

FINAL REPORT

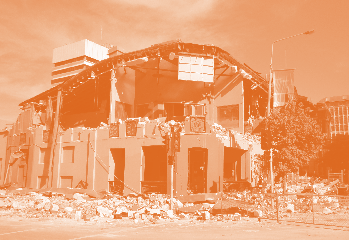


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**VOLUME 4**

EARTHQUAKE-PRONE BUILDINGS



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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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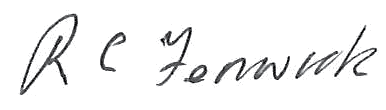
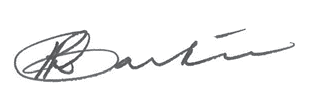
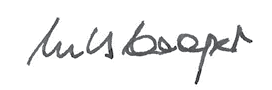
**Letter of Transmittal**

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 1170.5:20041. 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

**Recommendation**

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.

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 Recommendations1, 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 Sp 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 Sp 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**

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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

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

3

that have been handed down in Ma-ori oral tradition,

the case. Blume et al.

in 1961 highlighted the need

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 Bylaws1 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 19552, 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.

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 8.3:19654, 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:

19765) 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 4203:19765 set out the design seismic loadings in terms of the potential ductility of the different materials

and structural forms. The displacement ductility

The Earthquake Actions Standard, NZS 1170.5:20048, adopted a similar approach to the previous loading Standard in defining the seismic design actions.

was given by 4

/

*SM*

, where *S* was the structural type

However, the seismic hazard factor was updated

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 19846 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.

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 1992 edition of NZS 42037 replaced the three

the 2004 Standard8

a structural ductility factor of

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, *Sp*. 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 *Sp* 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 *Sp* factor results in the peak displacement being equal to the design displacement divided by *Sp*. The confusion over peak and design drifts may have been a contributing factor to the damage sustained by stairs in the Canterbury earthquakes.

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 Standard7 the maximum permissible structural ductility factor was 6 while in the 19765 and 19846 Standards the corresponding values were 5 and 6.25 respectively.

0.2

0.15

0.1

Acceleration (g)

0.05

0

1965

1976

1984

1992

2004

0 1 2 3 4 5

Period T (seconds)

**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 Hollings9 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 4203:19765, 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 Engineering10 in the mid-to-late-1970s, and use was also made of information in overseas codes of practice such as ACI 31811.

In 1982 the Concrete Structures Standard, NZS 3101:

198212, was published. This contained detailed information on detailing for ductility. This Standard was subsequently extended and updated in 199513 and 200614 as a result of findings from research in New Zealand and around the world.

The 1995 edition of NZS 310113 required all columns to be confined. The previous edition of NZS 310112 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 Standard13 given the uncertainty involved in the drift calculations.

The 2006 edition of NZS 310114 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 9.3:196415, NZS 4203: 19765 and in the 198212, 199513 and 200614 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 3404:198916, was published in 1989. It included sections covering capacity design and ductile detailing.

This Standard was updated in 199217 and again in

199718 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 MacRae19; MacRae et al.20, and Smith and Devine21.

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 to 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 196422. 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. Sheath23, 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: 19654) 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: 196424 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 9.2:196424. 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

8:19654. 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 8:19654 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 8:19654, 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 9.2:196424 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

8:19654 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:

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.

**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.

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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.