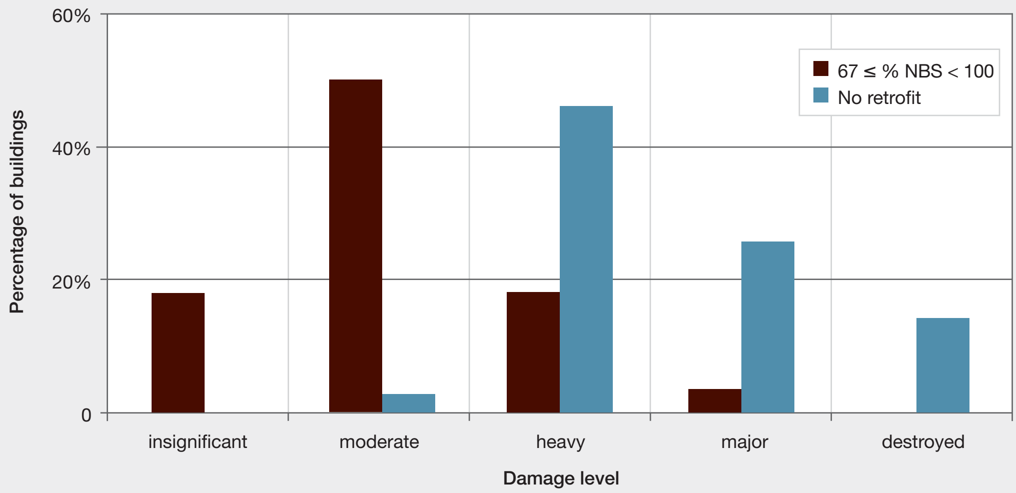


Figure 79: Damage comparison between URM buildings strengthened to 67–100% NBS and no retrofit (source: Ingham and Griffith[3])

Based on the data above, interpretation of the damage shows that:

- buildings that had received less than 33% NBS strengthening behaved in a similar manner to unstrengthened URM buildings, however there was a shift from major damage to moderate damage;
- a URM building strengthened to between 33% NBS and 67% NBS avoided being destroyed but otherwise the reduction in damage was not greatly better than for URM buildings that had received no retrofit; and
- URM buildings that were strengthened to between 67% NBS and 100% NBS showed a noticeable increase in performance compared to unstrengthened URM buildings.

We emphasise, as noted above, that in interpreting this data, it is important to note that the seismic hazard factor (Z) for strengthening work undertaken would have been 0.22; this factor was revised upward following the earthquakes to 0.3. Further, the direction of ground shaking in the September and February earthquakes must also be borne in mind. These matters are discussed in detail in section 2 of Volume 1 of this Report.

Other analyses in the Ingham and Griffith report compared the performance of buildings that had been subject to different kinds of strengthening, described as Types A and B earthquake improvements. Type A involved techniques that aimed to improve connections between the walls and diaphragms: securing and strengthening building elements such as gable ends (excluding parapets, which were assessed separately); installation of connections between the walls and the roof and floor systems, so that the walls would not respond as vertical cantilevers secured only at their base; and stiffening of the roof and/or floor diaphragms.

Type B improvements were defined as strengthening techniques that sought to strengthen masonry walls and/or to introduce added structure to supplement or replace the earthquake strength provided by the original unreinforced structure. They included strong-backs installed either internally or externally; steel moment frames; steel brace frames; concrete moment frames; the addition of cross walls; post-tensioning; and the use of shotcrete, and fibre-reinforced polymer. A comparison between two types of earthquake strengthening and those with no retrofit is shown in Figure 80 below.

In the sample of 31 buildings with no retrofit, 97% suffered severe, major, or heavy damage. However, Ingham and Griffith also noted that many strengthened buildings were also damaged, in some cases to a major extent.

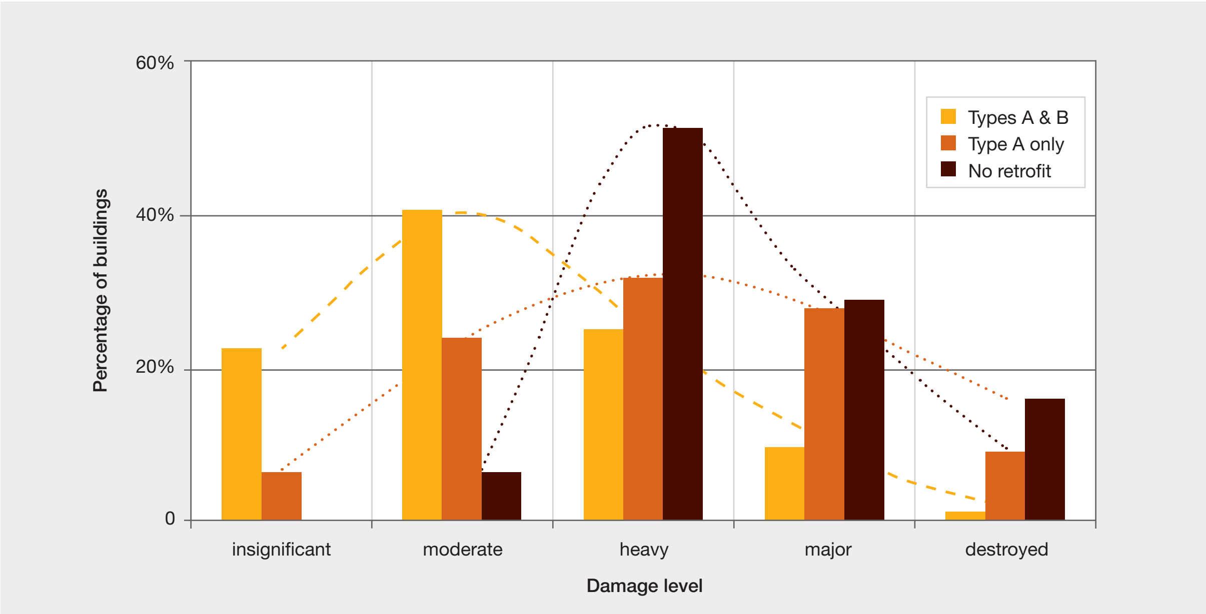
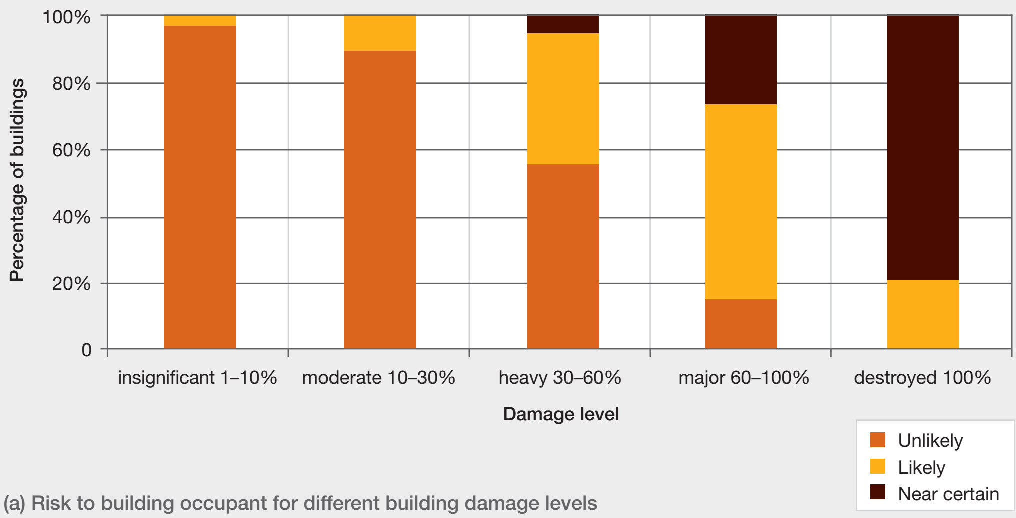
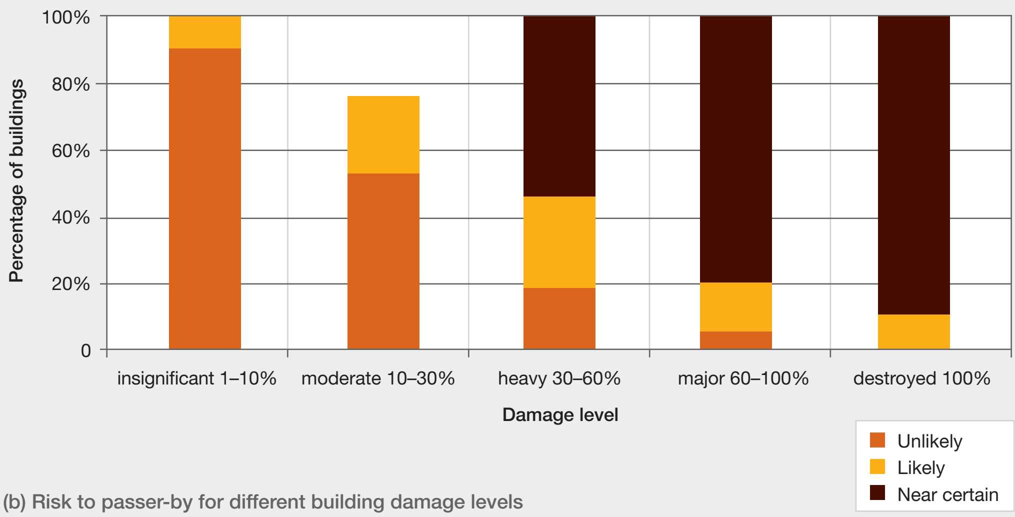


Figure 80: Plot of damage level against seismic strengthening types (source: Ingham and Griffith[3])

Figure 81 represents the conclusions in the Ingham and Griffith report about what they found was an escalating level of hazard to building occupants and passers-by caused by increased levels of building damage. Not surprisingly, the risk of fatality or injury increases with the level of damage sustained, but that is more pronounced for passers-by than building occupants.



(a) Risk to building occupant for different building damage levels



(b) Risk to passer-by for different building damage levels

Figure 81: Fatality and injury risk for different building damage levels (source: Ingham and Griffith[3])

Ingham and Griffith also compared risk to hypothetical occupants and passers-by, based on an assessment of the performance of the 94 surveyed buildings that could be assigned a percentage NBS. Their findings (acknowledged to be subjective) are shown in the following diagrams, and suggest that it is generally safer to be inside a URM building during an earthquake than outside it.

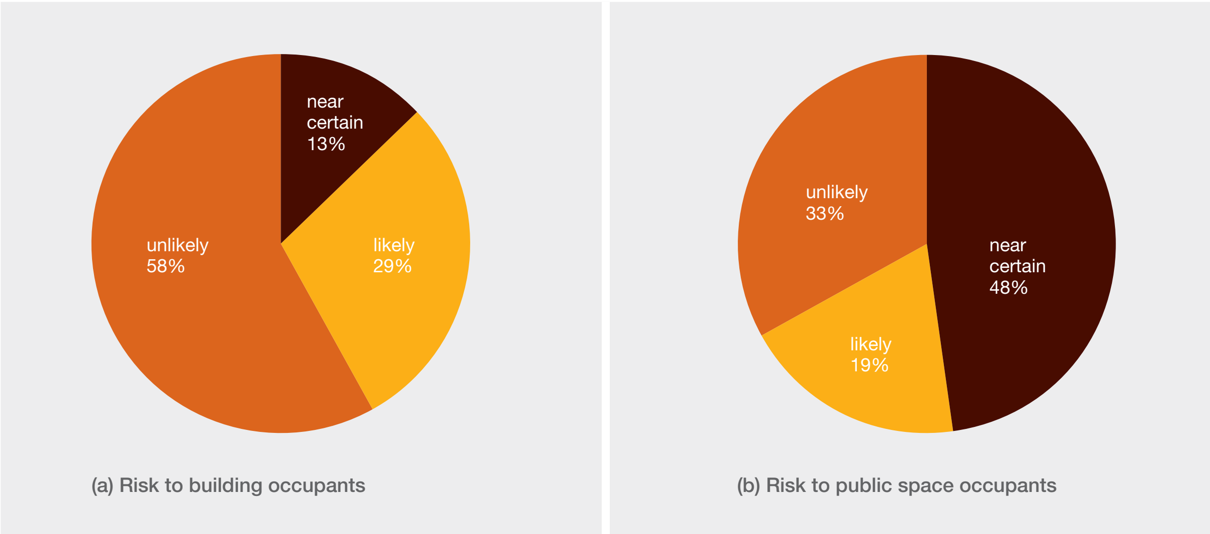


Figure 82: Risk of fatality or injury to building occupants and public space occupants (source: Ingham and Griffith[3])

They concluded that the increased risk to those in the adjacent public space was because walls are more likely to collapse outwards. Similarly parapets and gables fell onto adjacent property. These conclusions align with those of the Royal Commission, having considered the actual performance of all of the buildings whose failure in the February earthquake caused loss of life.

Ingham and Griffith also reported on the different levels of risk to occupants and passers-by from failure of URM buildings strengthened by Types A and B strengthening works, and those that had not been strengthened. The results are presented in the following Figure 83.

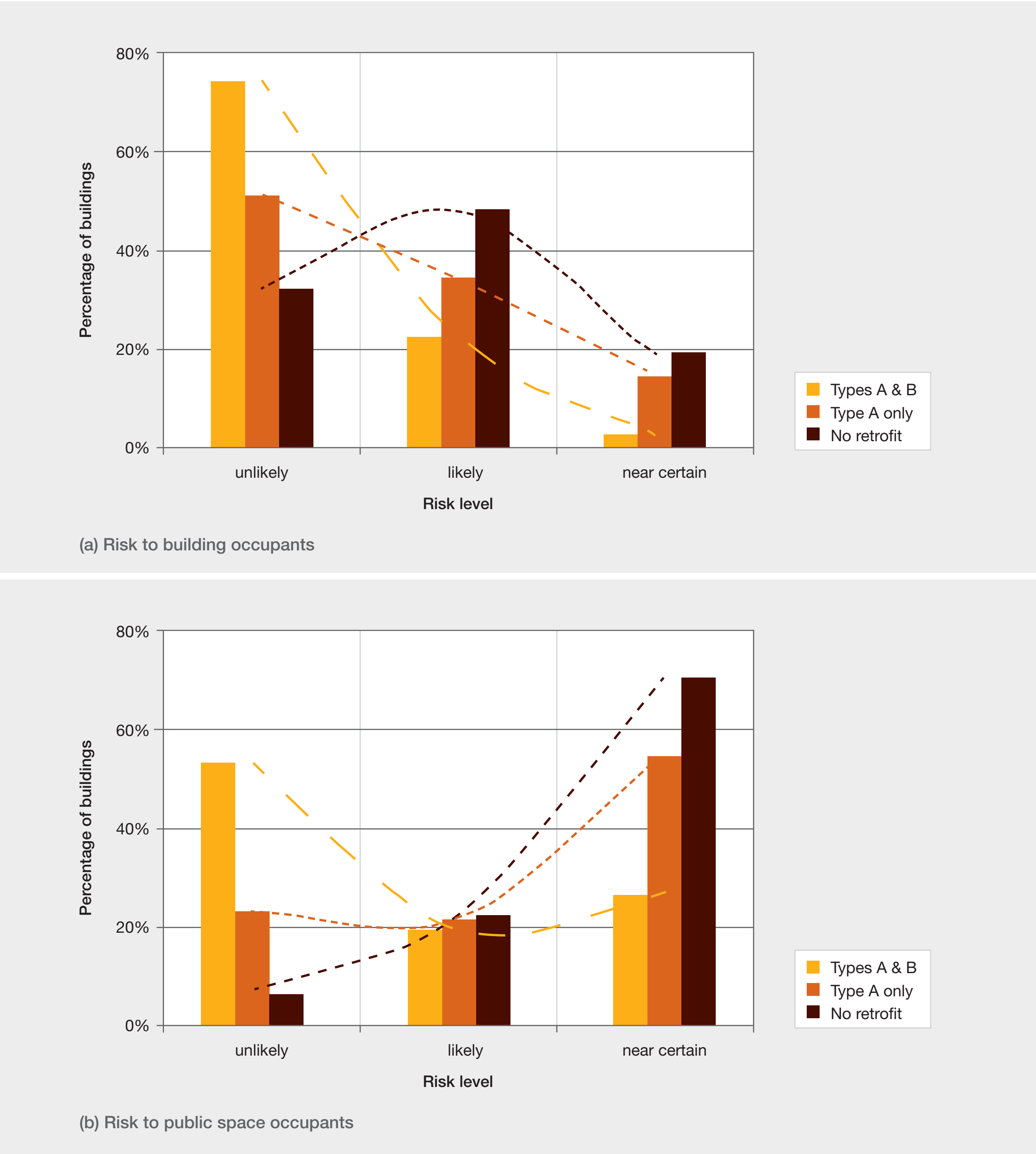


Figure 83: Plot of seismic strengthening level vs risk to building occupants and public spaces (source: Ingham and Griffith[3])

This enhancement of safety from retrofit is noted and reinforces the imperative to strengthen buildings.

There is considerable international experience of the behaviour of URM buildings in earthquakes, especially in areas such as California and Italy where URM buildings are also common. The Royal Commission engaged two engineers based in California to peer review the Ingham and Griffith reports: Mr Fred Turner, who is a structural engineer with the California Seismic Safety Commission, and Mr Bret Lizundia, a principal in the firm Rutherford and Chekene in San Francisco. Both are experts in this field. The peer reviews of Turner and Lizundia were also published on the Royal Commission's website.

Turner[6] and Lizundia[7] discussed the Californian experience with URM buildings. Lizundia noted that in California emphasis on strengthening is primarily to reduce the risk of death and injury. He observed that it is hard to assess accurately the properties of the old materials used in URM buildings. Turner noted that in

California programmes are referred to as "conservation" rather than strengthening, and are tailored to local government discretion. Although the standards of retrofit vary, the Royal Commission was informed that, by 2006, 70% of the approximately 26,000 URM buildings in California had been either retrofitted or demolished.

Strengthening of a URM building is also considered a "risk reduction programme" by the New Zealand Society for Earthquake Engineering, a term that reflects the limitations of such work. Turner emphasised the need to acknowledge that:

> …it is neither practical nor feasible to state conclusively that the public can be effectively protected from "all" falling hazards and that "strengthened URM buildings will survive severe earthquake ground motions".

He also observed that:

> …the public should be made aware of the practical limitations of seismic retrofits, considering the margins of safety from collapse and parts of buildings falling, particularly in light of the large known variability and uncertainty in the quality of building materials, the states of repair, and the integrity of connections between building components. In a retrofitted URM building, a single masonry unit that may fall from an appreciable height has the potential to be lethal or cause serious injury. Retrofits that represent best practices may not always guarantee that all masonry units will remain in place, nor that URM buildings will always avoid cost-prohibitive repairs or demolitions after experiencing severe ground motions.

Despite improvement made to many buildings, the Royal Commission is concerned to note that, from the sample of 94 URM buildings, over 60% that were strengthened to more than 67% NBS suffered moderate to heavy damage. Turner cautioned that the behaviour of URM buildings in earthquakes is difficult to predict because of the inherent weakness of component materials. This appears to be substantiated by the damage statistics derived from the Canterbury earthquakes experience. It is important to note in making this observation that the February earthquake was severe.

5.2.2 Heritage buildings

The New Zealand Historic Places Trust[8] (NZHPT) provided a report to the Royal Commission cataloguing 100 heritage listed buildings. Of that number, four were in Lyttelton and 96 in the Christchurch CBD. The heritage buildings discussed in the NZHPT report were all scheduled as such in the district plan. The NZHPT report describes each building, whether it had been retrofitted, damage resulting from the earthquakes, and the present status. Many damaged buildings have now been demolished for safety reasons.

The report analyses how a select sample of 100 heritage buildings performed in the Canterbury earthquakes. The buildings were either registered by the NZHPT or listed as heritage buildings in Christchurch City Council's District Plan. Of the 100 buildings studied:

- 72 were URM buildings;
- 15 were timber-framed buildings; and
- 13 were of other construction (i.e. reinforced concrete).

The report examined how buildings strengthened to different levels performed, grouping them by:

- earthquake strengthening of the entire building (30% of buildings);
- partial or incomplete strengthening (16%);
- bracing and ties (8%);
- no earthquake strengthening (27%); and
- unknown if strengthened (19%).

The analysis in the report shows:

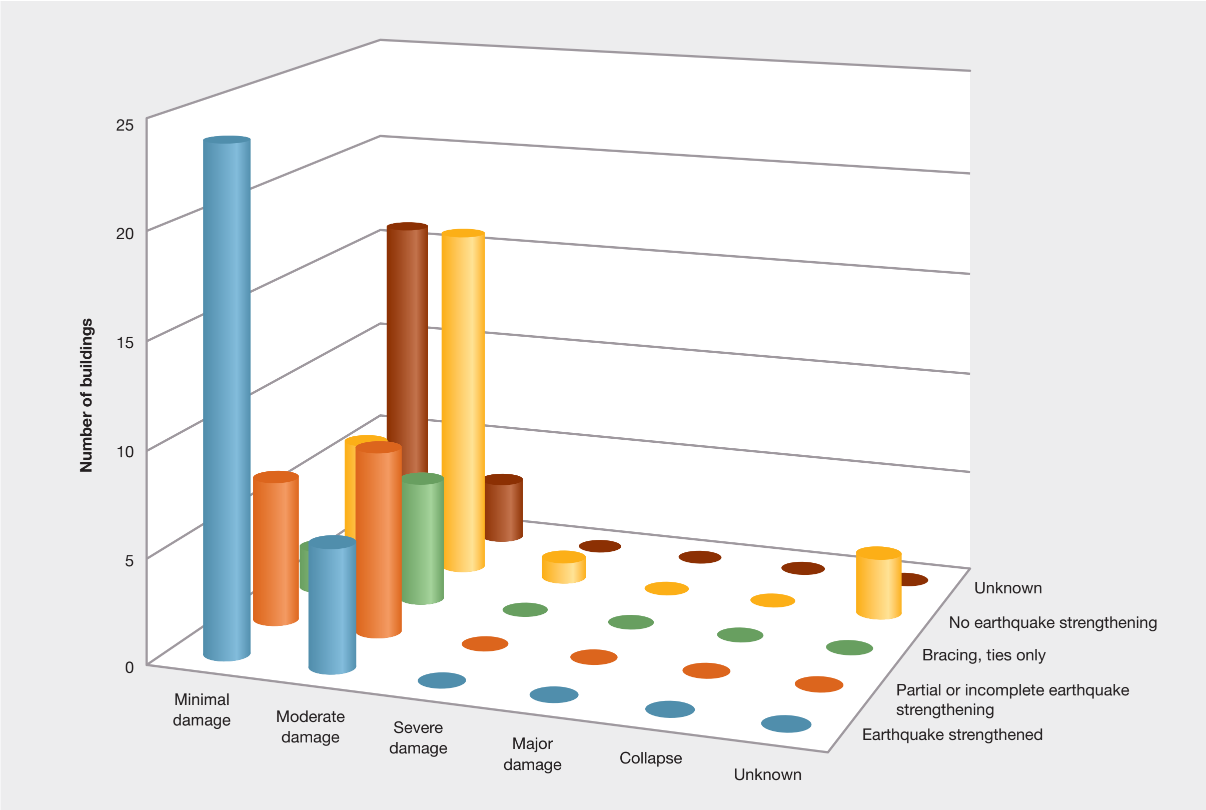
Table 1: Numbers of strengthened buildings damaged in the Canterbury earthquakes

Demolished	Demolition pending or possible	Buildings damaged		Number strengthened	Strengthened buildings damaged	
		Sept 10	Feb 11		Sept 10	Feb 11
40	21	97	95	54	54	54

Notes:

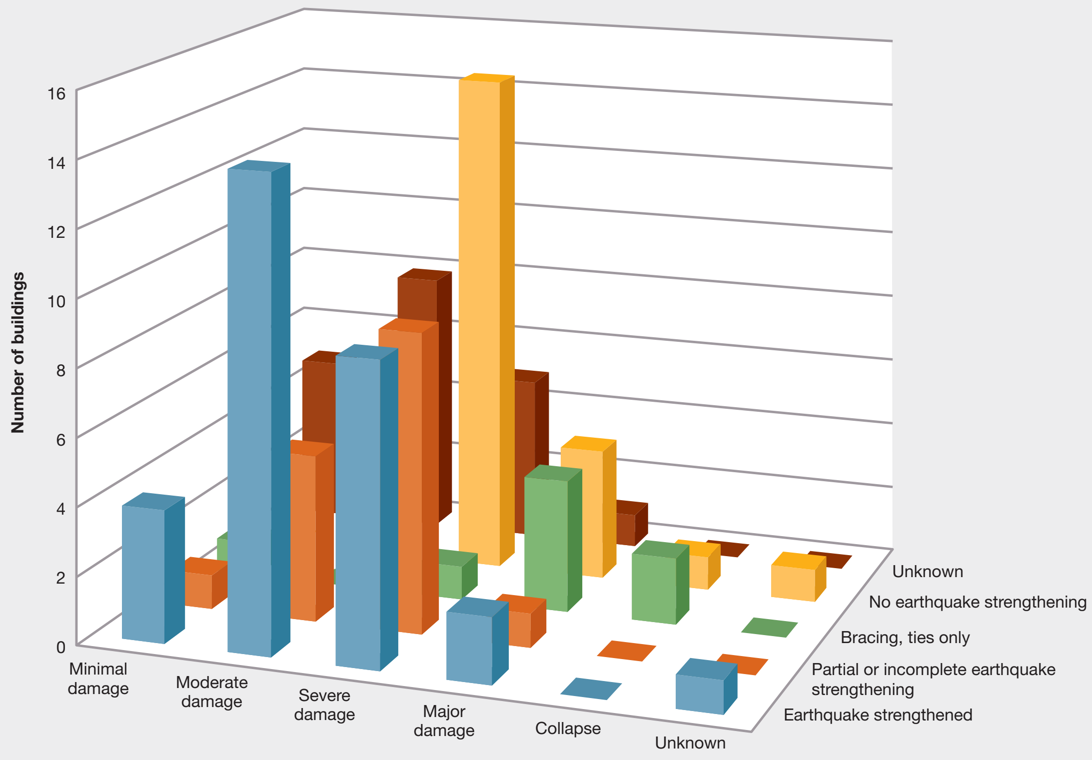
- The figures were current to January 2012.
- The damage assessment of three buildings in September 2010 was unknown.
- The damage assessment of two buildings in February 2011 was unknown.
- Three buildings collapsed in February 2011.

Although all 54 of the strengthened heritage buildings suffered damage following both the September and February events, the extent of the damage differed between the two events. The following graphs demonstrate the different impacts of the two events on the same sample of 100 heritage buildings. They also show how the different strengthening levels affected performance of the buildings.



	Minimal damage	Moderate damage	Severe damage	Major damage	Collapse	Unknown
Earthquake strengthened	24	6	0	0	0	0
Partial or incomplete earthquake strengthening	7	9	0	0	0	0
Bracing, ties only	2	6	0	0	0	0
No earthquake strengthening	6	17	1	0	0	3
Unknown	16	3	0	0	0	0

Figure 84a: Comparison between 100 strengthened and non-strengthened heritage buildings damaged in the earthquakes between September and December 2010 (source: New Zealand Historic Places Trust, March 2012)



	Minimal damage	Moderate damage	Severe damage	Major damage	Collapse	Unknown
Earthquake strengthened	4	14	9	2	0	1
Partial or incomplete earthquake strengthening	1	5	9	1	0	0
Bracing, ties only	1	0	1	4	2	0
No earthquake strengthening	0	5	15	4	1	1
Unknown	5	8	5	1	0	0

Figure 84b: Comparison between 100 strengthened and non-strengthened heritage buildings damaged in the earthquakes between January and June 2011 (source: New Zealand Historic Places Trust, March 2012)

5.3 Observations on the behaviour of URM buildings

There are three broad approaches to managing the risk posed by unreinforced masonry buildings in earthquakes. The first is to do nothing and accept the risk on the basis that damaging earthquakes resulting in building damage will occur infrequently. The second option is to demolish these building types, which would obviously impact on the heritage and character of New Zealand's cities and towns. The third way forward is to install some level of earthquake strengthening in these buildings. This third option is the intent of the current law. We do not suggest that it should be abandoned.

However, it should be emphasised that the strengthening of URM buildings requires careful consideration. URM buildings are made up of materials that are inherently good in compression but very weak in tension. The poor performance in earthquakes of URM buildings as a class can be attributed to the buildings' common characteristics. URM buildings are stiff, heavy and brittle structures, which attract large seismic accelerations in their structures. They have little capacity to deform once the strength of their elements has been exceeded, leading to abrupt failures.

The material properties and structural forms of URM buildings result in several potential seismic weaknesses. The deficiencies have been characterised and interpreted in the United States, for example in documents issued by the Federal Emergency Management Agency (FEMA), such as FEMA 547[9]. FEMA's documents[10] are also reasonably widely used in New Zealand.

When undertaking retrofit of URM buildings, it is important to understand these potential seismic deficiencies. By understanding these, a designer can determine the most critical feature of a particular structure. The most hazardous of these deficiencies are inadequately restrained elements located at height, for example, street-facing façades. Unrestrained parapets, chimneys, ornaments and gable end walls are also a high risk to public safety due to their low bending strength and high imposed accelerations. They are usually the first elements to fail in an earthquake and are a risk to people in a zone extending well outside the perimeter of the building.

The following is a general overview of common seismic deficiencies in URM structures:

Overall strength

Provided URM building elements are adequately tied together, the global strength of URM buildings is dependent on the in-plane shear capacity and the out-of-plane bending capacity of the walls. If these are found to be deficient, strengthening of existing elements or adding new lateral-force resisting elements will be required to cope with horizontal shear.

Overall stiffness

URM bearing walls are generally quite rigid. This leads to a structural system that has a low fundamental period of vibration, with higher seismic forces and lower displacements when compared to a tall flexible structure. In some buildings however, facades facing the street can be highly punctured with relatively narrow piers between openings. In addition to lacking strength, these wall lines may also be flexible, which can result in increased displacements and collapse.

Configuration

URM buildings vary substantially in structural layout. Buildings such as churches, which have irregular plans, tall storey heights, offset roofs, few partitions and many windows are particularly vulnerable. Many commercial URM buildings will have a fairly open street façade at ground level, resulting in a weak storey and torsional irregularity.

Load path

One of the most significant deficiencies in URM buildings is the lack of adequate ties between walls and floor diaphragms. Diaphragms (or floors) act as a mechanism for seismic loads to be distributed to lateral load resisting elements. Robust connections prevent forces becoming concentrated on one wall. Connections may also be used to reduce unrestrained wall heights, which increases their out-of-plane bending capacity. Older buildings that have not been maintained will have reduced material strengths due to weathering, corrosion and other processes which weaken mortar joints and connection capability. The "redundancy" of a building refers to the alternative load paths that are able to add to resistance. The ability to redistribute demands through a secondary load path is an important consideration as an earthquake-prone building with low redundancy will be susceptible to total collapse in the event of only one of its structural elements failing. Secondary load paths should be provided to increase the building's resilience.

Component detailing

URM buildings do not comply with modern ductile detailing requirements. Buildings designed to current codes have the ability to withstand loads past the design ultimate limit state, whereas URM buildings will generally fail at or even below the lateral loads they were designed for originally (due to deterioration). Walls can be undesirably slender (comparing thickness to height of wall) with large spans between supports, making the walls susceptible to out-of-plane failures. Cavity walls are vulnerable as the steel ties connecting the exterior wythes to the backing wall can be weakened by corrosion. Bracing of walls, parapets and chimneys is essential in strengthened buildings.

Diaphragm deficiencies

Diaphragms in URM buildings are usually floors constructed of wood and may lack both strength and stiffness. Diaphragms are essential for tying the building together and ensuring the lateral loads are transferred to the lateral load resisting elements, such as walls. If diaphragms are too flexible then their ability to do this will be compromised. Large displacements of these diaphragms can also lead to wall failures.

Foundation deficiencies

Differential settlement, liquefaction and lateral spreading will all have detrimental effects on URM buildings.

Material properties

Observations in the Ingham and Griffith reports based on what was observed in the Canterbury earthquakes indicate that in general, walls of URM buildings are made of weak mortar and strong bricks. Bricks that had fallen from considerable height had not fractured and were in reasonably good order, whereas the mortar could be crushed simply under finger pressure.

Vertical acceleration

The ground motions recorded in the CBD during the February earthquake had very high vertical components of acceleration due to the close proximity of the fault. In assessing the seismic performance of a number of URM buildings for the Royal Commission, Mr Peter Smith observed that the vertical acceleration temporarily reduced the gravity and compression forces in walls. This was particularly significant in the higher levels of the walls. The temporary reduction in this compression reduced the stability of the walls, which depended on gravity actions, and it reduced the pull-out strength of the ties that had been installed to restrain the walls and parapets.

5.3.1 Observed damage and modes of failure.

Based on the Ingham and Griffith reports, and the evidence we heard about the individual buildings discussed in section 4 of this Volume, we note that the Canterbury earthquakes resulted in common modes of URM building failure. We now describe these damage patterns and collapse mechanisms.

Parapet and chimney failures

A parapet is the vertical wall element that protrudes above the roofline. These, along with chimneys and ornaments, have little lateral load capacity and present the greatest hazard to life due to their location at height. Numerous unrestrained parapets, as well as some that had been strengthened, collapsed during the Canterbury earthquakes. If unrestrained, a parapet will act as a vertical cantilever that rocks at its base. Parapets were seen to fail around their roof line both inwards onto the buildings as well as outwards onto streets and public spaces. Before and after photographs of the building at 386–406 Colombo Street in Figures 85 and 86 illustrate that parapets were some of the most vulnerable, and generally the first, building elements to collapse.

Figure 85: 386–406 Colombo Street before the September 2010 earthquake (source: Ingham and Griffith)

Figure 86: 386–406 Colombo St after the February 2011 earthquake (source: Ingham and Griffith)

Awning failures

Falling parapets tended to land on the awnings and verandahs, causing the overload of the supporting tension rods. These typically collapsed due to a punching shear failure at the anchorage into the wall above.

Wall and gable end failures

The failure of URM walls may be in-plane or out-of-plane or a combination of these two mechanisms.

Façades

The façades of commercial URM buildings invariably incorporate large openings for windows and doors to the street, which make these wall structures particularly vulnerable. The balance of the wall was mostly comprised of brick columns and arch lintels above windows. While providing adequate vertical support for roof, ceiling and wall members, there was often no robust connection between façades and building side walls, and the floor and roof diaphragms behind.

The evidence presented to the Royal Commission in the hearings about individual URM buildings that failed causing loss of life (discussed in section 4) also clearly demonstrated these failure modes. We considered 25 individual buildings or structures, but omit from this discussion the free-standing wall that collapsed at 90 Coleridge Street, the interior chimney that collapsed in St Albans and the spandrel panel that fell from the carpark building at 43 Lichfield Street. Of the 22 remaining buildings, 19 had weak walls. Eleven were cases where the façades failed and rotated outwards onto the street. In seven cases the side walls failed and collapsed onto an adjacent building or inwards on the building itself. The Durham Street Methodist Church was another building that had weak walls, and it collapsed completely.

We note that there is an extensive review of various failure modes for URM buildings in FEMA 306[11]. This is an important reference source for those needing to assess buildings and design strengthening measures. We address these subjects in section 6 of this Volume.

5.4 Some conclusions

(a) URM buildings depend on gravity load for their stability. Ground motion can temporarily reduce this load and hence the buildings' stability. The Canterbury earthquakes have shown that high accelerations can occur in the region close to faults. Consequently, where fault lines are close to or suspected to be close to CBDs, allowance should be made for the likely high ground accelerations in an earthquake.

(b) The majority of the deaths and injuries caused by the failure of URM buildings in the February earthquake occurred when building façades collapsed onto adjacent footpaths and roads. The Royal Commission considers that in a situation where there are limited resources it is logical to provide a greater level of protection against collapse of elements that threaten the public than to the buildings as a whole.

(c) If the Ingham and Griffith figures are adjusted to reflect the fact that the shaking level in the February earthquake was between 1.5–2 times the design level, it may be observed that a retrofit level of 33% NBS gives a marked improvement against collapse or major damage to a building, compared with retrofit between 0 and 33% NBS. On this basis it appears the minimum retrofit to 33% NBS could be maintained as an appropriate level for the building as a whole.

References

1. Excluding the PGC and CTV buildings and the death of an infant caused by an internal exposed brick chimney breast collapsing, the majority of other fatalities (39 out of 41) were caused by typical unreinforced masonry buildings failing in some way. The other two deaths were caused by a free-standing concrete block wall collapsing onto the victim, and a concrete spandrel falling onto the victim's vehicle.

2. Ingham, J.M. and Griffith, M.C. (August 2011). *The Performance of Unreinforced Masonry Buildings in the 2010/2011 Canterbury Earthquake Swarm: Report to the Royal Commission of Inquiry*. Christchurch, New Zealand: Canterbury Earthquakes Royal Commission.

3. Ingham, J.M. and Griffith, M.C. (October 2011). *The Performance of Earthquake Strengthened URM Buildings in the Christchurch CBD in the 22 February 2011 Earthquake: Addendum Report to the Royal Commission of Inquiry.* Christchurch, New Zealand: Canterbury Earthquakes Royal Commission.

4. See section 2 of Volume 1 of this Report.

5. NZS 1170.5:2004. *Structural Design Actions, Part 5: Earthquake Actions – New Zealand*, Standards New Zealand.

6. Turner, F. (2011). *Review of "The Performance of Unreinforced Masonry Buildings in the 2010/2011 Canterbury Earthquake Swarm".* Christchurch, New Zealand: Canterbury Earthquakes Royal Commission.

7. B. Lizundia, Rutherford and Chekene. Letter to J. Gilliland, Executive Director, Canterbury Earthquakes Royal Commission, 30 September 2011.

8. New Zealand Historic Places Trust. (2012). *Heritage Buildings, Earthquake Strengthening and Damage: The Canterbury Earthquakes September 2010–January 2012: Report for the Canterbury Earthquakes Royal Commission.* Christchurch, New Zealand: Canterbury Earthquakes Royal Commission.

9. Rutherford and Chekene. (2006). *Techniques for the Seismic Rehabilitation of Existing Buildings* (FEMA 547/2006 Edition). Washington D.C., United States of America: Federal Emergency Management Agency.

10. Examples include Rutherford and Chekene. (2006). *Techniques for the Seismic Rehabilitation of Existing Buildings* (FEMA 547/2006 Edition). Washington D.C., United States of America: Federal Emergency Management Agency. And Rutherford and Chekene. (1990). *Seismic Retrofitting Alternatives for San Francisco's Unreinforced Masonry Buildings*. San Francisco, California, United States of America: Author. And Federal Emergency Management Agency. (2004). *Primer for Design Professionals: Communicating with Owners and Managers of New Buildings on Earthquake Risk* (FEMA 389). Washington D.C., United States of America: Author. And Applied Technology Council. (2009). *Unreinforced Masonry Buildings and Earthquakes: Developing Successful Risk Reduction Programs* (FEMA P-774/October 2009). Washington D.C., United States of America: Federal Emergency Management Agency.

11. Applied Technology Council. (1998). *Evaluation of Earthquake Damaged Concrete and Masonry Wall Buildings; Basic Procedures Manual* (FEMA 306). Redwood City, California, United States of America: The Partnership for Response and Recovery.

Note that Standards New Zealand was previously known as the Standards Institute of New Zealand.

Section 6: Assessing and improving the seismic performance of existing buildings

6.1 Introduction

Assessing and strengthening existing buildings is a complex task that requires specialist skills and experience. Buildings of different types and ages must be considered, which adds to the complexity. This section will discuss the assessment process and also address techniques for strengthening, and the costs involved, drawing on understanding developed both in New Zealand and overseas.

Except in passing, we do not cover here the post-earthquake inspection of buildings, which will be dealt with in Volume 7 of the Report. The present focus is on assessments carried out in anticipation of possible future earthquakes. Such inspections are designed to ensure that the likely performance of buildings is understood, and strengthening works appropriate to enhance a building's performance are able to be carried out.

6.2 Assessing the potential seismic performance of buildings

6.2.1 New Zealand Society of Earthquake Engineering Guidelines

It is important to have agreed procedures for evaluating the seismic resistance of existing buildings. Their purpose is to determine the susceptibility of buildings to damage from earthquakes, and to devise and implement structural improvements that will bring the buildings up to or above a predetermined minimum level. Evaluation of an existing structure requires not only knowledge of the current design standards but also an understanding of the potential limitations that older buildings have. These include material properties, methods of construction, and potential weakness in structural form. It is also necessary to consider the different levels of design strength and ductility associated with previous design standards.

For present purposes, it is possible to divide structural assessments into two broad types: those that are carried out to assess the strength of buildings in the event of a future earthquake and those that are carried out after an earthquake. However, there are many similarities and some overlap between these types of assessments. The terminology currently in use is shown below.

Table 1: Broad types of structural assessments of buildings

Building assessments for future earthquakes	Building assessments post-earthquake
Initial Evaluation Procedure (IEP)	Overall Damage Survey or Initial Assessment
Desktop Study	Rapid Assessments (Levels 1 and 2)
Detailed Assessment	Detailed Engineering Evaluation (DEE)

6.2.1.1 Building assessments post-earthquake

In the immediate aftermath of a major earthquake, Initial and Rapid Assessments are used as a basic sifting method for identifying the worst of the immediate hazards. The New Zealand Society for Earthquake Engineering (NZSEE) has prepared guidelines for territorial authorities in the document *Building Safety Evaluation During a State of Emergency: Guidelines for Territorial Authorities*[1] published in August 2009, which sets out a process of structural safety evaluations of damaged buildings. For a Rapid Assessment, inspectors do a quick visual evaluation of the type and extent of a building's structural damage, and on that basis are able to post a green (inspected), yellow (restricted use) or red (unsafe) placard. Rapid Assessments are initially Level 1 (external only) followed by Level 2 (where appropriate), which involves both external and internal visual inspection. The percentage of New Building Standard (% NBS) is not calculated in this process.

In the disaster recovery phase a Detailed Engineering Evaluation (DEE) may be required. In draft guidance from the former Department of Building and Housing, a DEE is defined as:

> A review of the building design, construction, and how the building has performed in recent earthquakes to understand its potential performance in future earthquakes and to determine what repair or strengthening is required to bring it into a satisfactory level of compliance or to simply improve its future performance.

The DEE is a similar assessment to a Detailed Assessment (discussed below) with the difference being that there is an assessment of the effects of the damage caused by one or more earthquakes. A percentage of NBS may be calculated in this process.

6.2.1.2 Building assessments for future earthquakes

The assessment of a building's performance in possible future earthquakes can be carried out by various methods. The recommendations of a NZSEE Study Group on earthquake risk buildings are embodied in *Assessment and Improvement of the Structural Performance of Buildings in Earthquakes*[3], dated June 2006, which we will refer to as the NZSEE Recommendations. This document contains the most recent methodology being used by the engineering profession in New Zealand.

The NZSEE Recommendations were developed to assist engineers because the processes used to assess the structural performance of a building in an earthquake are different from the processes used when designing buildings. The Recommendations suggest that the assessments should only be carried out by a chartered professional engineer with experience in earthquake engineering. We note that the Recommendations have no regulatory standing and there is no formal monitoring of practices in assessing existing buildings.

The NZSEE Recommendations describe two levels of assessment. The first is an Initial Evaluation Process (IEP) and the second a Detailed Assessment.

6.2.1.2.1 Initial Evaluation Process (IEP)

The IEP provides an approximate assessment of likely performance of a building in an earthquake. It is intended to be a coarse screening involving as few resources as reasonably possible to identify potentially high risk (or earthquake-prone) buildings. The objective of the IEP is to identify, with an acceptable level of confidence, all high risk buildings. At the same time the process must not catch an unacceptable number of buildings that would, on detailed evaluation, be outside the high risk category. It is expected that those carrying out the IEP would be New Zealand Chartered Professional Engineers with a background of experience in the design of buildings for earthquakes or in possession of some specific training. The IEP is designed as a largely qualitative process involving considerable knowledge of the earthquake behaviour of buildings and judgement as to key attributes and their effect on performance.

The procedure to be followed in an IEP is described in detail in the NZSEE Recommendations. Broadly, it comprises the following steps:

Step 1: Gathering general information on the building, for example photos, a rough sketch of the building plan, a list of any particular features that would be relevant to the building's seismic performance and a list of information sources used to complete the assessment.

Step 2: Calculating the baseline percentage new building standard $(\%\ NBS)_b$. This involves, first, calculating the nominal % NBS. The $(\%\ NBS)_{nom}$ is a general measure of the performance (with respect to requirements for a new building, NZS 1170.5:2004[4]) of a particular building in a given location, assuming it is well-designed, of regular form, with no critical structural weaknesses and complying with the relevant code provisions at the time it was built.

The $(\% \text{ NBS})_b$ modifies this nominal value to account for assessed ductility, location (hazard factor and near fault factor) and occupancy category (i.e. the appropriate return period factor) but again assumes a good structure complying with the code current at the time when it was built.

Step 3: Calculating the Performance Achievement Ratio (PAR), which may be regarded as the ratio of the performance of the particular building, as inspected, in relation to "a well-designed and constructed regular building of its type and vintage on the site in question". This step takes into account structural weaknesses such as irregularities, short columns, poor site characteristics, potential for pounding by neighbouring structures and other factors.

Step 4: Calculating the percentage of new building standard (% NBS) by multiplying the assessed baseline by the PAR. This is done for the longitudinal and transverse directions of the building and the lower of the two values is used.

Steps 5, 6 and 7: These steps involve marking the percentage of NBS buildings as "Potentially Earthquake-Prone" if the percentage of NBS is less than 33 or as "Potentially an Earthquake Risk" if less than 67. The final step is assigning a provisional Seismic Grade for seismic risk.

For unreinforced masonry buildings (generally built prior to 1935) an attributed scoring process is suggested as an alternative to Steps 2 and 3 above, given that these buildings are generally not designed to resist earthquakes. The percentage of NBS is then determined directly from the total attributed score.

6.2.1.2.2 Detailed assessment

The IEP described above provides only an approximate assessment of a building's likely performance in an earthquake. Detailed assessment procedures are intended to provide a more accurate assessment of the performance and validate the status of a high risk, potentially earthquake-prone building. The NZSEE Recommendations state that:

> They allow the engineer to look in more detail at the characteristics of the building, its response to earthquake shaking, the demands it places on structural elements, and the capacity of such elements to meet those demands by maintaining structural integrity under imposed actions and displacements.
>
> The focus is the determination of demand on structural elements, resulting from the response of the building, and assessment of the capacity of such elements to meet the demand without causing loss of structural integrity.

Engineers might use a variety of models, approaches, and analytical tools to assess this performance and are advised to carry out a full inspection of the building as part of their Detailed Assessment. The NZSEE Recommendations detail what should be included in this inspection. Given that an existing building's unique demands and capacities must both be calculated, the assessment inevitably takes more effort and time to determine the level at which Ultimate Limit State (ULS) will be reached, compared to an IEP.

Both the IEP and detailed assessment procedures result in a percentage of NBS being assigned to a building.

6.2.2 Grading systems

6.2.2.1 NZSEE grading system

The NZSEE Recommendations recorded the NZSEE's proposal that a grading system be introduced for buildings to reflect their assessed structural performance. The grading system proposed was set out in the Recommendations. It envisaged buildings being graded in bands from A+ to E. It was linked to the percentage of NBS value, and the Standards current at the time the building was built. Indications were given of the relative risk of the strength and/or deformation capacities of the building being exceeded over the life of the building. Grades D and E were for buildings classified as high risk: buildings with critical structural weaknesses would commonly fall within these two grades.

The Royal Commission understands that the uptake of this grading system has been low. It is not clear why this is the case. Such a system would avoid the misleading degree of accuracy implied when a percentage of NBS is stated (see section 6.2.4 below).

6.2.2.2 The Structural Engineers Association of Northern California Earthquake Performance Rating System (EPRS)

The Structural Engineers Association of Northern California[5] (SEAONC) has been developing an Earthquake Performance Rating System (EPRS) since 2006, which utilises existing evaluation methodologies and translates results into a format that may be more easily understood. In SEAONC's view, the objective of a methodology for rating the earthquake performance of buildings is to communicate seismic risk to non-engineers. We agree with that observation. The ultimate goal is for the rating system to spur action that will reduce seismic risk in the overall building inventory.

The SEAONC EPRS uses a scale of 1 to 5 stars and separately considers three dimensions: Safety (death, injuries and entrapment), Repair Cost (dollars), and Time to Regain Function (downtime). Descriptions of each star rating value are provided in Table 2. The EPRS has the aim of assessing both new and existing buildings in consistent terms to help address questions of interested non-engineers, who typically seek to contrast one building with another. The SEAONC EPRS does not predict precise numerical values; rather, it assigns a rating category based on definitions and expectations stated by the underlying evaluation methodology.

Rating	Safety
★★★★★	Building performance would not lead to conditions commonly associated with earthquake-related *entrapment*.
★★★★	Building performance would not lead to conditions commonly associated with earthquake-related *injuries*.
★★★	Building performance would not lead to conditions commonly associated with earthquake-related *death*.
★★	Building performance in select locations within or adjacent to the building leads to conditions known to be associated with earthquake-related *death*.
★	Performance of the building as a whole leads to conditions known to be associated with earthquake-related *death*.

Rating	Repair cost
★★★★★	Building performance would lead to conditions requiring earthquake-related repairs commonly costing less than 5% of the building replacement value.
★★★★	Building performance would lead to conditions requiring earthquake-related repairs commonly costing less than 10% of the building replacement value.
★★★	Building performance would lead to conditions requiring earthquake-related repairs commonly costing less than 20% of the building replacement value.
★★	Building performance would lead to conditions requiring earthquake-related repairs commonly costing less than 50% of the building replacement value.
★	Building performance would lead to conditions requiring earthquake-related repairs costing more than 50% of the building replacement value.

Rating	Time to regain function
★★★★★	Building performance would support the building's basic intended functions within *hours* following the earthquake.
★★★★	Building performance would support the building's basic intended functions within *days* following the earthquake.
★★★	Building performance would support the building's basic intended functions within *weeks* following the earthquake.
★★	Building performance would support the building's basic intended functions within *months* following the earthquake.
★	Building performance would support the building's basic intended functions within *years* following the earthquake.

Table 2: SEAONC definitions for star rating values for each of the three dimensions (source: SEAONC, 2011)

SEAONC acknowledges that a successful risk reduction programme is multidisciplinary, and states that the biggest challenges to earthquake risk reduction are not in engineering, but in finance, policy and regulation. The most effective rating system would be one that:

- fills existing knowledge gaps;
- leverages the interests of motivated stakeholders;

- does not mandate implementation without the needed resources; and
- involves minimal logistical costs to implement and regulate.

One challenge identified by SEAONC is that many owners of existing buildings do not want them to be given a seismic rating, and definitely do not want to pay for it. Market forces have been identified as a way to drive demand. It was envisaged that from the outset, the rating system would first be adopted by building owners, or "sellers", who would benefit from it (for example, developers who have just incurred significant expenditure to meet current seismic standards and are competing for tenants against older buildings that do not measure up, as well as major tenants who want information on downtime and risk to life and contents), and only later by "buyers" who request ratings in order to make comparisons between buildings. The system described above is specific to American practices and would need to be developed further to align with current evaluation procedures before being applied in New Zealand.

6.2.2.3 Discussion

We consider that providing a form of grading system that is more easily understood by territorial authorities, building owners, tenants and the general public would be highly beneficial. We consider that an appropriate grading system should be developed by the Ministry of Business, Innovation and Employment in consultation with territorial authorities, building owners, NZSEE, and other interested parties. Such a grading system could be based on or similar to that already set out in the NZSEE Recommendations, using letter grades A to E. The advantage of this form of grading system is that the general public are familiar with such grades and could more easily understand that a D or E grade would indicate a building that poses a clear earthquake risk. Conversely, buildings receiving higher grades may be able to attract higher rental returns and/or lower insurance premiums.

We note that, unlike the SEAONC rating system, the NZSEE grading system focuses on issues of life safety, and does not extend to considerations of repair cost and time to regain function. Concentration on life safety would make the grading system simpler to apply, and we expect that such a grading system would respond to the main emphasis of public concern about the seismic performance of buildings.

6.2.3 Practice in assessing the potential seismic performance of buildings

Knowing how buildings behave in earthquakes, how to identify the key elements of buildings, how to judge the way these elements are likely to perform in an earthquake and the threat that the failure of these elements poses to life requires considerable engineering judgement. Firms use a range of analysis software and modelling techniques, including hand calculations.

The Royal Commission sought information from engineering firms about the practice of assessing likely structural performance of buildings in an earthquake. Responses were received from OPUS International Consultants, Beca Carter Hollings & Ferner Ltd (Beca), and Sinclair Knight Merz. These responses indicate that although firms' methodologies and analytical tools are likely to be based on the NZSEE Recommendations[3] discussed above, and may be consistent within individual firms, there may be less consistency between different firms, resulting in potentially varying levels of assessment of individual buildings across New Zealand's building stock.

There are several reasons why assessments could vary within the industry. The NZSEE Recommendations have no regulatory standing, meaning there is no compulsion for them to be followed. There is no monitoring of the practice of assessing buildings to identify inconsistencies and address these, or to ascertain whether the NZSEE Recommendations are being followed. Assessing existing buildings, across a range of building types, requires knowledge and experience of each building type, and the standards or practices followed when the building was designed and constructed. Engineers are dependent on the quality of the plans and documentation they receive when judging the likely performance of a building. If the plans are inaccurate or incomplete, then the assessment will be inaccurate; for example, plans may not necessarily reflect how the building was actually constructed or altered. Given the age of some buildings, especially unreinforced masonry (URM) buildings, plans are also likely to only be available in paper form in council files (if at all). In carrying out assessments, engineers are therefore hampered by both the lack of ease of access to records and the inadequacy of many records when available.

Difficulties are experienced in judging how well an element will perform when it does not fully satisfy current design criteria. Guidance is required on details that are frequently encountered.

For example: the inelastic deformation capacity of plastic hinges in reinforced concrete beams where reinforcement is not fully constrained against buckling; beam column joints that do not contain the specified amount of joint zone reinforcement; or columns that are not confined to the level specified in current Standards. We recommend that research be undertaken so that guidelines can be produced on how such details can be assessed in a consistent manner.

The evidence given to the Royal Commission showed that there are inconsistencies in building assessment practice. It is clearly important that a degree of consistency occurs, given:

a) the result of an assessment may lead to a building being classified as earthquake-prone under the Building Act 2004 and therefore placing a requirement on the owner to undertake certain actions, at their cost; and

b) such assessments may be an important factor in decisions about a building's viability or tenancy.

Consistency and quality in building assessments could be achieved through the NZSEE Recommendations being given regulatory standing, and some monitoring being undertaken of their implementation. We note however that we propose that the NZSEE Recommendations be reviewed (Recommendation 72).

6.2.4 Issues with the term "new building standard" (NBS)

6.2.4.1 Introduction

Under the Building Act 2004 buildings are classified as earthquake-prone if they are unable to withstand a moderate earthquake. As discussed in section 2 of this Volume, the term "moderate earthquake" is defined in the Building (Specified Systems, Change the Use, and Earthquake-prone Buildings) Regulations 2005 as an earthquake that would generate shaking at the site of the building that is of the same duration, but 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 on that site. We note that the emphasis is on the level of shaking and its duration. Neither the Act nor the Regulation draws a comparison with the performance of a new building.

Both territorial authorities and the structural engineering profession have adopted the acronym NBS when assessing the potential seismic performance of an existing building. Expressions such as 100% NBS, 67% NBS and 33% NBS are increasingly used to describe the comparison between the seismic resistance of an existing building with that of a new building at its ULS.

We think it is likely that most non-engineers would assume that an existing building (be it of unreinforced masonry or built in accordance with Standards previously in force) assessed as 100% NBS, in accordance with the methodologies set out in the NZSEE Recommendations, would have a seismic performance equal to that of a new building built to current design standards. However, this is misleading, because in an earthquake that exceeded the design earthquake for the ULS, the existing building would be likely to collapse before a new building. We explain this further in the following sections, dealing respectively with reinforced concrete and unreinforced masonry buildings.

6.2.4.2 Reinforced concrete buildings

The NZSEE Recommendations state that "in determining the strength and deformation capabilities of an existing component, calculations shall be based on the probable values of strengths of materials in the buildings". This is different from the design of a new building where factors of safety are built into the design criteria to ensure that the specified performance can be met with a very low probability of failure. Using probable strengths and focusing on satisfying just the ultimate limit state requirements eliminates the conservative assumptions in both strength and deformation capacities.

In the design of a new structure, design strengths are used, and materials Standards specify material strain limits. The intention behind the use of conservatively assessed design strengths and material strain limits is to ensure, given material variability, that:

- an earthquake with an intensity equal to that considered for the design ultimate limit state can be sustained with a very high level of certainty (a very low probability of failure); and
- there is a margin of safety against collapse for an earthquake with a magnitude of shaking 1.5 times that of the design level earthquake.

In NZS 3101:2006[6] it has been assumed that the ratio of displacement ductility required for a 2500-year return period earthquake is 1.5 times that corresponding to a 500-year return period earthquake.

In NZS 1170.5:2004[4] the corresponding ratio (which is based on analyses in which elastic perfectly plastic hysteretic response was assumed) is given as 1.8. However, the elastic perfectly plastic assumption is not realistic for reinforced concrete. Using a more realistic hysteretic rule, in which strain hardening is accounted for and energy dissipation in small displacement cycles is induced, reduces the ductility demand. Allowance for these factors led to the 1.5 factor being used in NZS 3101:2006[6].

The difference in likely seismic performance of a building that is assessed on the basis of probable (average) strengths when compared to a new building, which is designed using design strengths, can be gauged from the average ratio of probable to design strengths.

The design strength of a section is taken as strength reduction factor times a theoretical strength, which is based on the assumption that the reinforcement and concrete both have their lower characteristic strengths. The average (probable) strength of reinforcement specified for use in potential plastic regions is 1.08 times the lower characteristic strength and the probable strength of concrete is generally taken as 1.5 times its specified strength. The use of these two strength ratios results in the probable strength of a section typically being 1.1 times the theoretical strength. Allowing for the strength reduction factor, which is taken as 0.85 for flexure, with or without axial load, gives a ratio of probable to design strength of $^{1.1}/_{0.85}$ that is approximately equal to 1.3.

For a building with an importance level of 2 the factors of safety inherent in the design of a new reinforced concrete building are intended to give the building probable strength and deformation capacities to enable the structure to survive a 2500-year return period earthquake without collapse. Assessment of a building given a classification of 100% NBS implies that it has probable strength and deformation capacities for the ultimate limit state earthquake with a return period of 500 years. On this basis the building with 100% NBS in which deformation is the limiting factor is five times as likely to reach its critical limiting deformation condition as a building designed to current design standards. If strength is critical rather than deflection, a building with 100% NBS is twice as likely to sustain the limiting conditions as a new building.

Table 3 below indicates the ratio of the number of times a critical condition may be reached in a building with a given percentage of NBS when it is compared to new building built to current design standards. This may be considered as a measure of the relative risk. Two ratios are given, one based on deformation and one based on strength. These values have been assessed from the ratios of earthquake return factor, R, to return periods given in NZS 1170.5:2004[4]. It is emphasised that these values are approximate and they are intended only to indicate the order of magnitude of relative risk.

% NBS	Deformation critical	Strength critical
100	5	2
67	12	5
33	50	21
20	125	50

Table 3: Ratio of number of times a critical condition is reached in an existing building with a given % NBS to a new building designed to current standards (relative risk)

6.2.4.3 Unreinforced masonry

The NZSEE Recommendations[3] propose that unreinforced masonry is assessed assuming that the masonry has 15% damping. Modifying the response spectrum for this level of damping reduces design accelerations and displacements to 65% of the corresponding values assumed in standard force-based design where 5% damping is assumed.

A more recent publication based on research at The University of Auckland[7] recommends that a displacement ductility of 2, together with a S_p factor of 0.7, should be used for unreinforced masonry elements. Where the period is not known, it was recommended that the k_u factor is taken as 1.2. Using these values the design response spectra are reduced to 58% of the standard 5% damped elastic response spectra. The justification given for this reduction is that URM structures behave in a non-linear mode, and they dissipate energy by rocking and sliding of bricks. We note that NZS 4230:2004, *Design of Reinforced Concrete Masonry Structures*[8], specifies that concrete masonry structure walls with minimum reinforcement would be designed as elastically responding with a structural ductility factor of 1 and an S_p factor of 1. In this case there would be no reduction in the standard 5% damped elastic spectra. The two sets of values for URM and concrete masonry structures are in sharp contrast with the lower strength and deformation demands being assumed in the assessment of unreinforced masonry structures, which have poorer and less defined material properties. This seems questionable. We consider that further study is required to justify this difference.

The reduction in design actions in URM structures is based on the results of tests on walls subjected to in-plane pseudo-static (see C4.3.2A in The University of Auckland's recent research publication[7]). Given the requirement for slip and rocking of masonry units within the walls, which is required to provide the damping, the question arises as to the effect of this disruption in the wall on the structural performance for out-of-plane actions, which will always be present in earthquakes. Furthermore, URM walls depend on gravity loading for their strength and for energy dissipation by sliding. Clearly the resistance associated with gravity loading could be appreciably modified by vertical ground motion, especially for masonry units near the top of a structure.

We consider that the recommendations for either the use of 15% damping, or the assumption of a structural ductility factor of 2 and an S_p factor of 0.7 for use with unreinforced masonry elements, should be treated with caution in assessing the percentage of NBS for an URM building. We expect that the relative risk of an URM building assessed as 100% NBS would be considerably greater than 5 when compared to a new building designed to current standards. We consider this is an area that requires more research, particularly for masonry members subjected simultaneously to in-plane and out-of-plane actions.

6.2.4.4 Conclusion

The Royal Commission considers that the present use of "33% NBS" conveys an incorrect expectation that the performance of a building in an earthquake is at 33% (or other nominated figure) of the capacity of a new building. This confusion was reported in and apparent from the evidence given at the Royal Commission's hearing into earthquake-prone buildings in November 2011. We consider the use of the undefined term "NBS" should be avoided. For reasons we address in section 6.2.4.1, the proper comparison is in fact with that of a new building at its ultimate limit state (ULS) and use of "% ULS" instead of "% NBS" would avoid the implication that the existing building's performance would match that of a new building. In the balance of this Volume, we use the term "% ULS" accordingly.

We consider that the Ministry of Business, Innovation and Employment should clearly describe to territorial authorities and the public the difference between the expected behaviour of an existing building built under previous standards or codes prior to collapse and the behaviour of a building which complies with the current Building Code.

6.2.5 Practical assessment considerations

In section 2 of this Volume we discussed the evolution of seismic design standards that has taken place in New Zealand since 1935. Against that background, we now note some matters that we consider should be taken into account in an assessment of the potential seismic performance of buildings designed to standards in force earlier than those which currently apply.

An initial step is to consider the differences in design strength and the ductility provisions that have been introduced between the time the building was designed and the current design standards were written. Fenwick and MacRae[9], and MacRae et al.[10] record these changes. Knowledge of the changes in design practice gives a guide to aspects of the structure that need to be studied closely.

6.2.5.1. Allowing for flexural cracking

The reduction in section properties that is made to allow for flexural cracking in reinforced concrete structures can make a significant difference to the calculated periods of vibration of buildings as well as the inter-storey drift levels. In assessing the seismic performance of buildings it is important that allowance is made for this effect. Table 4 below gives typical values assessed from the different recommendations for moment resisting frames and structural walls. The values given for the frames are weighted average values based on recommended stiffness values for beams and columns.

Year	Code Standard	Moment resisting frames	Structural walls
1965	NZSS 1900	1.0	1.0
1976	NZS 4203	0.75	0.75
1982	NZS 3101	0.67	0.5
1995	NZS 3101	0.43	0.3
2006	NZS 3101	0.43	0.3

Table 4: Recommended section properties for seismic analyses given as a proportion of gross section properties (source: Fenwick and MacRae, 2009, and MacRae et al., 2011)

6.2.5.2 Allowing for accidental torsion

In NZS 4203:1976[11] allowance was made for accidental torsion introduced into buildings due to torsional ground motion and the possible non-uniform distribution of live-load in the building. This effect was allowed for by requiring the calculated distance between the centre of mass and the calculated centre of lateral stiffness to be increased by a distance of one-tenth of the width of the building. This allowance has been maintained in all subsequent loading Standards.

6.2.5.3 Calculating inter-storey drifts

When assessing the inter-storey drift capability of an existing building in terms of current design standards it is essential to allow for a number of major changes that have occurred in the last two decades. These changes are briefly outlined below and further details are given in Fenwick and MacRae, and MacRae et al.

In NZS 4203:1976[11] and 1984[12] the design seismic forces were determined from the design response spectrum that was divided by the factor $^{4}/_{SM}$ to allow for the reduction in design forces associated with ductile behaviour. This reduction was equivalent to assuming the structure had a displacement ductility, $\mu = {}^{4}/_{SM}$. The equal displacement concept implies the resultant deflection is equal to μ times the elastic deflection induced by the design forces. However, in the design Standards the design displacement scaled to allow for inelastic deformation was defined as the elastic deflection times $^{2}/_{SM}$ for the equivalent static method and $^{2.2}/_{SM}$ (in NZS 4201:1984) for the modal response spectrum method. In effect the design displacement was being taken as 50% and 55% of the predicted peak displacement for the equivalent static and modal response spectrum methods respectively. Where stairs or ramps are connected at different levels of a building it was essential that allowance was made for the peak inter-storey drifts and for these elements the design inter-storey drifts were doubled.

In NZS 4203:1992[13] and NZS 1170.5:2004[4] the design inter-storey drift was taken as the structural performance factor, S_p, times the peak displacement based on the equal displacement concept. To this displacement an allowance was added to allow for the additional inter-storey drift associated with P-delta actions. The S_p factor for ductile structures was taken as 0.67 in NZS 4203:1992[13] and 0.7 in NZS 1170.5:2004[4]. Where peak values are required for the design of stairs or ramps the design displacement should be divided by S_p though this correction is not given in the design Standards. (We have previously recommended that the design displacement for stairs is further increased so that there is a safe means of egress in the event of an earthquake with an unusually high intensity of shaking.)

In buildings where the lateral resistance is provided by structural walls, multiplying the elastic drift by the structural ductility factor can appreciably under-estimate the inter-storey drifts in the lower levels of a building. This arises as the inelastic deformation is associated with the formation of a plastic hinge near the base of the wall. This discrepancy is illustrated in Figure 87 and it arises as the inelastic deformation is not spread over the height of the building, as is the case in a ductile moment resisting frame structure. In NZS 4203:1992[13] and NZS 1170.5:2004[4] this discrepancy was removed by requiring the critical inter-storey drifts to be based on the greater of the drifts found, by multiplying the elastic inter-storey drift by the structural ductility factor, or by the value found from the equivalent of a pushover analysis. In interpreting inter-storey drifts in structural wall buildings designed to Standards prior to 1992, it is important to make allowance for this discrepancy.

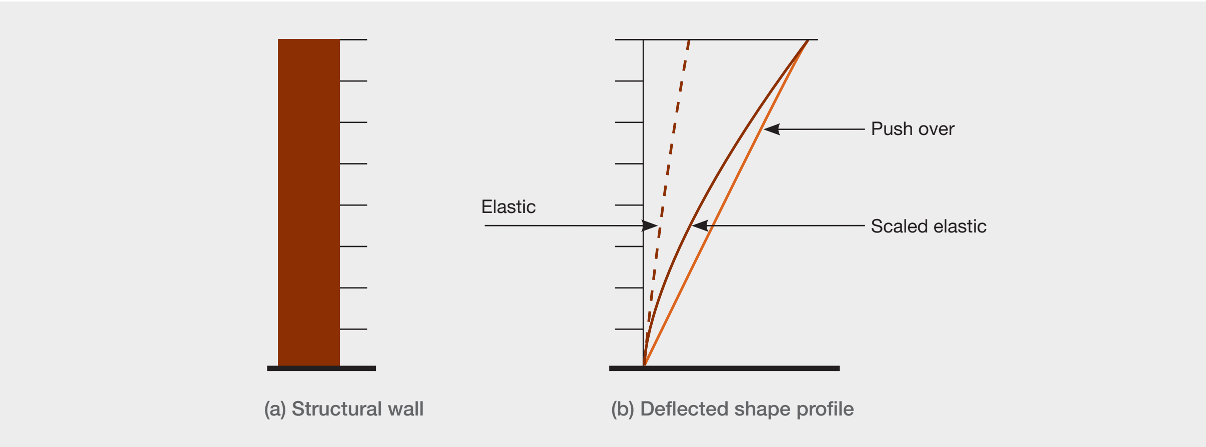


Figure 87 : Difference between push over and scaled elastic deflected shapes

Peak inter-storey drifts predicted by inelastic time history analyses are found to be appreciably higher than the corresponding values predicted from equivalent static and modal response spectrum methods. Figure 88 illustrates the difference that has been observed. To allow for this discrepancy a drift modification factor was introduced into NZS 1170.5:2004[4]. When assessing the performance of an existing building against current design criteria it is important to allow for the drift modification factor.

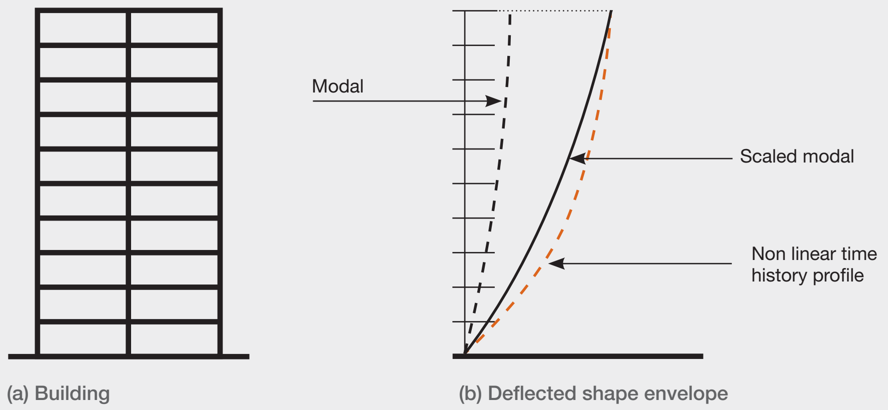


Figure 88: Drift modification factor

6.2.5.4 Allowing for P-delta actions

Allowance for P-delta actions was introduced into NZS 4203:1992[13]. For buildings where the seismic resistance is provided by ductile moment resisting frames the requirement to consider P-delta actions typically increases the lateral strength and inter-storey drifts by 30%. For structural walls the effect is smaller.

6.2.5.5 Confinement of columns

Prior to 1995 not all columns were required to be confined. The lack of confinement means that it is likely that some columns in existing buildings designed prior to 1995 will not be sufficiently ductile to sustain the inelastic deformation required by current design methods.

6.2.5.6 Load tracking and detailing of connections

In an assessment of an existing building the first step is to identify the load paths to ensure that inertial induced seismic forces have a logical load path so that the forces can be transmitted to the foundation soils. Each load path must satisfy the requirements of equilibrium and compatibility. Of particular concern are the parts of the load path that pass through the connections of different structural elements, such as occurs in beam-column joints. It is essential to ensure that there is a valid load path through the detail.

An example of load tracking though a structural steel junction is given in section 8.3 of Volume 2.

Figure 89 illustrates a case of a beam-column joint where there is no valid load path through the detail. The bottom reinforcement in the beam is anchored in the mid-region of the beam-column joint. To satisfy equilibrium, the flexural tension force in the beam reinforcement must be anchored at the location where the diagonal compression force through the joint meets the vertical compression force in the lower column. As drawn this requires the beam tension force to be resisted by tension in the concrete at the location marked by b. Once this concrete cracks in tension, equilibrium cannot be maintained and the cracks b-c and b-d will form and collapse will occur. If the beam reinforcement had been anchored on the far side of the joint zone from where it entered the column, the beam-column joint may have sustained a few load cycles before failure occurred. The addition of joint zone ties, preferably also with the addition of intermediate column bars, would have enabled a number of different load paths to be sustained through the detail, giving a more robust beam-column joint zone. The capacity of the joint zone to sustain inelastic load cycles is increased with the addition of joint zone ties and intermediate column bars.

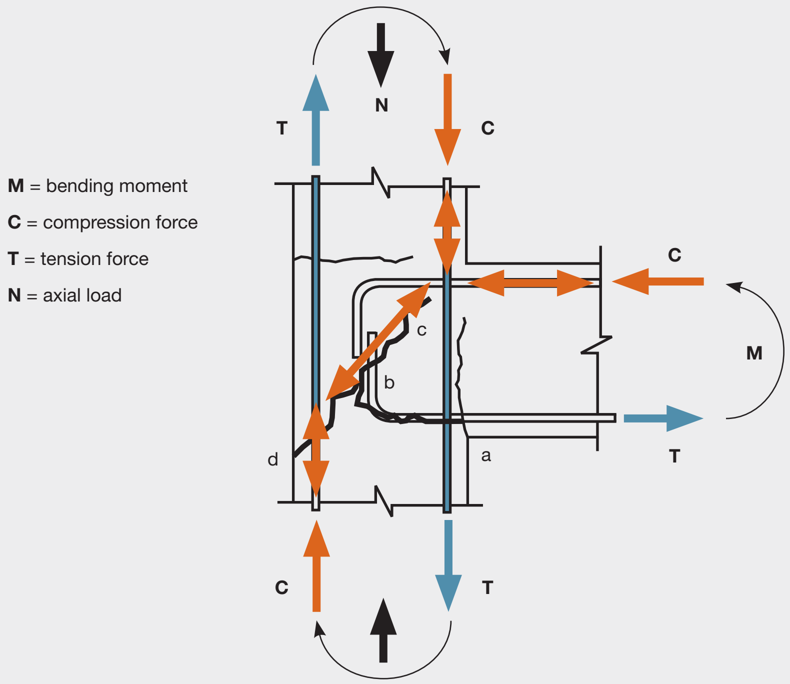


Figure 89: Inadequately detailed beam-column connection

6.2.5.7 Other factors

The Royal Commission's study of the representative sample of buildings highlighted a number of aspects of buildings that need to be considered in making an assessment of their potential seismic performance. The more important of these aspects are briefly described below, with greater detail given in Volume 2 of the Report.

In lightly reinforced structural elements such as walls and some beams it was found that only one crack formed and opened up creating high strains in the reinforcement. This was due to insufficient tension force being transmitted across the crack to induce secondary cracks in the wall. There were two main consequences. First, very high localised strains were induced in the reinforcement, which in some cases caused the reinforcement to fail. Secondly, the lack of flexural cracks meant that the wall was stiffer than assumed in the design, where allowance would have been made for the reduction in stiffness associated with flexural cracking. The consequence of this is that the building attracted higher seismic forces than indicated by the design calculations.

NZS 3101:1995[14] and NZS 3101:2006[15] do not have appropriate design criteria for moderately and heavily loaded walls, $N/A_g f_c' \geq 0.1$ and the assessment of these elements needs to be carried out with caution.

The formation of plastic hinges in reinforced concrete elements causes elongation to occur. This can have a number of adverse effects, which include:

- the formation of wide cracks in floor slabs that contain precast pretension units; and
- plastic hinges in coupling beams can push coupled walls apart. Where there are floors tied into the walls the restraint provided by the walls can increase the shear capacity of the coupling beams. In extreme cases this may cause the coupled wall to act as a single unit reducing its ability to dissipate seismic energy.

The formation of wide cracks in floors can result in the failure of non-ductile mesh. Where mesh is used to tie critical elements together, such as floors to structural walls, retrofit should be undertaken to provide a ductile connection.

Incompatible deformations of adjacent structural walls were found to cause local failures in adjacent elements, such as floors or beams that were tied into the walls.

Some structural elements such as L and/or T-shaped walls have a greater lateral strength in the forward direction of displacement than in the reverse direction. Under seismic actions this difference in strength can cause the element to ratchet in the weaker direction, thereby increasing the lateral displacement of the building.

Irregularities in plan and/or elevation can lead to concentrations of strain and displacement at certain locations in the building, which generally reduce the seismic performance of the building.

In a number of buildings built prior to the mid-1970s the perimeter columns were confined by deep spandrel beams or what was intended to be non-structural infill. However, this infill creates short columns that have frequently failed in shear.

Flexural torsional interaction in reinforced concrete members is not covered in the current Concrete Structures Standard, NZS 3101:2006[15]. It is postulated that this interaction may have reduced the seismic performance of a shear core that was subjected simultaneously to high flexural and torsional actions.

Particular care needs to be taken to identify irregularities in structural elements which sustain gravity loads and/or seismic actions. Such irregularities may take the form of offsets in structural walls or columns. Beams that are required to act as transfer elements also require careful consideration. Where these occur particular care is required to assess the limitations that these details impose on the seismic performance.

6.3 Techniques for and costs of retrofitting unreinforced masonry buildings

6.3.1 New Zealand experience

The Royal Commission obtained examples of seismically retrofitted buildings and costs from Beca Carter Hollings and Ferner Limited (Beca), and Opus International Consultants Limited (Opus). These are summarised in Appendix 1 to this Volume. These examples provided a description of the strengthening work undertaken, the associated costs and, for Christchurch buildings, how they performed in the Canterbury earthquakes.

The information showed that the techniques for retrofitting a building vary significantly depending on the size and complexity of the task. The main strengthening techniques used were:

- tie-back of gable walls and facades;
- façade retention;
- steel bracing;
- adding a layer of reinforced concrete to brick walls; and
- plywood diaphragms added.

The costs of the retrofits also varied significantly ranging from $430/m^2 for a relatively small, less complex project (such as façade retention) to $3600/m^2 for a complex project. Opus provided examples of buildings that had been strengthened and had performed well in the Canterbury earthquakes. These buildings were strengthened to 67% of the loadings Standards requirements for new buildings at the time of strengthening, at a cost ranging between 100% and 120% of a new replacement structure.

Holmes Consulting Group[16] conducted two studies in 2005 and in 2009 for the Christchurch City Council on the costs to upgrade heritage buildings. The Royal Commission requested an update of this information. The update[17] addressed the cost of upgrading all earthquake-prone buildings to 33% and 67% of Full Code Loading[18] (FCL). The update found that a reasonable average cost allowance for seismic strengthening is as follows:

- $500/m^2, (±30%) for 33% FCL; and
- $1250/m^2 (±30%) for 67% FCL.

In addition to these costs, allowance needs to be made for other costs such as repair, reinstatement and other required upgrades. The Royal Commission notes that the examples of buildings provided are for structures of note or community importance. They may not be representative of a more general pool of buildings and the costs may be greater than typical buildings would require.

6.3.2 USA experience

Rutherford and Chekene[19], consulting engineers in California, provided the Royal Commission with two reports detailing techniques for seismic retrofitting and costs. These reports detail various seismic strengthening techniques including:

- strong-backs installed either internally or externally;
- steel or concrete moment frames and steel brace frames;
- addition of cross-walls;
- post-tensioning; and
- Shotcrete, Fibre Reinforced Polymer (FRP) and other similar methods.

New Zealand practice is generally consistent with the approaches detailed in these reports.

For additional information on seismic retrofitting and the performance of buildings after the 22 February 2011 earthquake, see Ingham and Griffith[20], and the discussion in it.

6.3.3 Guidelines for strengthening URM buildings

Engineers at The University of Auckland[7] have prepared and made publicly available draft guidelines *(Assessment and Improvement of Unreinforced Masonry Buildings for Earthquake Resistance* and related commentary[7]*)* for assessing and improving the seismic strength of URM buildings. When complete they will be a major update, giving examples of the application of current URM analysis methodologies referred to in Chapter 10 of the NZSEE Recommendations[3].

They provide guidance and design examples for the calculation of design actions using Section 8 of NZS 1170.5:2004[4], described above. It is noted that out-of-plane design actions on a part, such as a parapet, are based on a rocking period of this element, which reduces the part spectral shape coefficient and hence the design actions. By strengthening these elements, the part's period will be reduced as the rocking motion of the part is inhibited, leading to a higher part design action coefficient, which must be accounted for.

In addition to these guidelines[7], the Royal Commission has been made aware[21] that an internationally representative group of seismic design engineers (including New Zealand experts) is working on an update to the American Society of Civil Engineers (ASCE) – Structural Engineering Institute (SEI)[22] *(Seismic Rehabilitation of Existing Buildings)* standard of practice for the design of retrofit. This document and its companion document, ASCE/S61 31-03[23] *(Seismic Evaluation of Existing Buildings)*, will be combined and the update is currently expected to cover both seismic evaluation and retrofit. A subgroup of the update committee is working specifically to improve procedures for URM buildings. They are also including a section "System – Specific Performance Procedures". This, which is also now in draft form, will describe parameters that may be assumed in assessments of simple URM structures.

6.3.4 Improving URM buildings

Ingham and Griffith[24] recommended a four-stage improvement process for URM buildings. These stages are:

> **1st stage**: ensure public safety by eliminating falling hazards. This is done by securing/strengthening URM building elements that are located at height (e.g. chimneys, parapets, ornaments and gable ends).
>
> **2nd stage**: strengthen masonry walls to prevent out-of-plane failures. This can be done by adding reinforcing materials to the walls and by installing connections between the walls and the roof and floor systems at every level of the building so that walls no longer respond as vertical cantilevers secured only at their base.
>
> **3rd stage**: ensure adequate connection between all structural elements of the building so that it responds as a cohesive unit rather than individual, isolated building components. In some situations it may be necessary to stiffen the roof and floor diaphragms, flexurally strengthen the masonry walls, and provide strengthening at the intersection between perpendicular walls.
>
> **4th stage:** if further capacity is required to survive earthquake loading, then in-plane shear strength of masonry walls can be increased or high-level interventions can be introduced, such as the insertion of steel and/or reinforced concrete frames to supplement or take over the seismic resisting role from the original unreinforced masonry structure.

In our Interim Report, we recommended that the first of the stages be implemented throughout New Zealand and that the second stage be implemented in areas of moderate and high seismicity. We also undertook to give consideration to stages 3 and 4. Since publishing the Interim Report, we have received a further report from Ingham and Griffith[20] recording the consequences of the 22 February 2011 earthquake, and conducted hearings in which there was extensive evidence about the performance of URM buildings.

On the basis of the further studies and information conveyed at the hearings we now confirm the views expressed in the Interim Report that, for safety considerations, falling hazards such as chimneys, parapets and ornaments should be given a higher level of protection. In addition, however, we consider that the external walls of all URM buildings should be supported by retrofit, even in areas of low seismicity.

We have recorded in section 4 of this Volume the many instances where external walls failed in the February earthquake, causing loss of life. We summarised the evidence in section 5.3.1, where we noted that 19 of the buildings that failed had weak walls, 11 were cases where the façades rotated and fell out into the street and seven were instances where side walls failed collapsing inwards, or onto adjacent buildings. We consider that there is a demonstrated need in the interests of public safety for these elements of URM buildings to be strengthened throughout New Zealand.

We also consider that the design actions for the elements and connections to be strengthened should be based on the provisions in NZS 1170.5: 2004: *Section 8 – Requirements for Parts and Components*[4]. A part is described in the commentary to the Standard as follows:

> A part is an item within, or attached to, or supported by the structure. Parts are not generally included in the design of the primary seismic load resisting system.
>
> It may also be an element of the main structural system which can be loaded by earthquake action in a direction not usually considered in the design of that element, such as face loading on a masonry shear wall, or upwards loading on a cantilever.

Thus "part" may include ornamentation, canopies, parapets, chimneys, gable ends and external walls. These provisions will determine that the factors used in determining the design actions on these parts and their connections will be greater than factors applied to the mass of the building as a whole. The site horizontal ground acceleration is modified to allow for the amplification of response up the height of the structure, as well as other modifications for the part spectral shape coefficient, part response factor and part risk factor.

For buildings less than 12m in height and with a fundamental period less than 0.5 seconds, the lateral force coefficient for the part is generally of the order of 2.25 times the base shear coefficient for an elastically responding structure.

The potential need to implement the third and fourth stages of retrofit recommended by Ingham and Griffith[24] should be taken into account in the detailed assessment of buildings that are earthquake-prone and strengthened in accordance with the findings of that detailed assessment.

6.4 Improving non-URM buildings

Determining what changes need to be made to an existing building to bring its seismic performance up to an acceptable level requires a high level of skill. An initial step would be to identify which structural features are likely to limit the seismic performance from a close examination of the structural drawings. Where to look for such critical features might be gained from knowledge of the changes that have occurred in design and construction practice between the time when the building was designed and the current time. Fenwick and MacRae, and MacRae et al. could help with this task.

In carrying out an assessment it should be noted that the detailing that is used is generally more important in terms of identifying the level of earthquake resistance against collapse than the design strength that was provided. Consequently the detailing that was used in the construction as described on the structural drawings and in the specification should be studied closely.

Caution is required in planning structural retrofit to ensure that one element, such as a column, does not adversely affect other structural elements. For example, retrofitting a column to increase its lateral deformation capacity by adding confinement may have the effect of increasing the seismic actions induced in the beam-column joints, which generally cannot be easily retrofitted. A consequence of this could be that the joint zone may fail in a brittle mode. Alternative strategies that could be considered include:

- stiffening the structure so that the seismic forces have an alternative load path, which reduces the deformation imposed on the column, or other structural element;
- weakening structural elements, such as beams where they frame into beam-column joints, by cutting some of the flexural reinforcement in the beams adjacent to the column faces. This action may reduce the seismic actions induced on the joint zone and on the columns to a safe level but at the expense of additional deformation that needs to be sustained in the beam.
- providing an alternative means of support for gravity loads in the event that either the columns or beam-column joints fail;
- reducing the seismic actions by reducing the seismic mass; and
- providing additional damping capacity (energy dissipation) to the structure by base isolation or other means as described in Volume 3.

6.5 Conclusions and recommendations – assessing and improving buildings

6.5.1 Assessing existing buildings

Assessing the likely strength of a building structure is a specialised task requiring not only analytical technique but experience that has led to the development of sound professional judgement. The Royal Commission considers these assessments should be undertaken by engineers with relevant experience. The training and organisation of the engineering profession is discussed in a later Volume of this Report.

The Royal Commission considers that improving New Zealanders' understanding of the nature of a building they may be purchasing, using or passing by is important. The NZSEE and SEAONC grading systems were discussed in section 6.2 of this Volume. We consider that developing such a grading system would be beneficial and should be developed by the Ministry of Business, Innovation and Employment in consultation with territorial authorities, building owners, NZSEE, and other interested parties. Such a grading system could be based on or similar to that already set out in the NZSEE Recommendations, using letter grades A to E.

Recommendation

We recommend that:

72. The Ministry of Business, Innovation and Employment should work with territorial authorities, building owners, the New Zealand Society for Earthquake Engineering and other interested parties to develop a grading system for existing buildings that is able to be understood by the general public and adequately describes the seismic performance of a building.

The Royal Commission considers that the NZSEE Recommendations[3] are generally sound. However, the IEP and Detailed Assessment processes should be reviewed to take into account the risk that plans may not accurately record actual construction decisions and materials, especially for older buildings. In addition, the review should consider substantive issues; for example, inadequate restraint of bars in beams and columns against buckling. The resulting new practice standards or methods for evaluating existing buildings should also be given regulatory standing and monitored, to ensure consistency in application and use, given the potential resulting classification as an "earthquake-prone building" under the Building Act 2004.

Recommendations

We recommend that:

73. The Ministry of Business, Innovation and Employment should review the NZSEE Recommendations[3] and, in conjunction with engineering practitioners, establish appropriate practice standards or methods for evaluating existing buildings.

    These practice standards or methods should have regulatory standing, and be monitored by the Ministry of Business, Innovation and Employment for consistency of application.

74. Structural engineers assessing non-URM buildings should be familiar with the practical assessment considerations discussed in section 6.2.5 of this Volume. Those considerations should also be referred to in the practice standards or methods developed in accordance with Recommendation 73.

We consider that the use of 15% damping, or the assumption of a structural ductility factor of 2 and an S_p factor of 0.7, should be used with caution in assessing the percentage ULS for an URM building. We expect that the relative risk of an URM building assessed as 100% ULS would be considerably greater than 5 when compared to a new building designed to current standards. We consider this is an area that requires more research.

As discussed in section 6.2.4 of this Volume, the Royal Commission considers that allocating a percentage of NBS to existing building performance in an earthquake conveys an incorrect expectation of the building's performance when compared to buildings designed to the current standards. We consider that the use of the undefined term "new building standard" (NBS) should therefore be avoided and the Ministry of Business, Innovation and Employment should clearly describe to territorial authorities and the public the difference between the expected behaviour of an existing building prior to collapse and the behaviour of a building that complies with the current Building Code.

Recommendations

We recommend that:

75. Further research should be carried out into the suitability of assuming 15 per cent damping, and a structural ductility factor of 2 and an S_p factor of 0.7, in assessing unreinforced masonry elements.
76. The Ministry of Business, Innovation and Employment should clearly describe to territorial authorities and the public the difference between the expected behaviour of an existing building prior to collapse, and the behaviour of a building that complies with the current Building Code.

6.5.2 Improving existing buildings

We consider that there is a demonstrated need in the interests of public safety for the hazardous elements of unreinforced masonry buildings to be strengthened throughout New Zealand. For the reasons we have addressed in this Volume, we consider that falling hazards such as chimneys, parapets and ornaments should be given a higher level of protection. In addition, we consider that the external walls of all URM buildings should be supported by retrofit, even in areas of low seismicity. We are also of the view that the design actions for the elements and connections to be strengthened should be based on the provisions in NZS 1170.5:2004: *Section 8 – Requirements for Parts and Components*[4].

The potential need to implement the third and fourth stages of retrofit recommended by Ingham and Griffith should be taken into account in the detailed assessment of URM buildings which are earthquake-prone and such buildings strengthened in accordance with the findings of that detailed assessment.

Recommendations

We recommend that:

77. For unreinforced masonry buildings, falling hazards such as chimneys, parapets and ornaments should be made secure or removed.
78. The design actions for the elements and connections to be strengthened should be based on the provisions in NZS 1170.5:2004: *Section 8 – Requirements for Parts and Components*[4].
79. The external walls of all unreinforced masonry buildings should be supported by retrofit, including in areas of low seismicity.
80. The detailed assessment of unreinforced masonry buildings that are earthquake-prone should take into account the potential need to:
    a ensure adequate connection between all structural elements of the building so that it responds as a cohesive unit;
    b increase the in-plane shear strength of masonry walls; or
    c introduce high-level interventions (such as the insertion of steel and/or reinforced concrete frames) to supplement or take over the seismic resisting role from the original unreinforced masonry structure.

    Such buildings should be strengthened in accordance with the findings of that detailed assessment.
81. Recommendations 75 to 80 should be undertaken within the same timeframes as recommended in Recommendations 82 to 86 for unreinforced masonry buildings.

We discuss the level at which a building should be considered earthquake-prone under the Building Act 2004 in section 7 of this Volume.

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Note that Standards New Zealand was previously known as the Standards Institute of New Zealand.

Section 7: Earthquake-prone buildings policy and legislation

7.1 Introduction

We have addressed in a summary way the existing statutory provisions for earthquake-prone buildings in section 2 of this Volume. In this section we now discuss in more detail the subject of policies for earthquake-prone buildings that territorial authorities are required to adopt and review under the Building Act 2004.

We also discuss related provisions of the Building Act that present questions of interpretation or act as impediments to addressing earthquake-prone buildings. Other issues covered include the interaction between the Building Act and the Resource Management Act 1991, and whether people such as building owners are appropriately informed when making decisions on earthquake-prone buildings.

7.2 Policies about earthquake-prone buildings

For ease of reference, we again set out section 131 of the Building Act 2004:

> **131 Territorial authority must adopt policy on dangerous, earthquake-prone, and insanitary buildings**
>
> (1) A territorial authority must, within 18 months after the commencement of this section, adopt a policy on dangerous, earthquake-prone, and insanitary buildings within its district.
>
> (2) The policy must state –
>
> (a) the approach that the territorial authority will take in performing its functions under this Part; and
>
> (b) the territorial authority's priorities in performing those functions; and
>
> (c) how the policy will apply to heritage buildings.

As we noted in section 2 of this Volume, section 132 of the Building Act requires territorial authorities to review a policy adopted under section 131 at least every five years. In adopting and reviewing the policy, the territorial authorities must follow the special consultative procedure set out in section 83 of the Local Government Act 2002.

This involves the giving of public notice of the proposed policy, enabling persons interested in it to make submissions, which must be considered by the council. When the Building Act 2004 came into force, territorial authorities were required to finalise their policies and submit them to the former Department of Building and Housing by May 2006.

As can be seen from section 131 of the Act, the policies adopted must state what approach the council intends to take in performing its functions "under this Part", the priorities that will be set, and how the policy will apply to heritage buildings. The Part of the Building Act in which section 131 appears deals generally with building, and we assume that the intended reference is in fact to "Subpart 6–Special provisions for certain categories of buildings". This means that a policy adopted under section 131 will relate only to dangerous, earthquake-prone and insanitary buildings, as the heading of the section implies. Our focus is on earthquake-prone buildings.

7.2.1 Active and passive earthquake-prone policies

Following the introduction of the 2004 Act, the former Department of Building and Housing prepared guidelines[1] intended to assist territorial authorities in the development of their policies on earthquake-prone buildings under the new statutory provisions. This document was entitled *Earthquake-Prone Building Provisions of the Building Act 2004: Policy Guidance for Territorial Authorities*, which we will refer to as the DBH Guidelines. The foreword to the DBH Guidelines noted that it was not "prescriptive", and that it was expected that territorial authorities, in consultation with their communities, would develop policies that struck a balance between the need to address earthquake risk and other priorities, taking account of the "social and economic implications of implementing the policy".

In the introduction section of the DBH Guidelines, it was observed that:

> The definition of an earthquake-prone building is set out in section 122 of the Act and in the related regulations that define 'moderate earthquake'. This definition is significantly more extensive and requires a higher level of structural performance for buildings than that provided by the Building Act 1991. It encompasses all buildings, not simply those constructed of unreinforced masonry or unreinforced concrete. Small residential buildings are exempt from these provisions.

It was also observed that while the legislation required all territorial authorities to address the issue of earthquake-prone buildings, the nature of individual responses could vary. It is also worth noting the statement setting out the Departmental view of the intent of the legislation. This was described as follows:

> **Intent of the Legislation**
>
> New Zealand is subject to earthquakes of varying severity and some parts of it are seismically more active than others. In these seismically more active locations, the population's life and health, its buildings and other built infrastructure are at considerable risk.
>
> The Building Act 2004 is the legislative expression of the government's policy objective for New Zealand buildings. The legislation relating to EPBs seeks to reduce the level of earthquake risk to the public over the time and target the most vulnerable buildings. Strengthening buildings to improve their ability to withstand earthquake shaking will involve costs to TAs, building owners and the community generally.
>
> For this reason, the government has not imposed a "one size fits all" approach to the management of problems associated with earthquake-prone buildings. The measures of the legislation recognise that local economic, social and other factors have an impact on the implementation of these provisions of the Act. The measures in the legislation also recognise the need for a consistent, transparent and accountable approach to the implementation of the provisions in order to protect both building owners and users.

Against the background of that view of the intent of the legislation, the balance of the DBH Guidelines emphasised that it was for each individual territorial authority to decide on the content of its policy. In an appendix to the document, a distinction was made between "active" and "passive" approaches.

Under an active approach, high risk buildings would be identified, and priorities and timeframes for action and guidelines for performance levels for upgrading set. The territorial authority would serve notice on the owners requiring them, at their cost, to carry out a detailed assessment and/or performance improvement as appropriate. This approach would provide a territorial authority with information about the earthquake-prone buildings in its district and enable it to make decisions about how they should be managed. It was noted that setting up and managing this approach would involve significant costs to the territorial authority and there would be a greater impact on building owners.

In outlining the alternative passive approach, the DBH Guidelines said:

> **A passive approach**
>
> If a TA were to adopt a more reactive approach, the IEP and detailed assessment and any improvement of structural performance would be triggered by an application under the Building Act for building alteration, change of use, extension of life or subdivision.
>
> With this arrangement, on receipt of an application relating to a building that the desktop research indicated could be earthquake-prone, a TA would undertake an IEP on the building. If this process indicated that the building was likely to be earthquake-prone, the TA would seek a detailed assessment of the building's structural performance before issuing a building consent. If the detailed assessment indicated that a building was earthquake-prone, a TA would issue a notice to reduce or remove the danger to the level set out in its EPB policy. This work could be undertaken as part of the building work for which an owner seeks consent. However, once an application activates the EPB policy, a TA should require any necessary upgrading to be undertaken even if a building owner decides not to undertake the building work set out in the application.
>
> This second approach has the significant disadvantage that it relies on a somewhat haphazard order of remediation based essentially on an owner's intention for a building. This could leave some significant high-risk buildings untouched for a long period of time.
>
> On the other hand, the cost of administering such a programme would be significantly less than an active programme.

In a passive approach, assessment is carried out to identify high risk buildings but improvement of structural performance is only required after an application for consent for alteration of an existing building (section 112 of the Building Act) or a change of use (section 115). Assessment of the structural performance of the building would be at the owner's cost. This approach imposes less time pressure on territorial authorities and is less costly to administer. However, the disadvantage is that it relies on a somewhat ad-hoc approach based on owners' intentions and this could leave some high-risk buildings untouched for a long period.

In practice, the provisions of the Act have resulted in territorial authorities allowing decades to carry out the strengthening of buildings, even when they have adopted an active policy that nominally requires the strengthening of all earthquake-prone buildings within the district. If an authority adopts a passive policy, the requirement to strengthen the building is triggered only when an application for a building consent for alterations is lodged with the territorial authority, or the Building Act provisions relating to change of use, extension of life or subdivision (sections 115 to 116A) are engaged. Consequently, many buildings have been left without strengthening, even when they are known to be earthquake-prone.

7.2.2 Territorial authorities' current earthquake-prone buildings policies

All 67 territorial authorities have adopted an earthquake-prone buildings policy. Analysis of these policies as at May 2012 showed that 43 had active policies (as characterised by the DBH Guidelines); 12 had passive policies and 12 had policies with some active elements and some passive elements. There has been an increase in the number of active policies since 2007 when 33 territorial authorities had active policies. Several territorial authorities are currently reviewing their policies.

Timeframes specified in the policies for (a) identifying potentially earthquake-prone buildings; (b) completing initial evaluations of those buildings; and (c) undertaking strengthening are summarised in the following table:

Table 1: Timeframes specified in territorial authority earthquake-prone policies (source: Department of Building and Housing, May 2012)

Policy element	Timeframe range (shortest maximum timeframe to complete to longest maximum timeframe to complete)	Average of timeframe ranges set in policies
Identify potentially earthquake-prone buildings	Within one year to within 30 years NB: only one policy sets the period at 30 years; the next longest period is within 20 years	2.6 years
Complete initial evaluations of those buildings	Within one year to within 25 years NB: only one policy sets the period at 25 years; the next longest period is within 10 years	2.5 years
Complete strengthening of earthquake-prone buildings	Within one year to within 70 years NB: only one policy sets the period at 70 years; the next longest period is within 55 years	17 years

Notes:

- Not all policies specify timeframes in which to identify potentially earthquake-prone buildings or in which to complete initial evaluations of those buildings.
- Territorial authorities that do specify timetables for action generally have active policies.

7.2.3 Issues arising under the current legislation and options to address these

It is clear from submissions and evidence to the Royal Commission, and the discussion above, that territorial authorities have widely varying policies to address earthquake-prone buildings. This variation is often, but not solely, related to the concepts of active or passive policies outlined in the DBH Guidelines. In practice, the ability for territorial authorities both to choose a level of passivity or activity, and the time-frames in which to take any specified action, have resulted in little or no action in many areas of New Zealand. Territorial authorities must take into account the social and economic nature of their city or district but the risk to life of hazardous older buildings should also be taken into account and the right balance struck. We do not consider the right balance has been achieved. We set out below the advantages and disadvantages of allowing passive or active policies, or removing the ability to have a passive policy. We also discuss the question of specifying timeframes in which action should be taken.

7.2.3.1 Active or passive policies

Option 1: Status quo – territorial authorities can elect to have an active or a passive policy

Advantages	Disadvantages
No change to current legislative provisions and associated departmental guidance	Inconsistent approach across country
Councils are familiar with the current approach	Passive approach can mean that buildings are never strengthened until they change use or are altered
Communities can decide if they wish to address the issue actively or not	

Option 2: Require territorial authorities to take an active approach

Advantages	Disadvantages
Councils will be aware of the earthquake-prone buildings in their districts and required to actively enforce the retrofit of these buildings until they are no longer considered earthquake-prone.	Smaller councils or councils in low seismic risk areas may not have the capability to enforce an active policy
Consistent approach across the country	More resource intensive for territorial authorities
	Greater impact on building owners (will be required to address the seismic resistance of their building)

We have taken these advantages and disadvantages into account in the subsequent discussion and in formulating the recommendations in section 7.4 below.

7.2.3.2 Timeframes

The Royal Commission heard submissions from territorial authority representatives urging that the maximum timeframe for strengthening earthquake-prone buildings should be set in legislation with provision made for territorial authorities, in consultation with their communities, to be able to reduce those timeframes but not extend them. Advantages and disadvantages of that approach, and the alternative of leaving the timeframe to the discretion of the individual territorial authorities, are set out in the following tables.

Option 1: Set timeframes for addressing earthquake-prone buildings nationally, with ability for territorial authority to reduce timeframes but not extend

Advantages	Disadvantages
More consistent approach across the country	Economic viability for some small or low risk areas
Certainty of action, increasing public safety	May remove possibility of independent judgement for special cases (i.e. significant buildings)
Enforceable approach	
Addresses issue of adjoining buildings (See discussion below)	

Option 2: Territorial authorities able to specify timeframes

Advantages	Disadvantages
Local communities can determine timeframes based on likely impacts and outcomes for their city or district	Inconsistency across the country
	Possibly lengthy timeframes adopted, resulting in inaction

Once again, we have taken the advantages and disadvantages of these options into account in formulating the recommendations in section 7.4 below.

7.3 The earthquake-prone threshold

As has been discussed in section 2 of this Volume, section 122(1) of the Building Act 2004 defines an earthquake-prone building as one that will have its ultimate capacity exceeded in a moderate earthquake, and would be likely to collapse causing injury, death or damage to other property.

A moderate earthquake is defined in the Building (Specified Systems, Change the Use, and Earthquake-prone Buildings) Regulations 2005. Regulation 7 of the Regulations defines a "moderate earthquake" as one 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…that would be used to design a new building at the same site".

It is this provision that is relied on for the proposition that, in order to avoid being categorised as earthquake-prone, an existing building must not be below 34% of new building standard (NBS). (We have addressed in section 6 of this Volume misleading aspects of the NBS concept and noted our preference for the term ultimate limit state (ULS), which we adopt in the following discussion.)

The Royal Commission has considered whether the definition of "moderate earthquake" should be amended to refer to a higher proportion of shaking than one-third of that used for the design of new buildings. If buildings were considered earthquake-prone when they could not withstand a higher level of shaking, territorial authorities would be empowered to require strengthening works for a wider pool of buildings.

The key issues in relation to whether such a change would be desirable are life safety, economic considerations and cultural (including heritage) values. We set out below seven options (including as the first option maintenance of the status quo) with a summary of what we consider the principal advantages and disadvantages of each would be. The discussion of the options below treats 34% ULS as the effective threshold under the existing law; the implied precision in translating one-third to 33.3% would not be sensible. (We also note that there are recommendations in section 6 of this Volume for specific strengthening works for unreinforced masonry buildings, which we consider should be carried out in any event.)

Option 1: Status quo – retain 34% ULS as the level below which a building is considered earthquake-prone

Advantages	Disadvantages
Engineers generally understand the current practice (albeit with some differences of implementation)	Does not achieve the same decrease in risk of building collapsing as would a higher percentage of ULS; for example, 67% ULS
Lower cost – see section 7.3.1 below	Benefit from building performance reduces over time (i.e. 34% in five years' time may not be equivalent to 34% now), potentially requiring further upgrade
Evidence of performance of buildings in Canterbury earthquakes does not show that 34% ULS is inadequate as a national standard	Because % ULS is assessed taking into account the seismicity levels for different regions, 34% in a low seismicity region is a very low level of performance

Option 2: Raise the level below which a building is considered to be earthquake-prone to 67% ULS

Advantages	Disadvantages
Reduces the likelihood of a building collapsing	Significant cost to building owners
Safer building stock in New Zealand, and for a longer period of time than for strengthening to 34% ULS	Economic impact due to building owners abandoning or demolishing buildings and no replacement building stock being developed, leading to businesses (especially smaller businesses in lower growth areas) closing due to lack of available, suitably priced premises
	Increased workload on territorial authorities to conduct building assessments and enforce requirements
May result in increased demolition of older buildings where cost of retrofit outweighs benefit, reducing hazard to the public	May result in increased demolition of older buildings where cost of retrofit outweighs benefit, resulting in loss of unreinforced masonry buildings, including heritage buildings, and the contribution they make to amenities
	Would require further expenditure and work on buildings already strengthened to 34% ULS

Option 3: Raise level at which a building is considered to no longer be earthquake-prone to as near as is reasonably practicable to 100% ULS

Advantages	Disadvantages
Safer building stock in New Zealand	Large cost to building owners
	Economic impact due to building owners abandoning or demolishing buildings and no replacement building stock being developed, leading to businesses (especially smaller businesses in lower growth areas) closing due to lack of available, suitably priced premises
	Increased workload on territorial authorities to conduct building assessments and enforce requirements
Likely to result in increased demolition of older buildings where cost of retrofit outweighs benefit, reducing hazard to the public	Likely to result in increased demolition of older buildings where cost of retrofit outweighs benefit, resulting in loss of unreinforced masonry buildings, including heritage buildings, and the contribution they make to amenities
	Would require further expenditure and work on buildings already strengthened to 34% ULS

Option 4: Keep the level at or below which a building is considered to be earthquake-prone at 34% ULS but allow territorial authorities to adopt a policy to achieve and enforce 67% ULS following public consultation

Advantages	Disadvantages
Engineers generally understand the current practice (albeit with some differences of implementation)	Does not achieve the same decrease in risk of building collapsing as a nationally-required higher percentage of ULS; for example, 67% ULS
	Inconsistent approach across country may cause confusion
Communities may focus on investing in the upgrade of key historic buildings for their district, with remaining buildings being demolished over time, reducing cost and increasing public safety	Communities may focus on investing in the upgrade of key historic buildings for their district, with remaining buildings being demolished over time, thereby reducing overall stock of older buildings (including some heritage buildings)

Option 5: Allow different levels at or below which a building is considered earthquake-prone, set nationally, for areas based on seismic risk and population density

Advantages	Disadvantages
Economic impact reduced on small/low socio-economic areas	Inconsistent approach across country may cause confusion
Public safety increased	Building owners may move out of CBD areas due to increased building strengthening requirements
	Territorial authorities may not have the capability to enforce

Option 6: Keep level below which a building is considered to be earthquake-prone at 34% ULS and ensure potentially dangerous aspects of building are mitigated (i.e. secure or remove falling hazards, strengthen walls to prevent out-of-plane failures)

Advantages	Disadvantages
Economic impact reduced on small/low socio-economic areas	Initial economic impact on building owners
Quick fix to at-risk buildings	Buildings that cannot remove the danger will have to be demolished
Cheaper than ensuring entire building is at 67% ULS	Communities will not have the ability to consider the particular nature of their city or district and building stock, and determine a higher level of safety if they consider it justified

Option 7: Keep level below which a building is considered to be earthquake-prone at 34% ULS, ensure dangerous aspects of a building are mitigated (i.e. secure or remove falling hazards, strengthen walls to prevent out-of-plane failures), and allow territorial authorities to adopt a policy to achieve and enforce a higher percentage of ULS following public consultation

Advantages	Disadvantages
Economic impact reduced on small/low socio-economic areas	Initial economic impact on building owners
Quick fix to at-risk buildings	Buildings that cannot remove the danger will have to be demolished
Communities with higher seismicity or large component of older building stock can decide to reduce risk for their area	

Having considered these various options, we are in no doubt that it is desirable that there be a clear national policy, that is actively pursued, understood by the relevant parties, and implemented. In particular, the need to address known key hazards presented by unreinforced masonry buildings, as discussed in section 5 of this Volume, is clear. However, we consider that the potential impact of setting the level at which a building is considered earthquake-prone much above 34% ULS is significant and is unlikely to be outweighed by the advantages.

The question of when the benefit in raising that level may outweigh the cost of doing so is discussed directly in section 7.3.1 below. The advantages and disadvantages of the options can also usefully be addressed under the headings of life safety, economic impact and cultural impact. These are discussed further in section 7.3.2, where we also make some observations about the perception of earthquake risk.

7.3.1 Earthquake-prone policy costs

The Ministry of Business, Innovation and Employment (MBIE) has engaged consultants Martin, Jenkins and Associates (MJA) to develop a model for the purposes of quantifying the costs and benefits to the New Zealand economy arising from various policy options for addressing earthquake-prone buildings.

Development of the model is largely complete, with its key inputs being:

- probability weighted range of large to very large earthquakes[1] based on the different seismicity of New Zealand regions, in accordance with GNS Science advice;
- benefits of forgone deaths (calculated using the New Zealand Transport Agency estimate of $3.67 million per life), injury costs and damage repair costs);
- costs of strengthening buildings; and
- discount rate of 6.5% used to convert future cashflows to current values for the net present value (NPV) analysis. This reflects the opportunity cost of capital, prescribed by the Treasury as appropriate for general purpose office and accommodation buildings.

The model has been formally reviewed by the economic research firm Infometrics. The Royal Commission has been provided with the model and understands its methodology and purpose. We note that there is significant uncertainty in the cost data sourced by MJA regarding the need for, and costs of, strengthening buildings across New Zealand. MJA comment that the data held by New Zealand authorities is "scarce and not particularly reliable". This probably reflects the generally cautious approach to earthquake-prone policy implementation taken by territorial authorities to date.

The Royal Commission notes that MJA have explored a number of avenues in an endeavour to gather and generate robust data about the building stock. This has included making use of Quotable Value Limited data, seeking information from all territorial authorities and contacting the largest councils for updated numbers on earthquake-prone buildings in their areas. As a result of this exercise, MJA advised that it is evident that "less than 10% of all pre-1976 buildings in New Zealand have had any sort of assessment".

In view of the shortcomings of the cost data, the focus of the NPV analysis has been to use the most conservative data reasonable, and determine whether any feasible policy options would generate a net benefit. MJA concludes that even under the most conservative of cost assumptions, there is no policy option that would generate a net benefit, due largely to a combination of the low probability of a large or very large earthquake occurring and the timing in which costs and benefits are incurred (costs of strengthening buildings are incurred in initial years; benefits associated with deaths, injuries and building repairs avoided accrue following an earthquake).

In order to determine the potential magnitude by which costs exceed benefits, the analysis was informed by a closer investigation of the potential costs of strengthening buildings across New Zealand (the key cost driver). As noted above, updated information was sought from the largest councils, which led to a tentative estimate of 15,000–25,000 buildings in need of strengthening[2]. With the repair costs estimated at $300/m^2 to strengthen to above 33% ULS and $640/m^2 to strengthen to 67% ULS, the following NPVs (compared to doing nothing) give some indication of the magnitude of the net total cost of the policy options, in 2012 dollars:

- status quo: above 33% ULS over an average 28 years – approximately $1 billion
- above 33% ULS within 15 years – approximately $1.7 billion; and
- 67% ULS within 15 years – approximately $7.6 billion.

It should be noted that social and economic costs associated with a major earthquake are excluded due to difficulty in isolating impacts of earthquake-prone building policy changes compared to impacts of damage to infrastructure, non earthquake-prone buildings and residential housing.

The merits of a policy change for the strengthening of earthquake-prone buildings should not be based on economic analysis alone. There are a number of non-quantifiable benefits that are relevant to the overall policy decision, as discussed at various points in this Volume. It should also be noted that strengthening will lead to an increased level of confidence, which has an intrinsic but unquantifiable benefit.

7.3.2 Other considerations

7.3.2.1 Life safety

Some guidance on setting standards for life safety can be gained by considering the lives lost and the injuries sustained in the Canterbury earthquakes.

The Royal Commission has examined all fatalities caused by building failure in the February 2011 earthquake. These fatalities are described in this Volume of the Report or in Volumes 2 (PGC building) or 6 (CTV building). Excluding the PGC and CTV buildings, and the death of an infant caused by an internal exposed brick chimney breast collapsing, the majority of other fatalities (39 out of 41) were caused by URM buildings failing in some way. Of the 41 deaths, 29 (70%) were caused by URM façades (or parts of façades) collapsing onto people exiting from or passing by the buildings. In 10 cases (24%) people died inside buildings, and of those six involved cases where a neighbouring building fell onto the building where the deceased were. The other two deaths were caused by a free-standing concrete block wall collapsing onto the victim (90 Coleridge Street) and a concrete spandrel falling onto a vehicle in which the deceased person was seated (43 Lichfield Street).

Care is needed in drawing conclusions applicable nationally from the evidence available in Christchurch. The ground motion characteristics resulting from earthquakes vary from earthquake to earthquake. In addition, the soil conditions in Christchurch are not representative of New Zealand as a whole. For these reasons, it is appropriate to consider the Christchurch experience as indicative only. It is also relevant to note that the commercial area of the CBD was largely unoccupied at 4:35am on 4 September 2010 and that several of the CBD buildings damaged in the September earthquake remained unoccupied, with barricades protecting public space (at least to some extent) when the 22 February 2011 earthquake occurred.

However, the extent of the loss of life in the February earthquake was largely unanticipated by the New Zealand community.

7.3.2.2 Economic impact

Although the economic consequences of a major earthquake are profound at the national level, the optimum decisions on strengthening based on economic impact will vary considerably from city or district to city or district. Decisions which are optimal in one part of the country may be less appropriate in another.

It is apparent from submissions by territorial authorities that the factors affecting decisions at the local level include:

- the proportion of earthquake-prone buildings in the portfolio of existing buildings;
- the intensity, volume and concentration of earthquake-prone buildings and hence the scale of economic risk to the local community as well as New Zealand as a whole;
- the level of economic activity: whether there is high, medium or low growth in the city or district;
- market considerations: availability and demand, robustness of the rental market, expectations of risk; and
- funding: availability of loan or grant funding to accelerate the reduction of earthquake risk.

7.3.2.3 Cultural impact

An important matter that must be taken into account in considering the future of existing buildings is the value communities place on the contributions historic buildings make to cultural values. These values may also have a significant economic worth. Napier and Oamaru are examples in which the local economy is closely aligned to the character of the heritage building stock.

Many structures have heritage value and some form a vital part of the built environment. Many heritage buildings are also earthquake-prone. In a report provided to the Royal Commission, the New Zealand Historic Places Trust[2] (NZHPT) noted:

> Heritage values are aspects or qualities of a place that are valued by communities. These values are identified and treasured to ensure survival for present and future generations. Ensuring that all the relevant threats and risks are identified is a core part of heritage planning. Heritage places and areas are often diverse and include buildings (including structures), historic gardens, historic sites having no physical buildings or structures, archaeological sites, and places and areas of significance to Māori.

Further, the NZHPT notes the responsibility at present assigned to territorial authorities:

> With regard to earthquake prone policies, the term 'heritage buildings' is used under section 131 of the Building Act 2004. Territorial authorities must state how their policy will apply to heritage buildings. This term is also used in section 125 of the Building Act 2004 with regard to provision for copies of requirement notices to be provided to the NZHPT.

7.3.2.4 Understanding earthquake risk

How government, society, communities and individuals think about and plan for the risk of an earthquake underlies the discussions about how to identify and deal with New Zealand's earthquake-prone buildings. The DBH Guidelines[1] suggested that some communities may take the view that all of the earthquake-prone buildings in their area should be strengthened, but others may consider a lower level of strengthening sufficient. This implies that communities decide the level of risk they find acceptable. However, the idea that people accept a certain level of risk when they enter, live and work in earthquake-prone or earthquake-risk buildings is something that is rarely articulated explicitly. In fact, it is difficult for communities and individuals to recognise and understand events like damaging earthquakes, which rarely occur but often have a very large impact when they do. This means that people may not make informed, accurate and well-balanced choices about the risks associated with earthquake-prone buildings, or even think about these risks at all.

Civil defence literature recognises how people's perceptions of risk affect the way they plan for a disaster. McClure et al.[3] discuss how people judge the probability of disasters according to a range of factors, including optimistic biases in people's judgements and whether or not they have personally experienced the event. Many people have an optimistic bias, which means that they see themselves as less likely than others to be harmed by an earthquake in the future, even if they live in a location prone to earthquakes. In 2010, J.S. Becker discussed in McClure et al.,[3] highlighted how optimistic bias may be compounded by people's beliefs about the different levels of risk particular hazards pose in different regions: people estimated the chance of being in an earthquake in Canterbury as less than for Wellington. Experiencing the event reduces optimistic bias. Hudson-Doyle[4] discusses how the civil defence literature explores various models scientists can use to communicate with the wider public about the probability of an event happening, particularly when the science is uncertain.

McClure et al. consider that New Zealanders should not use what has happened in Canterbury as a basis for their risk judgements. Instead, they should base their actions on the actual level of risk in their own region, regardless of how that compares to the rest of New Zealand.

We encourage the Ministry of Business, Innovation and Employment and other agencies such as GNS Science and the Ministry of Civil Defence and Emergency Management, and professional engineering bodies such as IPENZ and NZSEE, to assist the public to understand the levels of risk for their community and region.

7.4 Conclusions and recommendations

7.4.1 The earthquake-prone threshold

As noted in section 5.2.1, the September earthquake created ground motions approximately at the design level for the ULS under the current design standard, NZS 1170.5:2004. This was a level of shaking which was therefore well beyond the one-third level used for establishing that a building is earthquake-prone under the current legislation. The shaking in the February earthquake was 1.5–2 times the design level. Although Ingham and Griffith present data that suggest that the performance of URM buildings in the February earthquake that had been strengthened to 33% NBS was not significantly better than those that had not been strengthened, the test to which those buildings were subjected by the earthquake was well beyond that of a moderate earthquake as currently defined.

It must also be borne in mind that such strengthening as had taken place in the Christchurch CBD was based on a hazard factor, Z, of 0.22. It is clear now that the hazard factor did not accurately represent the actual level of seismic risk. If buildings had been retrofitted on the basis of the Z factor of 0.3 that was subsequently applied, the performance of buildings might have been better.

Overall, we do not consider that the experience of the Canterbury earthquakes should lead to the abandonment of the current one-third rule, which we have concluded should remain as the appropriate Standard. We have also noted, however, in various sections of this Volume that the majority of deaths due to the collapse of URM buildings in the February earthquake occurred in public places outside the buildings that failed, due to the out-of-plane collapse of façades, gable ends and parapets. Other deaths were the result of the collapse of walls from neighbouring buildings.

To counter what has been proven to be a particular source of danger, we consider that a higher level of protection should be given, to prevent this form of collapse, than is justified for the building as a whole. Apart from this one exception, there appears to be no evidence that to protect life safety the shaking level to be resisted for earthquake-prone buildings should be set higher than one-third of the requirement for new buildings.

The Royal Commission has therefore concluded that the present threshold for characterising a building as "earthquake-prone," based on the definition of "moderate earthquake" in the Building (Specified Systems, Change the Use, and Earthquake-prone Buildings) Regulations 2005 is appropriate and should be maintained.

However, we also consider that territorial authorities should also be empowered to adopt earthquake-prone building policies that are stricter than the statutory minimum where they consider that is appropriate, taking into account particular economic considerations, building characteristics, and/or seismic circumstances that are relevant to their districts. We see no reason to prevent that approach, which appears to have been successfully adopted and achieved community acceptance in Gisborne District.

We also consider that territorial authorities should be able to adopt a policy that would require a greater level of strengthening than the statutory minimum for buildings of high importance or high occupancy, where public funding is to be contributed to the strengthening or where the hazard to public safety justifies it.

Adoption of a policy that exceeded the statutory minimum would require the territorial authority to follow the special consultative procedures of the Local Government Act 2002. These policies would be able to take into account matters such as the affordability of strengthening, perceptions of reduced risk, local economic considerations, market influences such as rentals, rates, insurance, and other costs implicit in seismic risk.

7.4.2 Upgrade timeframe

We are of the opinion that the maximum time permitted to complete the evaluation and strengthening of existing buildings should be set nationally. The Royal Commission has heard evidence that the catalogue of existing buildings held by local authorities is incomplete. However, based on information provided by Quotable Value Limited to the former Department of Building and Housing, the number of existing commercial, industrial, high-rise residential and other non-residential buildings/unit titles across New Zealand is approximately 194,000. These properties represent a total area of over 170 million square metres of space.

The opportunity to extend time to rectify deficiencies has resulted in passive policy implementation, in turn resulting in divergent standards of safety from district to district. This approach has allowed structurally unsound buildings to remain a threat to the occupants and the public for a significant period, when measured against the estimated return period for an earthquake of damaging effect.

The size of the task required of territorial authorities and owners to address earthquake-prone buildings is such that, if the timeframes are set too tightly, there may be insufficient resources (whether in terms of engineering design or physically carrying out the necessary work) to comply with the obligations imposed. There might also be unintended impacts, such as the abandonment of buildings. There is nevertheless considerable merit in completing the work expeditiously as there is obvious benefit in society being better prepared before a destructive earthquake.

Having regard to these considerations and the cost of strengthening buildings, we consider that a period of two years should be set as the maximum time allowed for territorial authorities to complete initial evaluations of all URM buildings. A further five years should be allowed for all URM buildings to be strengthened to the required level. In the case of URM buildings we note that the requirement of strengthening to 34% ULS that we recommend in this section is in addition to the specific strengthening works that we have discussed in section 6 for the building as a whole and the obligation to apply a 50% ULS standard in respect of parapets, gable ends or façades. It might be that carrying out those works would result in the 34% ULS strength being achieved in any event.

For all other buildings, territorial authorities should identify those that are likely to be earthquake-prone through an initial evaluation process to be completed within five years. Owners would be allowed a further 10 years to undertake strengthening to above the earthquake-prone level or demolish buildings judged to be unsafe in a moderate earthquake.

From the end of this 15-year period, we consider that the state of the building stock should be monitored, having regard to the deterioration of buildings with the passage of time. The Ministry of Business, Innovation and Employment should give consideration to the best means of ensuring that this monitoring is carried out.

There should be legislative authority for territorial authorities to adopt a policy providing for shorter timeframes, after following the special consultative procedures of the Local Government Act.

Implementation of these changes to the existing legislation would mean that territorial authorities would not need to adopt earthquake-prone building policies after following the special consultative procedure, unless seeking to impose stricter obligations (whether as to the level of strengthening, or the time by which it is to be achieved): the rules would be set nationally in the legislation.

Implementation of these changes would also require each territorial authority to develop a database listing all earthquake-prone buildings in its district.

7.4.4 Exemptions

There are some buildings that are very seldom used and are so located that their failure in an earthquake is most unlikely to cause loss of life, or serious injury to passers-by. An example is rural churches (we note that Gisborne District Council treats these churches as a special case).

We consider that there is a good case for such buildings to be exempt from the general legislative requirements for earthquake-prone buildings. If that policy position is adopted, we consider it should be set out in legislation so that one rule applies nationally.

7.4.5 Recommendations

Recommendations

We recommend that:

82. The Building Act 2004 should be amended to require and authorise territorial authorities to ensure completed assessments of all unreinforced masonry buildings within their districts within two years from enactment of the Amendment, and of all other potentially earthquake-prone buildings within five years from enactment.
83. The legislation should be further amended to require unreinforced masonry buildings to be strengthened to 34% ULS within seven years from enactment of the Amendment and, in the case of all other buildings that are earthquake-prone, within 15 years of enactment.
84. The legislation should be further amended to require that in the case of unreinforced masonry buildings, the out-of-plane resistance of chimneys, parapets, ornaments, and external walls to lateral forces shall be strengthened to be equal to or greater than 50% ULS within seven years of enactment.
85. The legislation should provide for the enforcement of the upgrading requirements by territorial authorities, with demolition (at owner's cost) being the consequence of failure to comply.
86. The legislation should allow territorial authorities to adopt and enforce a policy that requires a shortened timeframe for some or all buildings in the district to achieve the minimum standard required by the legislation, after following the special consultative procedures in the Local Government Act 2002.
87. The legislation should allow territorial authorities to adopt and enforce a policy that requires a higher standard than the minimum ULS required by the legislation for some or all buildings in the district, after following the special consultative procedures in the Local Government Act 2002.
88. The legislation should allow territorial authorities to adopt and enforce a policy that requires a higher standard of strengthening for buildings of high importance or high occupancy, where public funding is to be contributed to the strengthening of the building or where the hazard to public safety is such that a higher standard is justified, after following the special consultative procedures in the Local Government Act 2002.
89. Guidance should be provided by the Ministry of Business, Innovation and Employment to territorial authorities on the factors to be considered in setting discretionary policies under the amended legislation. These factors should include the nature of a community's building stock, economic impact, numbers of passers-by for some buildings, levels of occupancy, and potential impact on key infrastructure in a time of disaster (e.g. fallen masonry blocking key access roads).
90. The legislation should exempt buildings that are very seldom used and are so located that their failure in an earthquake is most unlikely to cause loss of life, or serious injury to passers-by.

7.5 Drafting issues with the current legislation

The Royal Commission notes there are issues with or questions about the interpretation of sections of the Building Act 2004 and/or with how the current provisions for earthquake-prone buildings interact with other sections in the Building Act.

7.5.1 Section 124 of the Building Act 2004

It is clear from the evidence presented to the Royal Commission by representatives of territorial authorities that there is uncertainty about whether the councils may lawfully require that earthquake-prone buildings be strengthened to a level beyond the one-third level set out in the Regulations, and rival views have been advanced, based on differing legal advice. The issue arises directly when the territorial authority is exercising its powers under section 124(1) of the Building Act, which provides:

> **124 Powers of territorial authorities in respect of dangerous, earthquake-prone, or insanitary buildings**
>
> (1) If a territorial authority is satisfied that a building is dangerous, earthquake prone, or insanitary, the territorial authority may –
> (a) put up a hoarding or fence to prevent people from approaching the building nearer than is safe:
> (b) attach in a prominent place on, or adjacent to, the building a notice that warns people not to approach the building:
> (c) give written notice requiring work to be carried out on the building, within a time stated in the notice (which must not be less than 10 days after the notice is given under section 125), to –
> (i) reduce or remove the danger; or
> (ii) prevent the building from remaining insanitary.

The question is whether, in a notice issued under section 124(1)(c), a council can require work to be carried out that would require a building to be brought up to a state that exceeds the one-third threshold for earthquake-prone status. A legal opinion obtained by Christchurch City Council concluded that a council could not lawfully require strengthening beyond the one-third level. The majority of councils who presented evidence and submissions to the Royal Commission supported the view held by Christchurch City Council. An alternative approach has been advanced by the Gisborne District Council. That Council has adopted a policy that earthquake-prone buildings should be strengthened to a two-thirds level acting on the advice of the Council's solicitors that the minimum one-third requirement is applicable only to what constitutes an earthquake-prone building and not to the standard of upgrading that may be required once the building has been classified as earthquake-prone.

The issue turns on the meaning that should be given to the words "reduce or remove the danger", in section 124(1)(c)(i). Given that section 124(1) deals with dangerous, earthquake-prone and insanitary buildings, and that insanitary buildings are separately dealt with in sub-paragraph (1)(c)(ii), the phrase "reduce or remove the danger" is clearly used to apply to both dangerous buildings and those that might not be dangerous, but are nevertheless earthquake-prone. There is plainly still a distinction between the two kinds of building, as section 121(1) provides:

> **121 Meaning of dangerous building**
>
> (1) A building is **dangerous** for the purposes of this Act if, -
> (a) in the ordinary course of events (excluding the occurrence of an earthquake), the building is likely to clause –
> (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 on other property is likely because of fire hazard or the occupancy of the building.

This provision is consistent with the legislative history which, as we have explained in section 2 of this Volume, has consistently provided separately for dangerous buildings and earthquake-prone buildings since the Municipal Corporations Act 1968.

We doubt that it was intended that section 124(1)(c)(i) should have the effect of authorising a notice that required an earthquake-prone building to be strengthened beyond the level at which it would have ceased to be earthquake-prone. The Council's only relevant powers are in relation to earthquake-prone buildings as defined. The better view is that once an earthquake-prone building has been strengthened so that it would satisfy the one-third rule, it would cease to be subject to the council's powers to require improvement. Equally, a territorial authority's earthquake-prone buildings policy could not require strengthening of buildings that had satisfied the one-third rule and were therefore not earthquake-prone (or were no longer earthquake-prone). This is the conclusion that generally seems to have been reached by territorial authorities, and while the issue cannot be authoritatively resolved by the Royal Commission (that is a matter for the Courts), it is appropriate that we note our view that the powers in section 124(1)(c) of the Building Act do not authorise a requirement for seismic strengthening beyond that necessary to withstand a moderate earthquake as defined in the Regulations.

Ms Townsend, the Deputy Chief Executive of Sector Policy at the former Department of Building and Housing, who gave evidence to the Royal Commission, conceded that the Department had been of the view that the law did not authorise requirements for strengthening beyond the one-third threshold since 2005. We consider it is time this issue was addressed by Parliament.

However, as earlier discussed, we do consider it is appropriate to authorise territorial authorities to require a greater level of strengthening than the law currently appears to allow if they wish to do so as a matter of policy. The legislation should be amended to confer that power clearly. It is undesirable for there to be any uncertainty on such an important matter.

7.5.2 Sections 121–124 and section 129 of the Building Act 2004 – Dangerous buildings or parts of buildings

7.5.2.1 Parts of buildings

Evidence provided to the Royal Commission showed that there was uncertainty about the extent of the application of sections 122 and 124 of the Building Act 2004. The key issues are:

- whether building elements such as balconies, parapets, chimneys etc. that are likely to collapse and cause death in a moderate earthquake but where the remainder of the building is not earthquake-prone, fall within the meaning of section 122 of the Building Act 2004; and
- if a building with such weakness is an earthquake-prone building, does a territorial authority therefore have legal power to require retrofitting of these elements under section 124?

The legislation as currently drafted gives scope for argument on this issue. For example, section 122(1) refers to a building being earthquake-prone if, amongst other things, the building would be likely to collapse. Similarly, in the immediately preceding section, a building is said to be dangerous if the building is likely to cause injury or death. Then, by section 124(1), a council is empowered to put up a hoarding to prevent people from approaching the building. Arguably, these words are not apt to include only a particular part of the building being considered. The definition of "building" in section 8 of the Act does not assist.

The former Department of Building and Housing stated that, in its view, it was the intention that section 124 of the Building Act 2004 apply to parts of a building that are earthquake-prone. A Determination under the Building Act 2004 clarifying this intention was issued on behalf of the Chief Executive of the former Department of Building and Housing in June 2012. Notwithstanding that Determination we consider that legislative amendment to make it clear that parts of a building are included within sections 122 and 124 would be desirable to put the matter beyond doubt.

7.5.2.2 Immediate action required to repair or demolish a dangerous building that is not earthquake-prone

Territorial authorities also expressed concerns to the Royal Commission about their ability to require the repair or immediate demolition of buildings which, although not earthquake-prone, have been damaged in an earthquake and pose a danger.

For instance, if a building is damaged in a moderate earthquake and parts of the building appear dangerous such that immediate action to fix should be taken:

- section 121 would not apply as it did not happen "in the ordinary course of events (excluding the occurrence of an earthquake)"; and
- section 122 might not apply as the building may not be deemed earthquake-prone, or the statutory processes involved may result in timeframes that are too long to ensure the danger is addressed at an appropriate time.

This means that the general power conferred on territorial authorities by section 129 of the Building Act to take action to avoid immediate danger arising from the state of a building after an earthquake may not be available. That is so because section 129 applies only where there is immediate danger to the safety of people "in terms of section 121 or section 122". We note that in our discussion of the collapse of 605–613 Colombo Street (see section 4.9.4.3) we suggested that the CCC should have considered exercising its power to demolish under section 129. The Council was clearly reluctant to do so, despite the fact that under the Canterbury Earthquake (Resource Management Act) Order 2010 the power could have been exercised without a resource consent.

Appropriate powers to deal with buildings in a dangerous state in the aftermath of the Canterbury earthquakes were conferred by the Canterbury Earthquake Recovery Act 2011, in force from 19 April 2011. Section 38 of that Act authorised the Chief Executive of the Canterbury Earthquake Recovery Authority to carry out or commission certain works. These included the demolition of all or part of a building. That Act also provided, in section 39(2), for notice to be given to the owner or occupier, but under section 39(5) no notice was needed where the work was necessary because of sudden emergency causing or likely to cause loss of life or injury, damage to property (including any adjoining property) or damage to the environment. While section 38(6) of that Act also provided that the section did not override any requirements for resource consents or building consents that might apply to the works, such requirements could be varied by Orders in Council made under the Act.

Conferral of a power in these terms or similar terms would meet the perceived gap in territorial authority powers that was addressed in the submissions to the Royal Commission. We consider that it is important that territorial authorities are able to address buildings that pose a danger due to damage caused by an event such as an earthquake. That should include the ability to take immediate action in respect of a building in a dangerous condition as a result of an earthquake.

Recommendations

We recommend that:

91. The Building Act 2004 should be amended to make it clear that sections 122 and 124 of the Act apply to parts of a building.

92. The Building Act 2004 should be amended to empower territorial authorities to take action where a building is not deemed dangerous under section 121 or earthquake-prone under section 122 but requires immediate repair or demolition due to damage caused by an event such as an earthquake.

7.5.3 Adjacent and adjoining buildings

The Canterbury earthquakes showed there can be a significant risk to buildings that are next to damaged or dangerous buildings. Territorial authorities submitted that they should have the power to enforce a tighter timeframe for repair or other action if a building is affected by the risk of collapse of an adjoining building.

The Building Amendment Bill (No. 4), which is currently before Parliament, would go some way towards addressing this issue, if enacted in the form in which it was introduced. The Amendment would alter sections 124 and 125 of the Building Act 2004 to give councils the ability to restrict entry to affected buildings (defined as buildings which are "adjacent to, adjoining, or nearby a dangerous building as defined in section 121") for particular purposes, or to particular persons. We do not think that it is necessary to go further, in the context of our recommendation that there be set statutory timeframes for the strengthening of earthquake-prone buildings generally.

In addition, many agencies are required to consider different aspects of the consequences of earthquakes. Instances were reported at the Royal Commission's hearings in which communication of knowledge about the state of buildings, which might have been significant, did not take place. As examples, tenants were not advised of risk; neighbours did not appreciate the possibility of an adjacent collapse; and Earthquake Commission (EQC) assessors felt constrained by privacy obligations. This lack of communication is evident in the Royal Commission's findings on the buildings that collapsed causing death discussed in section 4 of this Volume (for examples, see section 4.8: 382 Colombo St, section 4.9: 593 Colombo St, section 4.14: 738 Colombo St, and section 4.25: 391 and 391A Worcester Street). Sharing of knowledge and information can reduce the level of risk that dangerous structures create. We have noted that the privacy provisions of the Earthquake Commission Act 1993 inhibit the sharing of information and we recommend an amendment to these provisions (see section 4.25.4.3 of this Volume). In our opinion statutory bodies, engineers and other professional persons should have a duty to disclose to the relevant territorial authority and any affected neighbour, information of which they have become aware that a building in a dangerous or potentially dangerous condition. Building owners should have a similar obligation in respect of their own tenants, and neighbouring occupiers. Legislation should provide for this duty, and also for the protection of those carrying it out from civil or other liability, or allegations of professional misconduct.

Recommendations

We recommend that:

93. The proposed amendments to sections 124 and 125 of the Building Act 2004 in the Building Amendment Bill (No. 4) should be enacted.
94. Section 32(4) of the Earthquake Commission Act 1993 should be amended to allow for disclosure of information that may affect personal safety. A suggested wording is set out in section 4.25.4.3 of this Volume.
95. Legislation should provide for:
    - a a duty to disclose information that a building is in a dangerous or potentially dangerous condition to the relevant territorial authority and any affected neighbouring occupier;
    - b the above duty to be applied to statutory bodies, engineers and other professional persons who have become aware of the information;
    - c a similar duty on building owners in respect of their own tenants and neighbouring occupiers; and
    - d the protection of those carrying out these duties in good faith from civil or other liability or allegations of professional misconduct.

7.5.4 Buildings divided into separately owned parts.

Mr Joe Arts (owner of a heritage building in the Christchurch CBD) presented evidence to the Royal Commission on the issue of separately owned titles in a building and "party walls". The building that he owned through a family company was built in 1905. He illustrated the weak state of the party wall that separated his part of the building from an adjoining tenancy and indicated that he had to meet the cost of strengthening because of difficulties in securing a contribution from the neighbouring owner without resorting to expensive litigation. He stated that his part of the building could be fully strengthened to meet the current design standard, a process that was underway when the September earthquake struck. However, in order for those works to be effective, it was necessary for the party wall to be strengthened. Mr Arts submitted that there should be a requirement on all owners of parts of a building that will behave in an earthquake as a single structure to strengthen their part of the building at the same time.

A policy for party-wall notification is included in the Dunedin City Council's earthquake-prone buildings policy. Under this policy, if a building is being strengthened, the Council will notify all owners of neighbouring parts of buildings that share party walls and recommend that they should also strengthen their building and work cooperatively with the other building-part owners.

There is a similar issue that needs to be addressed which arises when walls become end walls as a result of the removal of walls on a neighbouring property which have previously provided support to the adjoining building (see the discussion of the building at 246 High Street in section 4.19 of this Volume for an illustration of this issue).

There are three possible options to address the matter of separately owned parts of a building, as discussed below.

Option 1: Do nothing

Advantages	Disadvantages
Maintains property rights of individual owners	Potential inconsistency in the strengthening levels of the entire building

Option 2: Include a policy in the territorial authority's earthquake-prone encouraging concurrent action by building-part owners

Advantages	Disadvantages
Maintains property rights of individual owners	Has persuasive value only as territorial authorities can only recommend strengthening
Market forces will impact on owners' decision to strengthen building	Territorial authorities can take different approaches on whether to include in an earthquake-prone policy
Potentially increased resistance to earthquakes	Possible adverse reaction from building owners
Costs to strengthen fall equally on all owners	

Option 3 – Ensure by legislation that separately owned parts of a building are strengthened contemporaneously as part of the requirement to strengthen to 34% ULS (or a higher percentage where that is the territorial authority's policy)

Advantages	Disadvantages
Consistency	Would remove owners' property rights
Increased safety for building occupiers	Adverse reaction from building owners not intending to strengthen their part of the building on the same timeframe
Overall strengthening required by law means whole building to be addressed in any case	
Potentially increased resistance to earthquakes	
Costs to strengthen fall equally on all owners	

If this matter is not addressed, owners of different parts of a building may not take collective action at the same time, which would be more efficient, provident and effective. The objective of earthquake strengthening to a nationally set standard within definite timeframes is unlikely to be achieved if owners of individual titles in what is effectively one building cannot be compelled to strengthen at a similar time. While it would be possible for the issues to be resolved in litigation before the Courts, resources would be better allocated to carrying out the strengthening works for the whole building at one time. Providing through legislation an appropriate process by which the relevant issues could be resolved between owners is likely to result in more efficient, effective and timely implementation of the strengthening objectives.

Recommendations

We recommend that:

96. Legislation should ensure that all portions of a structure are included in the requirement to strengthen buildings to achieve the minimum level required by the legislation by the due date. In drafting the legislation, consideration should be given to providing for a fair process in which all owners of a building divided into separate titles may be required to strengthen the building at the same time

97. Territorial authorities should be authorised and required to ensure the acceptable strength of remaining walls, particularly end walls, when issuing building consents for the removal of adjoining walls.

7.5.5 Altering an existing building

Section 112 of the Building Act 2004 deals with alterations to existing buildings. Section 112(1) prevents building consent authorities from issuing building consents for alterations unless satisfied that, after the alteration, the building will comply as nearly as is reasonably practicable with the provisions of the Building Code that relate to means of escape from fire and access and facilities for persons with disabilities. The subsection provides:

> A building consent authority must not grant a building consent for the alteration of an existing building, or part of an existing building, unless the building consent authority is satisfied that, after the alteration, the building will-
>
> (a) comply, as nearly as is reasonably practicable… with the provisions of the building code that relate to-
>
> (i) means of escape from fire; and
>
> (ii) access and facilities for persons with disabilities (if this is a requirement under section 118); and
>
> (b) continue to comply with the other provisions of the building code to at least the same extent as before the change of use.

The Royal Commission heard evidence that section 112(1)(a)(ii) can operate as an impediment to building owners strengthening their buildings. This is because many old or historic buildings are difficult to alter to allow for disabled access, and in some cases there can be heritage and resource consent issues that need to be pursued. The need to comply with this provision has added a cost consideration that has been influential in the decision whether or not to proceed with the strengthening work.

Representatives of the former Department of Building and Housing informed the Royal Commission that this provision was included at Select Committee stage when the Building Act 2004 was being considered by Parliament, and it was not then envisaged that it would be an impediment to earthquake strengthening being undertaken.

While it is important that egress from a building at a time of fire or earthquake (section 112(a)(i)) remains subject to this rule, we consider it would be preferable if building consents could be issued for strengthening works without the need to comply with the disabled access rule. We say that having regard to the need to strike an acceptable balance between cost and strengthening work, and the desirability of the latter actually being carried out. This objective could be achieved by simply adding words of exemption to the provision, limited to building consents for works to strengthen the building.

Recommendation

We recommend that:

98. Section 112(1) of the Building Act 2004 should be amended to enable building consent authorities to issue building consents for strengthening works without requiring compliance with section 112(1)(a)(ii). The existing provision would continue to apply to building consents for other purposes.

7.5.6 Inclusion of residential buildings

As has been seen, section 122(1) of the Building Act 2004 defines buildings as earthquake-prone by reference to the ability of buildings to survive a moderate earthquake. However, the subsection does not apply to all kinds of buildings, because section 122(2) excludes buildings that are used wholly or mainly for residential purposes unless they are of two or more storeys, or contain three or more household units. In the result the vast majority of dwellings are not covered by the legislation.

Several territorial authorities submitted to the Royal Commission that residential buildings should be included in the definition of earthquake-prone buildings. Wellington City Council, for example, submitted that, although mandatory strengthening requirements should not apply to residential buildings, territorial authorities should be able to take action in respect of particular elements, e.g. unreinforced masonry chimneys, concrete tile roofs, and substandard foundations. Wellington City advised us that it has endeavoured to take a proactive approach to this by encouraging homeowners to secure or fix these parts of their homes.

Advantages and disadvantages of considering residential buildings as earthquake-prone buildings are set out in the following table.

Advantages	Disadvantages
Safer residential building stock	Cost impact for building owners
Owners/potential owners and tenants will have more information about the status of the house they are living in	Increased workload for territorial authorities due to the potential assessment of buildings
Buildings or parts of buildings that are hazards in significant earthquakes are able to be made safer	

There are clearly some elements of residential buildings that pose hazards in earthquakes, for example, unreinforced masonry chimneys, and it is desirable that these should be made more resilient. We also consider that the significance of this issue is one that will vary across New Zealand, depending on the seismic risk of the region and the nature of the housing stock. We therefore consider that this should be addressed by territorial authorities in consultation with their communities.

Recommendation

We recommend that:

99. The Building Act 2004 should be amended to authorise territorial authorities to adopt and enforce policies to address hazardous elements in or on residential buildings (such as URM chimneys), within a specified completion timeframe consistent with that applied to non-URM earthquake-prone buildings in their district.

7.6 Addressing the cost of strengthening existing buildings

As discussed in section 7.3.1 above, the cost of strengthening existing buildings across New Zealand to 34% ULS, and addressing the main hazard elements of unreinforced masonry buildings, is very significant. The Royal Commission has heard from several parties that the costs of upgrade can be a significant barrier to, for example, the retention of historic buildings, leading to inaction due to competing claims on resources. The Property Council submitted that there should be changes in the taxation regime to allow for the deductibility of earthquake strengthening expenditure. It was noted that, historically, the treatment has been that such costs must be capitalised, meaning that effectively there is no ability to deduct because of the removal of tax depreciation on buildings.

The Property Council urged the Royal Commission to recommend that the Government change the tax regime to allow for the deductibility of strengthening costs.

We do not consider that this is a matter on which we can properly make a recommendation under our Terms of Reference. Indeed, funding for, or other assistance mechanisms to support, the strengthening of earthquake-prone buildings (including heritage buildings) are not matters our Terms of Reference require us to address. However, we record our view that it is important that barriers to addressing the risk posed by earthquake-prone buildings are considered, and removed or mitigated as and where possible.

7.7 Impediments to the rebuild, repair, or demolition of dangerous buildings – the Resource Management Act 1991 and the Historic Places Act 1993

District plans made under the Resource Management Act 1991 contain provisions that require resource consent applications to be made where buildings are scheduled for protection. Buildings are typically scheduled for protection where they are considered by territorial authorities to be of special merit in terms of architectural, historical or other qualities, such as impact on the streetscape or significance as part of a group of buildings. It is also common for district plans to rank protected buildings in accordance with the assessed importance of particular buildings, and to provide for different kinds of resource consent accordingly. Depending on the nature of the alteration proposed (e.g. the action proposed might be minor or significant, or it might be proposed to demolish the building altogether), applications for resource consent may or may not be publicly notified. District plans are made following a public process in which affected persons and members of the public have the right to make submissions, and to pursue arguments about the provisions at hearings before the councils, and in the Environment Court. Notionally, at least, when the various statutory procedures have been completed and the district plan becomes operative, its provisions reflect the community's collective view as to the rules that should govern the use of land and buildings in the district.

There is a quite separate process under the Historic Places Act 1993, which also seeks to recognise buildings that are of historical or cultural significance. That Act seeks to promote the identification, protection, preservation and conservation of the historical and cultural heritage of New Zealand (see section 4). The New Zealand Historic Places Trust maintains a register of historic places, historic areas, wahi tapu and wahi tapu areas. While inclusion in the register provides recognition of the importance of a building, it does not provide statutory protection. However, territorial authorities must have regard to the register in preparing their district plans. In addition, the New Zealand Historic Places Trust will usually be treated as an affected party in the case of applications for consent to alter a registered building that is also scheduled in a district plan.

Further, there are provisions in the Historic Places Act that relate to archaeological sites. Under section 2 of that Act, an archaeological site is defined so as to include, among other things, any place in New Zealand that was associated with human activity that occurred before 1900, or any place that is or may be able (after investigation by archaeological methods) to provide evidence relating to the history of New Zealand. It is unlawful to destroy, damage or modify any archaeological site without the authority of the New Zealand Historic Places Trust. Buildings erected prior to 1900 might be within this definition, and if so, their demolition would require the Trust's authority.

We heard evidence of cases where it is clear that the need to obtain a resource consent delayed demolition of buildings in Christchurch after the September earthquake, and the building subsequently collapsed in February causing loss of life. We refer in particular to the building at 605–613 Colombo Street discussed in section 4.12.2.4 of this Volume.

The Royal Commission considers that the immediate securing of dangerous buildings should not be impeded by the consent process and that life safety should be a paramount consideration for all buildings, regardless of heritage status. We consider that it would be appropriate for legislation to make it plain that, where a building is in a state that makes demolition or the carrying out of other works necessary to protect persons from injury or death, no consent for those works is required, regardless of whether the building is protected by a district plan or registered under the Historic Places Act.

Recommendation

We recommend that:

100. Legislation should provide that, where a building is in a state that makes demolition or protective works necessary to protect persons from injury or death, no consent is required, regardless of whether the building is protected by a district plan, or registered or otherwise protected under the Historic Places Act 1993.

7.8 Knowledge

7.8.1 Public Information and education

The Royal Commission considers there is considerable confusion and misunderstanding among building owners, tenants and territorial authorities about the risk buildings pose in earthquakes, what an assessment of building strength means, the likelihood of an earthquake, and the legal obligations under the Building Act 2004 for earthquake-prone buildings. This contributes to inaction and delay in addressing earthquake-prone buildings. It is desirable in particular that building owners have a better understanding of their rights and obligations. The Royal Commission believes that raising awareness about these matters would be of significant assistance in addressing earthquake-prone buildings.

We also consider that territorial authorities should be required to maintain and publish a schedule of earthquake-prone buildings. We have noted in section 7.4.2 that implementation of the changes in our Recommendation 80 above would result in territorial authorities having databases of the earthquake-prone buildings in their district. We consider that the creation of public knowledge about the status of a building as earthquake-prone would be an effective means of encouraging the strengthening of existing buildings.

Recommendations

We recommend that:

101. Territorial authorities should be required to maintain and publish a schedule of earthquake-prone buildings in their districts.

102. The Ministry of Business, Innovation and Employment should review the best ways to make information about the risk buildings pose in earthquakes available to the public and should undertake appropriate educational activities to develop public understanding about such buildings.

103. The engineering and scientific communities should do more to communicate to the public the risk buildings pose in earthquakes, what an assessment of building strength means, and the likelihood of an earthquake.

7.8.2 Roles of other parties

The Royal Commission heard evidence from which we conclude that there is a lack of knowledge amongst industry participants, such as insurers, valuers and property managers, about the risks involved with earthquake-prone buildings and the legal obligations under the Building Act 2004. These parties play an influencing role in the market, through pricing, purchasing and leasing advice. This lack of knowledge has potentially prevented building owners and tenants making informed decisions about the risk from, and requirements for, earthquake-prone buildings. Parties who are in an advisory position to building owners and tenants need to ensure that they understand, to an appropriate level, the issues relating to earthquake-prone buildings, and that this information is communicated to those they are advising in an understandable way.

Recommendations

We recommend that:

104. Industry participants, such as insurers, valuers, and property managers, should ensure that they are aware of earthquake risks and the requirements for earthquake-prone buildings in undertaking their roles, and in their advice to building owners.

105. The Ministry of Business, Innovation and Employment should support industry participants' awareness of earthquake risks and the requirements for earthquake-prone buildings through provision of information and education.

7.8.3 Territorial authorities and subject matter experts

We have noted above that assessing and strengthening existing buildings is a task requiring specialist knowledge and expertise. We consider that territorial authorities and subject matter experts (such as academics and specialist practising structural engineers) would benefit from sharing information and research among themselves on assessing, and seismic retrofit techniques for, particular kinds of buildings. Unreinforced masonry buildings would be a particularly useful subject for such information sharing due to their specific (and common) characteristics and location throughout New Zealand. Information currently under development that would assist in respect of unreinforced masonry buildings is discussed in section 6.3.3 of this Volume.

Recommendation

We recommend that:

106. Territorial authorities and subject matter experts should share information and research on the assessment of, and seismic retrofit techniques for, different building types.

References

1. Earthquake impacts modelled were MM8 to MM11 on the Modified Mercalli Intensity scale, representing damage states from 'heavily damaging' to 'devastating'. Earthquakes less than MM8 were excluded on the basis they only cause limited damage. Earthquakes above MM11 were excluded as they have a probability of occurrence near to zero for New Zealand towns and cities. We discuss the Modified Mercalli Intensity scale, as well as other measures of earthquake magnitude in section 2.6.1 of Volume 1.

2. Includes pre-1976 buildings only. If post-1976 buildings were to be included, the cost of strengthening to 67% ULS would be substantially higher, with only a small relative increase in benefits.

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

4. New Zealand Historic Places Trust. (March 2012). *Heritage Buildings*, *Earthquake Strengthening and Damage: The Canterbury Earthquakes September 2010–January 2012: Report for the Canterbury Earthquakes Royal Commission*. Wellington, New Zealand: Author.

5. McClure, J., Wills, C., Johnston, D. and Recker, C. (2011). How the 2010 Canterbury (Darfield) earthquake affected earthquake risk perception: Comparing citizens inside and outside the earthquake region. *Australasian Journal of Disaster and Trauma Studies*, Volume 2011(2): 3-10.

6. Hudson-Doyle, E.E. (June 2010). Communicating uncertainty to the public: Brief report on key literature and recommendations. Extracted from Hudson-Doyle, E.E., (et. al.) (2011). *Communicating Uncertainty in Natural Hazard Events*. Manuscript in preparation.

Appendix 1: Seismic retrofit case studies

Beca

Below are cases studies provided by Beca Carter Hollings and Ferner Limited. These ranged in complexity and cost, however it is not possible to draw general conclusions from the case studies due to their uniqueness.

1932 Church, Auckland

This church is a Category I historic place in the traditional layout with bell tower, tall narrow nave, aisles, transept, ceiling vaulting, etc. The era of construction spanned the Napier earthquake in 1931. After the earthquake the architect introduced a gravity concrete frame system in response to concerns at the time, but essentially the bulk of the building comprises load-bearing unreinforced brick. This church was strengthened in 2008 after it was deemed earthquake-prone due to a fundamental load path deficiency across the nave, and poor face load performance of some large brick wall panels.

The church was strengthened to 50% NBS as it was believed that this had no real impact on the historic fabric and it would deliver a substantial reduction in risk to occupant safety.

The church was strengthened in the following way. Ground beams were installed between existing concrete pilasters in the floor cavity beneath the aisles to create upside-down portal frames. Similarly, the existing steel roof trusses were connected to the concrete pilasters at eaves level to ensure they also became portals. Steel rod roof bracing was installed to stop the building components moving independently (including bell tower). The bracing also served to tie back the top of the four tall gable walls. Steel “strong-back” beams were installed behind large high brick wall panels to improve their face load performance. Stainless helically wound drill-in brick cavity ties were installed from the exterior to tie the thin outer brick skin to the much thicker inner one (large gable brick wall panels treated only). Selected sensitive brittle stone ornamentations were discretely “pinned” back.

The cost of this work in 2008 was $300,000 for a floor area of 700m^2, which equated to $430/m^2.

1972 Church, Hawke’s Bay

This was a small single level building comprising largely unreinforced concrete block masonry walls with a high stud height and a timber-framed roof. The building was deemed earthquake-prone due to a load path deficiency, principally a lack of a roof and ceiling diaphragm. The unreinforced front gable wall was also found to be lacking performance under face loading. The target performance level of the church was 67% NBS. However, any new structural components added were detailed to achieve 100% NBS on the basis that the owner could retrofit to an even higher level of performance in the future if necessary. This was found to be achievable without significant extra cost.

The church is to be strengthened in the following way. A plywood ceiling diaphragm is to be added to provide a load path for lateral loadings. A 100mm thick reinforced concrete overlay is to be added to the front gable wall to improve the face load performance of this unreinforced element. An existing Fibrolite lined timber gable wall will be re-lined in plywood to improve its in-place resistance and connection to the new ceiling diaphragm and existing foundation.

The anticipated cost of this work in 2011 was $200,000 for a floor area of 260m^2. This equates to $770/m^2 [1].

The Birdcage, Auckland

This is a two storey, Category I, historic building constructed around 1886 in unreinforced brick. The building has timber suspended floors, two chimneys and a corrugated iron roof on timber framing. The building was deemed earthquake-prone due to its reliance on load-bearing unreinforced masonry brick walls and a nominal connection to the timber floor and roof diaphragms.

The main reason for the strengthening and restoration work was the need for the temporary move of the building while excavation work on the new Victoria Park tunnel was undertaken. The target performance level was as near as practicable to 100% NBS and the new ground floor of the building was re-built as a suspended concrete slab.

The building was strengthened in the following way. The rear walls were overlain by a shotcrete wall with drilling epoxy dowels securing the existing brick masonry. A plywood diaphragm was constructed to the underside of the first floor and also above the second floor ceiling. Steel chords were installed to the perimeter of each diaphragm. The two front ornamental walls and two internal walls were post-tensioned vertically to improve their face load performance. Concrete ring beams were installed both sides of all walls to facilitate the relocation but also to anchor the vertical post-tensioning noted above. The chimneys were strengthened flexurally with carbon fibre strips and tied back to the roof.

The cost of the strengthening work in 2010 was $1,440,000 for a floor area of 400m^2. This equated to $3,600/m^2.

Opus

Opus International Consultants Ltd provided four case studies to demonstrate seismic retrofit of buildings and how they performed after the earthquakes. All of these buildings differ in complexity with the costs estimated at 100–120% of a new building. Opus have not been able to supply the cost per square metre.

The following seismic retrofit of buildings performed well in the earthquakes:

- Ivey Hall, Lincoln University;
- Christchurch Boys' High School, Main Block; and
- Christchurch Family Court.

The Christchurch Environment Court did not perform well and suffered moderate to severe damage as a result of the February 2011 earthquake.

Ivey Hall, Lincoln University

The Ivey Hall building at Lincoln University was originally constructed in 1880 as a residence for students and the Director of the School of Agriculture. Extensions were made in 1881, 1918 and in 1923. The building was a two storey unreinforced concrete and brick building structure of approximately 38m x 38m in floor plan area. The building includes many ornate features including gable walls with parapets and a tower and clock above the main entrance.

The structural retrofit of this building involved the complete removal and replacement of the original internal structure and was carried out in 1986. This makes the work more of a façade retention and rebuild than a retrofit. A new slab on ground was installed at the lowest level, with spray concrete installed to the inside of all external walls from this new slab up to the parapet level. A series of shear walls were installed towards the northern end of the building from the ground floor to the ceiling level of the upper storey. An entirely new level 1 floor structure was installed using a rib and infill system supported on reinforced concrete beams and columns. The new high level ceiling system includes a combination of a ply diaphragm and steel angle cross bracing. The pitched roof has a series of tubular steel trusses.

The structural retrofit to the existing brick walls at Ivey Hall was designed to comply with 67% of the loading Standard of the day (NZS 4203:1984[3]). The other new elements within the building were designed to comply with 100% of this Standard.

The Ivey Hall building has generally performed well in the February earthquake and following aftershocks. The newer components from the internal rebuild show only minor signs of damage. The main area of noticeable damage was limited to the original façade, where cracks have formed in brick and stone elements.

As the work carried out at Ivey Hall was a façade retention and complete rebuild, the cost of this work has been placed at approximately 100–120 per cent of the cost of a new building (at the time of the work), when compared to the general cost of a typical university building with a similar floor area and function. The reasons for the construction work costing more than an entire rebuild are to do with the costs associated with the façade retention, increased care required during the demolition and the need to work within and around the confines of the original building.

Christchurch Boys' High School, Main Block

The Main Block at Christchurch Boys' High School was built at the Te Kura Street, Riccarton site in 1926. The Main Block includes a two storey brick masonry building approximately 100m long and 12m deep. The building includes an ornate concrete clock tower above the main entrance.

The structural retrofit, designed in 1987, included the installation of shotcrete (spray concrete) to the inside face of all of the existing brick walls in order to increase the strength of these walls. Both the shotcrete to the external walls and the new internal walls were installed from the footings up to the roof structure. Dowel bars were used to tie the brickwork to the new concrete structure. Internal concrete walls were also added in both the longitudinal and transverse directions to resist lateral loads in both directions. The existing level 1 concrete floor system was retained and tied into the retrofit works. Other items strengthened included the clock tower, using an internal shotcrete lining and the brick parapets, which were restrained with structural steel members fixed to the back of the parapet and attached to the roof structure.

The structural retrofit to the existing brick walls at the Christchurch Boys' High School Main Block was designed to comply with 67% of the loading Standard of the day (NZS 4203:1984[3]). The other new elements within the building were designed to comply with 100% of this Standard. The Main Block at Christchurch Boys' High School has performed well in the recent seismic events. The main areas of damage were isolated areas of dislodged brick work, especially at the gable end walls. There was also some minor damage to the clock tower and to non-structural items throughout the building.

The cost of the retrofit work carried out at Christchurch Boys' High School Main Block has been placed at approximately 100–120 per cent of the cost of a new building (at the time of the work), when compared to the general cost of a typical Ministry of Education building with a similar floor area and function. The reasons for the construction work costing more than an entire rebuild are to do with the costs associated with working around the existing structure, increased care required during demolition of certain elements and the need to work within and around the confines of the original building.

Family Court, Christchurch

The Family Court building, located at 85 Armagh Street in Central Christchurch, was first constructed as the Magistrates Court in 1881, with a series of additions added in 1908. The building is listed with the Historic Places Trust as a Category I Historic Building. The building is a stone clad brick structure with a single story section in the south west and north east corners and two storey sections in the south east and north corners. The floors in the strengthened building are typically reinforced concrete slabs and the roof structures are constructed from timber framing. The building includes high gable end walls on the western façade, large ornate chimneys and parapets in several locations.

The structural retrofit carried out in 1997 involved the removal of one layer of the internal brick wall and the installation of a 150mm thick reinforced shotcrete lining, dowelled on a regular pattern to the existing masonry walls. The original ground floor timber frame floor was removed to allow the shotcrete to continue to the footings. The timber-framed ground floor system was replaced with a concrete rib and timber infill floor system. Steel members were introduced into the roof structure in the single storey section in the south west corner. For the two storey sections, the original timber floor systems were set into the new concrete lining. Individual dowel bars were used to restrain the parapet capping stones.

The structural retrofit at the Family Courts was designed to comply with 67% of the loading Standard[4] of the day.

The Family Court building has in general performed very well in the recent seismic events. Only minor damage has been noted to the spray concrete walls, where shrinkage cracks from the original construction have opened up slightly in the upper level plant room. There is an internal concrete masonry wall with large (20mm wide) cracks adjacent to the Armagh 2 Courtroom. Otherwise, the damage is limited to minor cracks and potential minor sloping in the ground floor slab as a result of differential settlement due to liquefaction and lateral spreading. During the inspection process, the carpets were removed and the slab was found to be in satisfactory condition. The concrete filled chimneys have suffered noticeable damage and have been removed and will be reinstated. There were cracks throughout the building to non-structural linings.

The cost of the retrofit work carried out at the Family Court building has been placed at approximately 100–120% of the cost of a new building (at the time of the work), when compared to the general cost of a typical Ministry of Justice building with a similar floor area and function. The cost of the retrofit reflects the extensive building works carried out, the labour intensive nature of this type of retrofit and the high level of finishes used for the fit out.

Environment Court, Christchurch

The Environment Court building at 282–286 Durham Street, Christchurch, was constructed for the Canterbury Society of Arts in 1890 as a gallery space. A second adjacent building of similar design was added in 1894. The buildings were constructed of unreinforced brick masonry with steel roof trusses. Both buildings had few external windows in order to provide internal wall space to display the art. The buildings were essentially a high single storey building, though there was a two level section towards the rear of the building. The buildings were acquired by the Ministry of Justice in 1972, when the space was renovated into two court rooms with judge's chambers and jury rooms. At this time, a reinforced concrete block extension was added to the rear adjacent to Armagh Street.

The building was strengthened in 1972. The strengthening included removing ornate decorations and a series of steel elements were added. These steel elements included vertical channel sections under the existing steel roof trusses, and horizontal channel sections internally at approximately quarter points up the height of the walls. Externally, steel bands were added and fixed back to the internal channels. Plate cross bracing was added to the roof and also to a number of wall sections.

The structural retrofit to the existing brick walls at the Environment Court was designed to comply with 67% of the loading Standard[5] of the day.

The Environment Court building suffered moderate to severe damage as a result of the 22 February 2011 earthquake. The top of the tall gable end wall to the rear of the building has fallen outwards. There were several tension-only braces in the roof space that failed. The amount of movement to the internal linings of the external walls suggest that sections of the wall bracing failed. This is consistent with the level of damage noted around the footings for the new wall bracing.

There were also isolated areas of loose bricks around the external façade.

The cost of the retrofit work carried out at Environment Court has been placed at approximately 100–120% of the cost of a new building (at the time of the work), when compared to the general cost of a typical Ministry of Justice building with a similar floor area and function. The cost of the retrofit reflects the extensive building works carried out and the difficulties associated with this level of retrofit.

Conclusions

Overall, the costs of retrofitting a building can vary on the size and complexity of the task. The main techniques used were

- tie back of gable walls and facades;
- steel bracing;
- shotcrete; and
- plywood diaphragms added.

The costs of the retrofits can vary ranging from \$430/m^2 to \$3,600/m^2 for a complex project like the Birdcage. All of the Opus examples cost between 100–120 per cent of a new building.

The Opus examples were all retrofitted to 67% of the current loading Standard at the time the building was strengthened.

All of the buildings in Christchurch performed well with the exception of the Environment Court, which has now been demolished.

References

1. Cost of strengthening works only. GST and prior engineering assessment costs excluded.

2. Approximate cost of strengthening works only inclusive of concrete ring beam to base of walls also required to facilitate relocation. GST and prior engineering assessment costs excluded.

3. NZS 4203:1984. *Code of Practice for General Structural Design and Design Loadings for Buildings*, Standards New Zealand.

4. NZS 4203:1996. *Code of Practice for General Structural Design and Design Loadings for Buildings*, Standards New Zealand.

5. NZSS 1900:1965. *Chapter 8 – Basic Design Loads*, Standards New Zealand. P 12: 1965 a commentary on Chapter 8 of NZSS 1900:1965. PW 81/10/1 1970. NZSS 1900: Chapter 8:1965 required public buildings in Zone B (Christchurch) to be designed for a seismic coefficient of 0.12g.

Note that Standards New Zealand was previously known as the Standards Institute of New Zealand.

Appendix 2: Terms of Reference

Royal Commission of Inquiry into Building Failure caused by Canterbury Earthquakes

Elizabeth the Second, by the Grace of God Queen of New Zealand and her Other Realms and Territories, Head of the Commonwealth, Defender of the Faith:

To The Honourable MARK LESLIE SMITH COOPER, of Auckland, Judge of the High Court of New Zealand;
Sir RONALD POWELL CARTER, KNZM, of Auckland, Engineer and Strategic Advisor; and
RICHARD COLLINGWOOD FENWICK, of Christchurch, Associate Professor of Civil Engineering:

GREETING:

Recitals

WHEREAS the Canterbury region, including Christchurch City, suffered an earthquake on 4 September 2010 and numerous aftershocks, for example—

(a) the 26 December 2010 (or Boxing Day) aftershock; and

(b) the 22 February 2011 aftershock:

WHEREAS approximately 180 people died of injuries suffered in the 22 February 2011 aftershock, with most of those deaths caused by injuries suffered wholly or partly because of the failure of certain buildings in the Christchurch City central business district (CBD), namely the following 2 buildings:

(a) the Canterbury Television (or CTV) Building; and

(b) the Pyne Gould Corporation (or PGC) Building:

WHEREAS other buildings in the Christchurch City CBD, or in suburban commercial or residential areas in the Canterbury region, failed in the Canterbury earthquakes, causing injury and death:

WHEREAS a number of buildings in the Christchurch City CBD have been identified as unsafe to enter following the 22 February 2011 aftershock, and accordingly have been identified with a red card to prevent persons from entering them:

WHEREAS the Department of Building and Housing has begun to investigate the causes of the failure of 4 buildings in the Christchurch City CBD (the 4 specified buildings), namely the 2 buildings specified above, and the following 2 other buildings:

(a) the Forsyth Barr Building; and

(b) the Hotel Grand Chancellor Building:

WHEREAS it is desirable to inquire into the building failures in the Christchurch City CBD, to establish—

(a) why the 4 specified buildings failed severely; and

(b) why the failure of those buildings caused such extensive injury and death; and

(c) why certain buildings failed severely while others failed less severely or there was no readily perceptible failure:

WHEREAS the results of the inquiry should be available to inform decision-making on rebuilding and repair work in the Christchurch City CBD and other areas of the Canterbury region:

Appointment and order of reference

KNOW YE that We, reposing trust and confidence in your integrity, knowledge, and ability, do, by this Our Commission, nominate, constitute, and appoint you, The Honourable MARK LESLIE SMITH COOPER, Sir RONALD POWELL CARTER, and RICHARD COLLINGWOOD FENWICK, to be a Commission to inquire into and report (making any interim or final recommendations that you think fit) upon (having regard, in the case of paragraphs (a) to (c), to the nature and severity of the Canterbury earthquakes)—

Inquiry into sample of buildings and 4 specified buildings

(a) in relation to a reasonably representative sample of buildings in the Christchurch City CBD, including the 4 specified buildings as well as buildings that did not fail or did not fail severely in the Canterbury earthquakes—

  (i) why some buildings failed severely; and

  (ii) why the failure of some buildings caused extensive injury and death; and

  (iii) why buildings differed in the extent to which—

    (A) they failed as a result of the Canterbury earthquakes; and

    (B) their failure caused injury and death; and

  (iv) the nature of the land associated with the buildings inquired into under this paragraph and how it was affected by the Canterbury earthquakes; and

  (v) whether there were particular features of a building (or a pattern of features) that contributed to whether a building failed, including (but not limited to) factors such as—

    (A) the age of the building; and

    (B) the location of the building; and

    (C) the design, construction, and maintenance of the building; and

    (D) the design and availability of safety features such as escape routes; and

(b) in relation to all of the buildings inquired into under paragraph (a), or a selection of them that you consider appropriate but including the 4 specified buildings,—

  (i) whether those buildings (as originally designed and constructed and, if applicable, as altered and maintained) complied with earthquake-risk and other legal and best-practice requirements (if any) that were current—

    (A) when those buildings were designed and constructed; and

    (B) on or before 4 September 2010; and

  (ii) whether, on or before 4 September 2010, those buildings had been identified as “earthquake-prone” or were the subject of required or voluntary measures (for example, alterations or strengthening) to make the buildings less susceptible to earthquake risk, and the compliance or standards they had achieved; and

(c) in relation to the buildings inquired into under paragraph (b), the nature and effectiveness of any assessment of them, and of any remedial work carried out on them, after the 4 September 2010 earthquake, or after the 26 December 2010 (or Boxing Day) aftershock, but before the 22 February 2011 aftershock; and

Inquiry into legal and best-practice requirements

(d) the adequacy of the current legal and best-practice requirements for the design, construction, and maintenance of buildings in central business districts in New Zealand to address the known risk of earthquakes and, in particular—

  (i) the extent to which the knowledge and measurement of seismic events have been used in setting legal and best-practice requirements for earthquake-risk management in respect of building design, construction, and maintenance; and

  (ii) the legal requirements for buildings that are “earthquake-prone” under section 122 of the Building Act 2004 and associated regulations, including—

(A) the buildings that are, and those that should be, treated by the law as "earthquake-prone"; and

(B) the extent to which existing buildings are, and should be, required by law to meet requirements for the design, construction, and maintenance of new buildings; and

(C) the enforcement of legal requirements; and

(iii) the requirements for existing buildings that are not, as a matter of law, "earthquake-prone", and do not meet current legal and best-practice requirements for the design, construction, and maintenance of new buildings, including whether, to what extent, and over what period they should be required to meet those requirements; and

(iv) the roles of central government, local government, the building and construction industry, and other elements of the private sector in developing and enforcing legal and best-practice requirements; and

(v) the legal and best-practice requirements for the assessment of, and for remedial work carried out on, buildings after any earthquake, having regard to lessons from the Canterbury earthquakes; and

(vi) how the matters specified in subparagraphs (i) to (v) compare with any similar matters in other countries; and

Other incidental matters arising

(e) any other matters arising out of, or relating to, the foregoing that come to the Commission's notice in the course of its inquiries and that it considers it should investigate:

Matters upon or for which recommendations required

And, without limiting the order of reference set out above, We declare and direct that this Our Commission also requires you to make both interim and final recommendations upon or for—

(a) any measures necessary or desirable to prevent or minimise the failure of buildings in New Zealand due to earthquakes likely to occur during the lifetime of those buildings; and

(b) the cost of those measures; and

(c) the adequacy of legal and best-practice requirements for building design, construction, and maintenance insofar as those requirements apply to managing risks of building failure caused by earthquakes:

Exclusions from inquiry and scope of recommendations

But, We declare that you are not, under this Our Commission, to inquire into, determine, or report in an interim or final way upon the following matters (but paragraph (b) does not limit the generality of your order of reference, or of your required recommendations):

(a) whether any questions of liability arise; and

(b) matters for which the Minister for Canterbury Earthquake Recovery, the Canterbury Earthquake Recovery Authority, or both are responsible, such as design, planning, or options for rebuilding in the Christchurch City CBD; and

(c) the role and response of any person acting under the Civil Defence Emergency Management Act 2002, or providing any emergency or recovery services or other response, after the 22 February 2011 aftershock:

Definitions

And, We declare that, in this Our Commission, unless the context otherwise requires,—

best-practice requirements

includes any New Zealand, overseas country's, or international standards that are not legal requirements

Canterbury earthquakes

means any earthquakes or aftershocks in the Canterbury region—

(a) on or after 4 September 2010; and

(b) before or on 22 February 2011

Christchurch City CBD

means the area bounded by the following:

(a) the 4 avenues (Bealey Avenue, Fitzgerald Avenue, Moorhouse Avenue, and Deans Avenue); and

(b) Harper Avenue

failure

in relation to a building, includes the following, regardless of their nature or level of severity:

(a) the collapse of the building; and

(b) damage to the building; and

(c) other failure of the building

legal requirements

includes requirements of an enactment (for example, the building code):

Appointment of chairperson

And We appoint you, The Honourable MARK LESLIE SMITH COOPER, to be the chairperson of the Commission:

Power to adjourn

And for better enabling you to carry this Our Commission into effect, you are authorised and empowered, subject to the provisions of this Our Commission, to make and conduct any inquiry or investigation under this Our Commission in the manner and at any time and place that you think expedient, with power to adjourn from time to time and from place to place as you think fit, and so that this Our Commission will continue in force and that inquiry may at any time and place be resumed although not regularly adjourned from time to time or from place to place:

Information and views, relevant expertise, and research

And you are directed, in carrying this Our Commission into effect, to consider whether to do, and to do if you think fit, the following:

(a) adopt procedures that facilitate the provision of information or views related to any of the matters referred to in the order of reference above; and

(b) use relevant expertise, including consultancy services and secretarial services; and

(c) conduct, where appropriate, your own research; and

(d) determine the sequence of your inquiry, having regard to the availability of the outcome of the investigation by the Department of Building and Housing and other essential information, and the need to produce an interim report:

General provisions

And, without limiting any of your other powers to hear proceedings in private or to exclude any person from any of your proceedings, you are empowered to exclude any person from any hearing, including a hearing at which evidence is being taken, if you think it proper to do so:

And you are strictly charged and directed that you may not at any time publish or otherwise disclose, except to His Excellency the Governor-General of New Zealand in pursuance of this Our Commission or by His Excellency's direction, the contents or purport of any interim or final report so made or to be made by you:

And it is declared that the powers conferred by this Our Commission are exercisable despite the absence at any time of any 1 member appointed by this Our Commission, so long as the Chairperson, or a member deputed by the Chairperson to act in the place of the Chairperson, and at least 1 other member, are present and concur in the exercise of the powers:

Interim and final reporting dates

And, using all due diligence, you are required to report to His Excellency the Governor-General of New Zealand in writing under your hands as follows:

(a) not later than 11 October 2011, an interim report, with interim recommendations that inform early decision-making on rebuilding and repair work that forms part of the recovery from the Canterbury earthquakes; and

(b) not later than 11 April 2012, a final report:

And, lastly, it is declared that these presents are issued under the authority of the Letters Patent of Her Majesty Queen Elizabeth the Second constituting the office of Governor-General of New Zealand, dated 28 October 1983*, and under the authority of and subject to the provisions of the Commissions of Inquiry Act 1908, and with the advice and consent of the Executive Council of New Zealand.

In witness whereof We have caused this Our Commission to be issued and the Seal of New Zealand to be hereunto affixed at Wellington this 11th day of April 2011.

Witness Our Trusty and Well-beloved The Right Honourable Sir Anand Satyanand, Chancellor and Principal Knight Grand Companion of Our New Zealand Order of Merit, Principal Companion of Our Service Order, Governor-General and Commander-in-Chief in and over Our Realm of New Zealand.

ANAND SATYANAND, Governor-General.

By His Excellency's Command—

JOHN KEY, Prime Minister.

Approved in Council—

REBECCA KITTERIDGE, Clerk of the Executive Council.

**SR 1983/225*

Modifications to Reporting Requirements and Powers of Royal Commission of Inquiry into Building Failure Caused by Canterbury Earthquakes

Elizabeth the Second, by the Grace of God Queen of New Zealand and her Other Realms and Territories, Head of the Commonwealth, Defender of the Faith:

To The Honourable MARK LESLIE SMITH COOPER, of Auckland, Judge of the High Court of New Zealand; Sir RONALD POWELL CARTER, KNZM, of Auckland, Engineer and Strategic Adviser; and RICHARD COLLINGWOOD FENWICK, of Christchurch, Associate Professor of Civil Engineering:

GREETING:

WHEREAS by Our Warrant, dated 11 April 2011, issued under the authority of the Letters Patent of Her Majesty Queen Elizabeth the Second constituting the office of Governor-General of New Zealand, dated 28 October 1983, and under the authority of and subject to the provisions of the Commissions of Inquiry Act 1908, and with the advice and consent of the Executive Council of New Zealand, we nominated, constituted, and appointed you, the said The Honourable MARK LESLIE SMITH COOPER, Sir RONALD POWELL CARTER, KNZM, and RICHARD COLLINGWOOD FENWICK, to be a Commission to inquire into and report (making any interim or final recommendations that you think fit) upon certain matters relating to building failure caused by the Canterbury earthquakes:

AND WHEREAS by Our said Warrant you are required to report finally to His Excellency the Governor-General of New Zealand not later than 11 April 2012:

AND WHEREAS it is expedient that the time and other requirements for reporting under Our said Warrant should be modified as hereinafter provided:

NOW, THEREFORE, We do by these presents require you to report and make final recommendations (required and otherwise) on the matters in Our said Warrant as follows:

(a) not later than 29 June 2012, on matters that would inform early decision-making on rebuilding and repair work that forms part of the recovery from the Canterbury earthquakes;

and

(b) at any time before 12 November 2012 on any other matter, if you are able to do so; and

(c) not later than 12 November 2012, on all matters on which you have not otherwise reported:

AND WHEREAS it is expedient that the powers conferred by Our said Warrant be modified, We do by these presents declare that the powers are exercisable by the Chairperson, or a member deputed by the Chairperson to act in the place of the Chairperson, despite the absence of 1 or 2 of the persons appointed to be members of the Commission, so long as at least 1 other member concurs in the exercise of the powers:

AND it is declared that nothing in these presents affects any act or thing done or decision made by the Commission or any of its members, in the exercise of its powers, before the making of these presents:

And We do hereby confirm Our Warrant dated 11 April 2011 and the Commission constituted by that Warrant, except as modified by these presents:

And, lastly, it is declared that these presents are issued under the authority of the Letters Patent of Her Majesty Queen Elizabeth the Second constituting the office of Governor-General of New Zealand, dated 28 October 1983, and under the authority of and subject to the provisions of the Commissions of Inquiry Act 1908, and with the advice and consent of the Executive Council of New Zealand.

In Witness whereof We have caused these presents to be issued and the Seal of New Zealand to be hereunto affixed at Wellington this 7th day of February 2012.

Witness Our Trusty and Well-beloved Lieutenant General The Right Honourable Sir Jerry Mateparae, Chancellor and Principal Knight Grand Companion of Our New Zealand Order of Merit, Principal Companion of Our Service Order, Governor-General and Commander-in-Chief in and over Our Realm of New Zealand.

[L.S.]

LT GEN SIR JERRY MATEPARAE, Governor-General

By His Excellency's Command-

JOHN KEY, Prime Minister.

Approved in Council-

REBECCA KITTERIDGE, Clerk of the Executive Council.

Appendix 3: Expert advisers

Expert advisers

Jason Ingham, Associate Professor, Department of Civil Engineering and Environmental Engineering, The University of Auckland

Michael Griffith, Professor, Department of Civil, Environmental and Mining Engineering, University of Adelaide

International peer reviewers/experts

Bret Lizundia, Principal, Rutherford & Chekene, Consulting Engineers, San Francisco

Fred Turner, Staff Structural Engineer, Alfred E. Alquist Seismic Safety Commission, California

Appendix 4: Submitters and witnesses

Submission received: Unreinforced masonry (URM) buildings and earthquake-prone buildings policies	
Person or organisation	**Paper**
Mr Joe Arts	*The Canterbury Earthquakes Royal Commission: Unreinforced Masonry and other Earthquake-Prone Buildings: Requirements for Seismic Strengthening*
Auckland Council	*Auckland Council Canterbury Earthquakes Royal Commission Submission*
Christchurch City Council	*Submissions on the Legal Requirement for Earthquake-Prone Buildings and Related Matters (Issues 3(b) to 3(d))*
	Additional submissions on the Legal Requirement for Earthquake-Prone Buildings and Related Matters (Issues 3(b) to 3(d))
Department of Building and Housing	*Submission on "Unreinforced Masonry and other Earthquake-prone Buildings – Requirements for Seismic Strengthening"*
Dr David Hopkins	*The Canterbury Earthquakes: Implications for Building and Construction Standards*
International Council on Monuments and Sites New Zealand	*ICOMOS New Zealand: Submission to the Canterbury Earthquakes Royal Commission*
Local Government New Zealand	*Submission to the Royal Commission in the matter of Inquiry into building failure caused by Canterbury Earthquakes*
Napier City Council	*Brief submission by Napier City Council regarding the Earthquake-Prone Policy adopted by the Napier City Council and its impact on Art Deco heritage buildings*
New Zealand Historic Places Trust	*Submission of New Zealand Historic Places Trust Pouhere Taonga to Canterbury Earthquakes Royal Commission*
New Zealand Society for Earthquake Engineering	*Objectives, status, and future of the 2006 NZSEE Guidelines on "Assessment and Improvement of the Structural Performance of Buildings in Earthquakes"*
	Submission by email on 9 November 2011 regarding the NZSEE Guideline "Assessment and Improvement of the Structural Performance of Buildings in Earthquakes"
Property Council New Zealand	*Submission by Property Council New Zealand Incorporated on the Performance of Unreinforced Masonry Buildings in the 2010/2011 Canterbury Earthquake Swarm*
Mr Adam Thornton	*Submission of Adam William Thornton to the Canterbury Earthquakes Royal Commission: Earthquake-Prone Buildings & Strengthening of Existing Buildings*
Wellington City Council	*Submission on Unreinforced Masonry Buildings – Legal requirements for earthquake-prone buildings*
	Submission by Wellington City Council to Royal Commission of Inquiry into Building Failures Caused by the Canterbury Earthquakes: *"Issue 3 - Legal and best practice requirements"* *"Issue 4 – Change of New Zealand Design Standards/Codes of Practice over time"* *"Issue 6 – Future measures"*

Witnesses who appeared at the hearing for unreinforced masonry (URM) buildings and earthquake-prone buildings policies (7–15 November 2011)		
Person	**Organisation**	**Hearing**
Joe Arts	Christchurch CBD property owner	9 November 2011
Eugene Bowen	Chief Executive, Local Government New Zealand	15 November 2011
Ian Bowman	Conservation Architect, International Council on Monuments and Sites New Zealand	8 November 2011
Bruce Chapman	Chief Executive, New Zealand Historic Places Trust Pouhere Taonga	7 November 2011
Patrick Cummuskey	Special Projects Policy Advisor, Auckland Council	14 November 2011
Bob DeLeur	Manager, Building Policy, Auckland Council	14 November 2011
Glen Hazelton	Policy Planner (Heritage), Dunedin City Council	14 November 2011
Dr David Hopkins		9 November 2011
Jason Ingham	Associate Professor, Department of Civil Engineering and Environmental Engineering, The University of Auckland	7 November 2011
Dr Marion Irwin	Former Hazards Manager, Civil Defence and Emergency Management, Auckland Council	14 November 2011
Rob Jury	New Zealand Society for Earthquake Engineering	15 November 2011
Dave Kelly	Deputy Chief Executive, former Department of Building and Housing	15 November 2011
Bret Lizundia	Principal, Rutherford & Chekene, Consulting Engineers, San Francisco	8 November 2011
Stephen McCarthy	Environmental Policy and Approvals Manager, Christchurch City Council	14 November 2011
Neil McLeod	Chief Building Officer, Dunedin City Council	14 November 2011
Peter Mitchell	General Manager, Regulation and Democracy Services, Christchurch City Council	14 November 2011
Daniel Newman	Policy Director, Property Council New Zealand	9 November 2011
Bob Parker	Mayor, Christchurch City Council	14 November 2011
Bruce Petry	Architect, International Council on Monuments and Sites New Zealand	8 November 2011
Ian Petty	Building Services Manager, Gisborne District Council	14 November 2011
David Reynolds	Heritage Consultant, International Council on Monuments and Sites New Zealand	8 November 2011
Jeremy Salmond	Conservation Architect, International Council on Monuments and Sites New Zealand	8 November 2011
John Scott	Group Manager, Building Consents and Licensing Services, Wellington City Council	14 November 2011
George Skimming	Director, Special Projects, Wellington City Council	14 November 2011
Mike Stannard	Chief Engineer, Department of Building and Housing	9 November 2011
Frances Sullivan	Senior Policy Analyst, Local Government New Zealand	15 November 2011

Witnesses who appeared at the hearing for unreinforced masonry (URM) buildings and earthquake-prone buildings policies (7–15 November 2011)		
Person	**Organisation**	**Hearing**
Neil Taylor	Chief Executive, Napier City Council	14 November 2011
Adam Thornton	Managing Director, Dunning Thornton Consultants	9 November 2011
Suzanne Townsend	Deputy Chief Executive, former Department of Building and Housing	9 November 2011
Fred Turner	Staff Structural Engineer, Alfred E. Alquist Seismic Safety Commission, California	8 November 2011
Celia Wade-Brown	Mayor, Wellington City	14 November 2011

Appendix 5: Glossary of terms

Building safety evaluation	The process of evaluating the suitability of buildings for occupancy following an earthquake. The New Zealand Society for Earthquake Engineering (NZSEE) published *"Building Safety Evaluation during a State of Emergency – Guidelines for Territorial Authorities"* in August 2009. These guidelines refer to Level 1 and 2 Rapid Assessments.
Christchurch City Council's Building Evaluation Transition Team (BETT)	The team was established following the 4 September 2010 earthquake, to preserve public safety and to return to normal operations by: continuing identification of unsafe properties/dwellings; reviewing and updating information held against property files; and reviewing cordon placement.
CPEng	An acronym for Chartered Professional Engineer, which is the title applied to engineers who are registered as such following compliance with requirements set out in the Chartered Professional Engineers of New Zealand Act 2002.
CPEng report	A report on the structural state of a building prepared by a Chartered Professional Engineer.
Diaphragm	A structural element that transmits in-plane forces (diaphragm forces) to and between lateral-force-resisting elements. In buildings, floors usually act as diaphragms and are occasionally called diaphragms. Diaphragm forces are the in-plane forces acting in a floor (diaphragm).
Earthquake-prone building policy	The Building Act 2004 required territorial authorities to adopt a policy on earthquake-prone buildings within its district and then to review the policy within five years. The CCC adopted a policy on 25 May 2006 and, following a review, a further policy on 10 September 2010.
Earthquake-risk building	A building is assessed as an earthquake-risk building if, when assessed against the minimum requirements in current buildings standards, it satisfies between 33% and 67% of the minimum design actions for strength and ductility for the ultimate limit state.
Epoxy fittings	An adhesive connection used to fix elements to each other.
g	A unit of measurement of the force exerted on a building by an earthquake compared to the force of gravity. 1g represents the force imposed by gravity. 0.5g is half the force imposed by gravity.
Hazardous appendage survey	The CCC conducted surveys of some buildings to determine the state of appendages such as parapets, chimneys and cornices, and to identify the presence of loose masonry, mortar deterioration and cracking.
Heritage building (or historic building)	The New Zealand Historic Places Trust maintains a register of historic places, historic areas, wahi tapu and wahi tapu areas under the Historic Places Act 1993. In addition, the CCC lists heritage buildings in the CCC District Plan. A building entered on the Trust's register and/or listed in the District Plan is often referred to as a heritage building.
Horizontal accelerations	The extent to which the ground accelerates in a horizontal direction at a particular site as a result of an earthquake.
In-plane and out-of-plane forces	Forces acting in the plane of a wall as distinct from out-of-plane forces, which act in a direction normal (at right angles) to the face of the wall.
Initial Evaluation Procedure (IEP)	Initial evaluation procedure, made to establish buildings that are likely to be earthquake-prone or earthquake-risk buildings.

Level 1 Rapid Assessment	An initial post-earthquake evaluation of a building based upon an external visual inspection only.
Level 2 Rapid Assessment	A post-earthquake evaluation of a building based upon an internal and external inspection of a building. The NZSEE Guidelines state that it will include reference to available drawings, but calculations are not envisaged. The Royal Commission heard that invasive examination was not conducted as part of these assessments.
New Building Standard (NBS)	Building Codes prescribe the standard a new building should be constructed to, including its seismic strength. The concept is based on the principle that, where a building is constructed or strengthened to a standard equivalent to the requirements of the Code, it can be described as 100% NBS. It is also sometimes referred to as Full Code Loading (FCL), on the basis that the Building Code requires a new building to be capable of sustaining a certain amount of force, or load. A building constructed or strengthened to FCL should be capable of sustaining the loading required by the Code.
Precast concrete façade panels (or spandrel panels)	Non-structural elements placed on the exterior of a building.
Seismic risk building survey	The CCC conducted surveys to determine the seismic risk of some of the buildings that were the subject of hearings. Where these surveys had been carried out, they took place in 1991 or 1992, although some were conducted in the 1970s. The survey involved ascribing a numerical rating of different characteristics of the building, following which the building would be classified on an A to D scale. A classification of A led to a recommendation of immediate action; B and C, remedial action within two and ten years respectively; and D, no action if the building was well maintained.
Ultimate Limit State (ULS)	See Volume 1, section 3: Introduction to Seismic Design of Buildings.
URM	An acronym for unreinforced masonry, which is a term used to describe bricks (secured by mortar) and/or concrete used in the construction of a building without any form of steel reinforcing. This type of construction is not permissible under modern building codes, which typically require reinforcement of building elements.
Vertical accelerations	The extent to which the ground accelerates in a vertical direction at a particular site as a result of an earthquake.

Canterbury Earthquakes
Royal Commission
Te Komihana Rūwhenua o Waitaha

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