**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 700m2, which equated to $430/m2.

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 260m2. This equates to $770/m2 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 400m2. This equated to $3,600/m2.

**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 4203:19843). 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 4203:19843). 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 Standard4 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 Standard5 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/m2

to $3,600/m2 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**

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| **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 andSites 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 EarthquakeEngineering | *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 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”* | *Submission on Unreinforced Masonry Buildings – Legal requirements for earthquake-prone buildings* |
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| **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 onMonuments and Sites New Zealand | 8 November 2011 |
| Bruce Chapman | Chief Executive, New Zealand Historic Places TrustPouhere 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 7 November 2011 and Environmental Engineering, The University of Auckland |
| Dr Marion Irwin | Former Hazards Manager, Civil Defence and EmergencyManagement, 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 SitesNew 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 onMonuments and Sites New Zealand | 8 November 2011 |
| John Scott | Group Manager, Building Consents and LicensingServices, 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 |

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| **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 SafetyCommission, 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.