Canterbury Earthquakes Royal Commission
Te Komihana Rūwhenua o Waitaha

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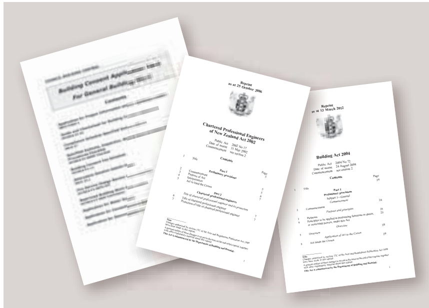
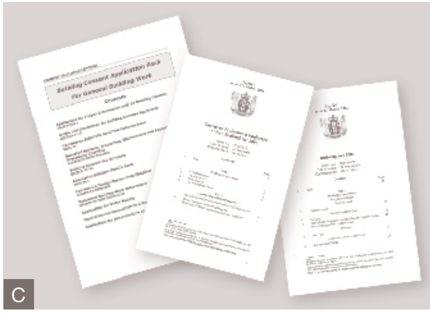
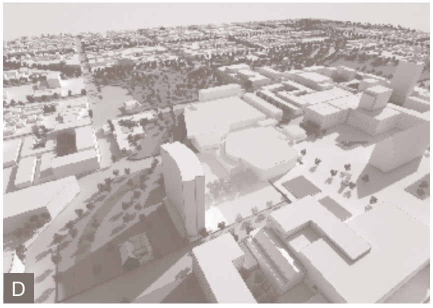


FINAL REPORT

VOLUME 7
ROLES AND RESPONSIBILITIES





A. Safety assessment personnel at work in the Christchurch Central Business District after the 22 February 2011 earthquake (source: Applied Technology Council)

B. Barricades erected on Colombo Street after the 4 September 2010 earthquake

C. The Building Act 2004, the Chartered Professional Engineers of New Zealand Act 2002 and a building consent application pack

D. Context for the new Square, the civic heart of central Christchurch (source: Central City Development Unit/Canterbury Earthquake Recovery Authority)

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Section 1: Introduction

The Royal Commission's Terms of Reference require us to consider "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".

The Terms of Reference specifically provide that, in doing so, we must investigate, among other things, the legal and best-practice requirements for the assessment of buildings after earthquakes and of any remedial work carried out on them. In section 2 of this Volume, the Royal Commission explores the legal and best-practice requirements underpinning the building safety evaluation process following a severe earthquake. The Canterbury earthquakes have provided a very stern test of the existing legal requirements and perceived best-practice in assessing buildings after earthquakes. We consider the lessons able to be learned from these events. This builds on observations already made in Volume 4, where we discussed the approach taken in Christchurch after the September and Boxing Day earthquakes to assess individual buildings that failed in the February earthquake. Our observations also discuss how buildings should be managed after the transition from civil defence to normal building control arrangements.

Among the recommendations that we make are recommendations relating to the manner in which buildings are evaluated after significant earthquakes, the development of evaluation guidelines, and training for building safety evaluators. Other recommendations cover the placarding system used in the rapid assessment process; we favour in principle changing from green to white the placards currently used to indicate that a building has been inspected without significant damage being observed. We also make recommendations about the kinds of evaluations to which buildings should be subjected to before their long-term reoccupation after a significant earthquake.

The Terms of Reference also require the Royal Commission to consider "the roles of central and local government, the building and construction industry and other elements of the private sector in developing and enforcing legal and best-practice requirements".

Through the course of our Inquiry we identified systemic issues relating to the regulatory framework for buildings. These issues include misunderstandings of the framework, a complex and confusing suite of regulatory documents, and quality assurance issues. There was also a fundamental issue raised by some submitters about a lack of "leadership" in the regulatory field. Section 3 of this Volume briefly describes the key elements of the current building control framework. We then discuss and make recommendations to address these issues. (Volume 4 of this Report discusses and makes recommendations about the legal and best-practice requirements for buildings that should be treated by law as earthquake-prone. That subject is not revisited in this Volume.)

Recommendations in section 3 include various proposals to enhance quality assurance. Examples are a proposed requirement for provision of a Structural Design Features Report with the building consent applications for all commercial and residential buildings of three or more storeys (provided, in the case of residential buildings, the building will contain three or more household units) as well as for proposed buildings in importance levels 3–5 as defined in the relevant Standard.[1] The structural design features report would then be used to assess whether the building is complex. Complex structures would require certification by a recognised structural engineer, a qualification that we address in section 4. We also make recommendations in section 3 that are designed to enhance the leadership of the sector, by providing for the position within the Ministry of Business, Innovation and Employment (MBIE) of Chief Structural Engineer, with a leadership role in relation to complex buildings; and for the development by MBIE, in consultation with interested groups, of a policy and regulatory work programme. This programme would identify the priorities for the development, review and update of compliance documents and Standards. The development and implementation of the Programme would be the responsibility of the Chief Structural Engineer. We also recommend that Standards referenced in the Building Code should be available online, free of charge.

The Royal Commission also examined current arrangements for the education and training of structural and geotechnical engineers in New Zealand, the competence standard used by the Institution of Professional Engineers New Zealand (IPENZ) to register engineers, and the occupational regulations and ethical rules that apply to the engineering profession. Section 4 of this Volume reports our consideration of these matters. We compare New Zealand practice with that of other countries, and describe how the training of engineers here conforms with international best-practice.

We were confirmed in our decision to inquire into these matters as a result of evidence that we heard in relation to the failure in the February earthquake of individual buildings considered as part of the representative sample of buildings, including the CTV building. While the failure of the CTV building had tragic consequences and can in large part be attributed to the inadequacy of its design, we discuss other cases as well where the designers of the buildings had evidently failed to recognise fundamental aspects of structural behaviour. A closely linked concern relates to the ability of the regulatory system to pick up defective designs in the processing of building consents for complex structures. In the case of the CTV hearing, there was evidence from experienced structural engineers that it would not have been reasonable for the Christchurch City Council (CCC) checking engineer to have identified some design defects. It is against the background of the discussion in section 4 that we recommend that legislation should provide for Recognised Structural Engineers to be involved in the design or peer review of complex structures. Such engineers would be Chartered Professional Engineers but with special competence in the field of structural engineering, and who would be well experienced in the design of complex structures. We propose that a set of qualifications and competencies for Recognised Structural Engineers be developed by MBIE in consultation with the Chartered Professional Engineers Council, IPENZ and others.

In section 5 of this Volume we examine local government management of earthquake risk. The Terms of Reference for the Royal Commission require us to consider whether or not the legal and best-practice requirements for building design, construction and maintenance adequately manage risks of building failure caused by earthquakes. The Terms of Reference refer explicitly to the role of local government in developing and enforcing legal and best-practice requirements. One way of minimising the failure of buildings in future earthquakes is to ensure that new development occurs on land that is suitable for development, having regard to its susceptibility to liquefaction, lateral spreading or significant softening of soils in earthquakes, and the ability to provide suitably robust foundations for new buildings. In Volume 1 we dealt with issues such as subsurface soils investigation, ground improvement techniques and issues of foundation design. However, we also thought it appropriate to consider how the local authorities in the Canterbury region had dealt with the issue of earthquake risk in exercising their Resource Management Act powers, and we commissioned Mr Gerard Willis of Enfocus Limited to examine the way that the planning documents of both the Canterbury Regional Council (CRC) and the CCC deal with earthquake risk. The Enfocus report considered the steps the CRC and the CCC have taken under the Resource Management Act 1991 to avoid and mitigate the effects of natural hazards, one of which is earthquakes. We have taken that report into account as well as submissions on it.

Drawing on the experience in the Canterbury region, we recommend that sections 6 and 7 of the Resource Management Act 1991 be amended to ensure that regional and district plans are prepared in a way that acknowledges the potential effects of earthquakes and liquefaction, and to ensure that such risks are considered in the processing of resource and subdivision consents.

References

1. See Table 3.2 in AS/NZS 1170.0:2002. *Structural Design Actions Part O: General Principles*, Standards Australia/Standards New Zealand.

Section 2: Building management after earthquakes

2.1 Introduction

Of the 185 people who lost their lives in the earthquake on 22 February 2011, 175 people died as a result of building failures. The Royal Commission has investigated all of the buildings and structures that failed causing these deaths. We have considered the failures of the Canterbury Television (CTV) building, and the Pyne Gould Corporation (PGC) building, where respectively 115 people and 18 people died. We have also inquired into the failures of other individual buildings or structures that resulted in the deaths of 42 people. In all but one of these individual buildings, the deaths were caused when older, unreinforced masonry buildings or brick or block structures failed.

The Royal Commission has received evidence that describes the manner in which these buildings were assessed after the 4 September 2010 earthquake and the process for assigning placards to buildings.

This section considers the framework and assumptions that underpin the management of buildings after an earthquake, both during and after a state of emergency. We briefly outline New Zealand's civil defence and emergency management framework and give an overview of the building safety evaluation process used to assess buildings after an earthquake. In section 2.4, we discuss who should be responsible for the development and maintenance of this process. We consider whether or not the process needs a specific legislative mandate, and what its objectives and scope should be. The Royal Commission heard evidence that the objectives of the building safety evaluation process are not well understood by the public and some building safety evaluators. Skilled evaluators are needed to successfully carry out a building safety evaluation operation, so we consider the methods, frameworks and assumptions evaluators use when they assess buildings. We particularly focus on whether the use of damage-based assessments is appropriate and if evaluators need to change the way in which they account for aftershocks. This section also explores options to ensure that New Zealand has sufficient numbers of skilled evaluators. The Royal Commission considered it important to look at whether or not the current system is the right approach or model. Having done so, we consider that the current approach is appropriate and in accordance with international best-practice. However, we recommend making changes to improve the delivery of the current system. We have not found a viable alternative.

Section 2.5 records the results of our investigation into the delivery of the building safety evaluation operations after the Canterbury earthquakes. In section 2.6, we discuss the issues that arose when the responsibility for the building safety evaluation process transitioned from civil defence to normal building management arrangements. The Royal Commission considers that these issues negatively impacted on the building safety evaluation operation after the Canterbury earthquakes, especially the management of buildings that may be suitable for reoccupation but still in need of repair. We review options for a transition mechanism and make recommendations for change.

This section must be read in the context of earlier Volumes of our Report. We note that some of the problems that arose with the delivery of the building safety evaluation process and its transition to normal building management arrangements demonstrate issues with the normal management of buildings: for example, the legislative barriers delaying the repair or demolition of damaged buildings. We discuss and make recommendations about particular issues raised in this section in Volume 4 of the Report. The recommendations we make in this section regarding the management of unreinforced masonry buildings after earthquakes should also be read in the context of our discussion about these buildings in Volume 4.

The Royal Commission considers that, overall, New Zealand was very well served by the engineers, building control officials, and other civil defence workers who participated in the building safety evaluation operations in Canterbury, most of whom were volunteers who worked to ensure the safety of the wider Christchurch community in very difficult circumstances. Some of the volunteers gave valuable evidence to the Royal Commission to assist our understanding of where improvements can be made. New Zealand owes them a debt of gratitude.

2.1.1 Background

At 4:35am on 4 September 2010, a 7.1 magnitude earthquake occurred with an epicentre 40km west of Christchurch, on a previously unknown fault beneath the Canterbury Plains. This earthquake damaged Christchurch's older brick and masonry buildings, historic stone buildings and Canterbury homesteads. It seriously affected the city's eastern suburbs and Kaiapoi, both of which experienced liquefaction and lateral spreading. Broken water and sewer pipes caused flooding. A state of local emergency was declared.

The magnitude 4.7 aftershock on 26 December 2010, which we will refer to as the Boxing Day aftershock, occurred at 10:30am. It had an epicentre located 1.8km north-west of Christ Church Cathedral. Although its effects were localised, this aftershock caused further damage to buildings in the Central Business District (CBD). No state of emergency was declared.

On 22 February 2011, at 12:51pm, what is now known as the Port Hills Fault ruptured. The fault ruptured on a northeast-southwest orientated fault at a shallow depth, reaching to within one kilometre of the surface. This earthquake had a magnitude of 6.2. Its epicentre was located 6km south-east of Christchurch's CBD. Although this earthquake was of a lesser magnitude than the September earthquake, it was the most destructive of the Canterbury earthquakes because its resulting ground motions were extremely high. Many buildings damaged in the September earthquake were brought down and many heritage buildings sustained major damage. Many modern buildings experienced higher structural failure and a number of modern buildings were damaged beyond repair. Christchurch experienced widespread liquefaction. One hundred and eighty-five people died from the injuries they received in this earthquake. A national state of emergency was declared. Failures that resulted in loss of life are reported in Volumes 2, 4 and 6.

A magnitude 6.0 aftershock occurred on 13 June 2011 at 2.20pm. Its epicentre was located near Sumner. This aftershock caused further widespread damage in Christchurch and Lyttelton. Once again, Christchurch experienced widespread liquefaction and there were rock falls from cliffs in the Port Hills suburbs.

There is a detailed discussion of the Canterbury earthquake sequence and the seismicity of Christchurch and the wider Canterbury region in Volume 1 of this Report.

2.1.2 The scope of this section of the Report and the Royal Commission's approach

This volume of the Report considers lessons learned from the building safety evaluation operations carried out after the earthquake events that occurred between September 2010 and June 2011.

The Royal Commission received several reports on the building safety evaluation operations. A report from the Ministry of Civil Defence and Emergency Management[1] sets out the key principles and the underlying approach behind New Zealand's civil defence and emergency management framework. The Ministry of Civil Defence and Emergency Management was in the process of preparing an independent review of the civil defence and emergency management operations after the September earthquake when it was overtaken by events following the February earthquake. A draft of this report[2] was made available to the Royal Commission. In addition, we commissioned a review of the building safety evaluation operations after the Canterbury earthquakes by the New Zealand Society for Earthquake Engineering[3] (NZSEE). This report was prepared by Mr David Brunsdon of the Kestrel Group. Further, Christchurch City Council[4] (CCC) provided the Royal Commission with a report on the building safety evaluation operation in the Christchurch CBD after the September earthquake. At our request, CCC also released a draft report focusing on the processes used after the state of emergency, by Ms Esther Griffiths (now Ms Newman) and Mr Dene McNulty[5]. This report was not finalised and was not formally "received" by the CCC. In the discussion that follows, we refer to these documents as "the reports" received by the Royal Commission.

We have also had regard to the draft report by the Applied Technology Council (ATC)[6] on the building safety evaluation operation after the February earthquake, prepared by Mr Ronald Gallagher, Mr Jim Barnes and Mr Bret Lizundia. ATC developed the Californian building safety evaluation process on which New Zealand's is based. The authors of its draft report on the Christchurch operation in February 2011 are experts in these processes. Mr Bret Lizundia gave evidence to the Royal Commission as our international peer reviewer on this topic.

On 4 November 2011, the Royal Commission called for submissions on the subject of building assessments after earthquakes; submissions closed on 17 February 2012. We received seven submissions. On 21 June 2011, the Royal Commission called for submissions on our *Discussion Paper*: *Building Management After Earthquakes*. We received 12 submissions on the discussion paper. Appendix 3 of Volume 5 lists these submitters.

The Royal Commission held a hearing on managing buildings after earthquakes on 3–4 September 2012. A list of the witnesses who gave evidence at this hearing can be found in Appendix 3 of Volume 5. The Royal Commission has also held hearings on the CTV building, the PGC building, and the failure of many individual buildings causing death. Evidence from these hearings, discussed in Volumes 2, 4 and 6 of this Report, informs the discussion, conclusions and recommendations we set out in this section.

To provide context for our discussion, we give below an overview of New Zealand's civil defence and emergency management framework.

2.2 New Zealand's civil defence and emergency management framework

The intent of the civil defence and emergency management framework is to deal with the consequences of a disaster by:

- *reducing* the risk associated with the disaster;
- building *readiness* to respond to the disaster;
- *responding* to the disaster; and
- setting up *recovery* processes that reduce the impacts of future disasters.

2.2.1 National civil defence arrangements

New Zealand's civil defence and emergency management framework is set out in the Civil Defence and Emergency Management Act 2002. Figure 1 sets out the key elements of this system.

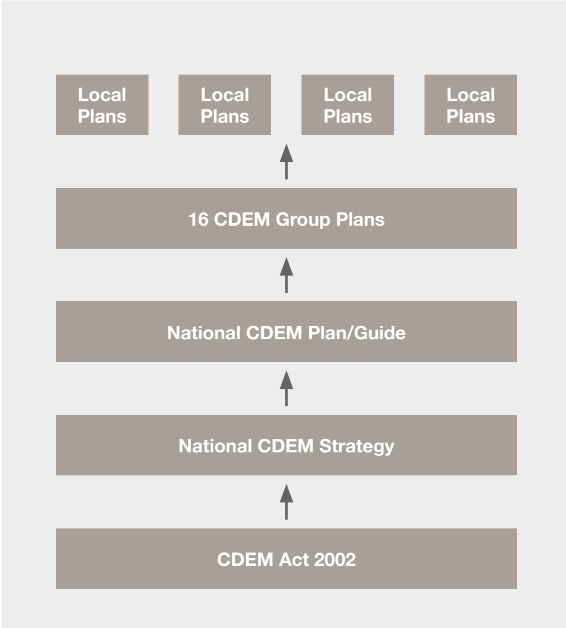


Figure 1: Key elements of New Zealand's civil defence and emergency management framework (source: adapted from the Ministry of Civil Defence and Emergency Management, 2011)

The Civil Defence and Emergency Act 2002 requires the development of a National Civil Defence and Emergency Management Strategy[7] and a National Civil Defence and Emergency Management Plan[8]. The National Civil Defence and Emergency Management Plan is set out in an Order in Council (the National Civil Defence Emergency Management Plan Order 2005) and is supported by a Guide[9]. These documents identify community goals, set out how to respond to a national emergency and describe how to support the local management of emergencies.

The Minister of Civil Defence can declare a national state of emergency in all or part of the country. The Minister and/or local authorities can declare local emergencies. A state of emergency can last up to seven days, although it can be extended indefinitely in seven day increments. Declaring a state of emergency allows civil defence authorities to exercise a wide range of statutory powers.

2.2.2 Local civil defence arrangements

New Zealand's civil defence framework is constructed from elements put in place at the local level. Section 12 of the Civil Defence and Emergency Management Act 2002 requires local authorities to establish Civil Defence and Emergency Management Groups for each region of New Zealand. Each Group is required to develop a Civil Defence and Emergency Management Plan. These Groups are a core element in New Zealand's civil defence and emergency management framework. New Zealand has 16 Civil Defence and Emergency Management Groups. The Canterbury Group is made up of 10 local authorities.

Territorial authorities are the first to respond to emergencies in their own areas. They are expected to take the lead in responding to a disaster such as earthquake. Regional and national civil defence and emergency management both activate to support the territorial authority managing the response to the disaster. Regional or national civil defence and emergency management may also take over if the territorial authority is significantly impacted and/or overwhelmed.

Each local authority must plan and provide for civil defence and emergency management within its district. A fundamental principle in New Zealand's civil defence framework is the idea that the amount of detail that a local authority puts in its emergency management plans should reflect the level of risk a particular disaster poses to the buildings in the district. The emergency management plans for larger cities and areas of higher seismicity should therefore be more detailed and specific.

2.2.3 The civil defence response to the Canterbury earthquakes

Within an hour of the earthquake at 4:35am on 4 September 2010, the CCC, Waimakariri District Council and Selwyn District Council each declared a local state of emergency for their area. They each established their own Emergency Operations Centre run by a Local Controller. The Canterbury Civil Defence and Emergency Management Group also set up an Emergency Coordinating Centre at the Environment Canterbury premises in Christchurch. The Local Controllers were in charge of their district's response to the earthquake, including their building safety evaluation operation. All three local states of emergency ended at midday on 16 September 2010.

The earthquake on 22 February 2011 occurred at 12.51pm. CCC declared a local state of emergency at 2.45pm. The immediate response was led by CCC staff, who established an Emergency Operations Centre in the Christchurch Art Gallery, as the primary emergency operations centre in the main council building was inaccessible. At 10.30am on the following day, the Minister for Civil Defence declared a national state of emergency. At this point, the local state of emergency ceased to have effect and the National Controller became responsible for the response to the earthquake. The state of national emergency was extended 10 times before being terminated on 30 April 2011.

In its report to the Royal Commission, CCC[4] refers to uncertainty about whether to declare a local state of emergency after the Boxing Day aftershock. In the end, it established an Emergency Operations Centre, but did not declare a local state of emergency. The Council considered the damage observed in the city did not meet the requirements for declaring a state of emergency set out in the Civil Defence and Emergency Management Act 2002. We discuss these requirements in section 2.4.2.1 of this Volume.

The NZSEE[3] records that the scale of the rapid assessment operation carried out after the September earthquake was large by international standards. The civil defence and emergency management response to the February earthquake was on a scale unprecedented in New Zealand. ATC[6] states that:

> The extent of liquefaction, the extensive damage to mid-rise and high-rise buildings, and the challenges posed in the evaluation, repair, and recovery process were unprecedented.

2.3 The building safety evaluation process

Guidelines issued by the NZSEE[10] envisage that each territorial authority will develop and implement its own building safety evaluation process. In accordance with international best-practice, New Zealand's building safety evaluation framework uses local reconnaissance teams to assess the damage to buildings caused by a disaster. These teams indicate the results of this assessment by placing colour-coded placards on individual buildings.

2.3.1 Guidelines for the building safety evaluation process

Works Consultancy Services (formerly part of the Ministry of Works) released New Zealand's first guidelines for a building safety evaluation process in 1991.

In 1998, the NZSEE released guidelines for territorial authorities, *Building Safety Evaluation During a State of Emergency: Guidelines for Territorial Authorities*[10], which we refer to as the NZSEE Guidelines. Section 6.2.1 of Volume 4 discusses the different NZSEE documents for assessing buildings before and after earthquakes: this discussion is summarised in Appendix 1 of this Volume.

The response to the earthquake in Gisborne in December 2007 was the first time a building safety evaluation operation based on this type of approach was implemented in New Zealand. In 2009, the former Department of Building and Housing endorsed the current version of the NZSEE Guidelines.

Since 2004, the NZSEE Guidelines have been in a constant state of revision. In 2008, the former Department of Building and Housing established a reference group to participate in the NZSEE's review. This reference group is made up of representatives from the NZSEE, other engineering technical societies, government agencies, and several local authorities. The CCC is a member of this reference group. The NZSEE published revised Guidelines in 2009, with the endorsement of the former Department of Building and Housing.

International best-practice suggests that such guidelines incorporate the lessons learnt from major earthquakes and the reference group decided to take into account the earthquakes in Padang, Indonesia and L'Aquila, Italy in 2009. In July 2010, members of the reference group were asked to review a new version of the Guidelines, but this revised version had not been officially adopted when the September earthquake occurred. The Ministry of Civil Defence and Emergency Management and the Ministry of Business, Innovation and Employment are revising the NZSEE Guidelines to incorporate the lessons learnt from the Canterbury earthquakes.

2.3.1.1 International best-practice

New Zealand looked to international best-practice when developing its building safety evaluation process. The NZSEE Guidelines draw heavily on California's building safety evaluation process, as set out in the ATC-20 documents[11]. A common system of evaluation facilitates cooperation between trained persons from countries that experience earthquakes. New Zealand was supported by overseas specialists during the Canterbury earthquake sequence.

Although detailed engineering evaluations (DEEs) are conceptually part of the building safety evaluation process, many countries focus on developing and maintaining the rapid assessment phase of the process; this is the focus of the NZSEE Guidelines.

We now describe the building safety evaluation process.

2.3.2 Overview of the building safety evaluation process

As summarised in Table 1, the NZSEE Guidelines[10] set out the three phases of New Zealand's building safety evaluation process:

- the Overall Damage Survey;
- rapid assessments; and
- DEEs.

Purpose	Timing*	Initiated by	Task	Conducted by	Comment
Overall Damage Survey	Within hours after event	Civil Defence staff, emergency service action plans, territorial authority action plans	Assess aggregate damage and identify affected areas	Emergency services, territorial authority staff, Civil Defence volunteers	No entry of premises, no formal records, emphasis on extent of damage, areas of high impact, identifying areas of priority for rapid assessment, estimating manpower and skill base needs etc
Level 1 Rapid Assessment (Figure 2)	During a period of a state of emergency declared under the Civil Defence Emergency Management Act	Controller; Building Safety Evaluation Leader	Asertain level of structural damage to individual buildings and note other hazards; assess building safety and decide appropriate level of occupancy; recommend security and shoring requirements	Structural and civil engineers, architects and other personnel from the building industry volunteer status	Formal system, typically based on exterior inspection only; placards posted on buildings, central record maintained, note made of sites needing further inspections, unsafe areas cordoned off
Level 2 Rapid Assessment (Figure 3)				Structural engineers, building services and geotechnical engineers volunteer status	Formal system based on inspection of interior and exterior of the building plus reference to available drawings. Calculations not envisaged. May result in revised placards posted on buildings, central record updated, unsafe areas cordoned off, urgent work recommendations Typically for priority inspection of critical facilities (for situations where facilities operators do not have contracted engineers), or where further information that raises concerns is received
Detailed Engineering Evaluation and Remedial Work	Typically longer-term, but may be immediate for critical structures	Building owners, insurance companies, Territorial Authorities	Ascertain extent of structural damage, establish losses for insurance purposes, and recommend remedial work to restore functionality and compliance with Building Code	Engineers, architects and loss adjusters contractual agreement	Meets insurance and restoration requirements under the Building Act 2004 These evaluations are likely to involve review of construction documentation, and the preparation of detailed engineering reports

Table 1: Summary of building safety evaluation inspection categories (source: NZSEE Guidelines, 2009)

Note: All timings are indicative estimates only

2.3.2.1 The Overall Damage Survey

The Overall Damage Survey is the first step in the building safety evaluation process. This survey is carried out by civil defence workers within hours of the disaster occurring. It is a quick stocktake of the extent of the damage caused by the disaster. Decision makers are likely to use the Overall Damage Survey when deciding whether or not to declare a state of emergency. It is also used to indicate what locations the rapid assessment teams should focus on.

An initial purpose of the Overall Damage Survey is to identify the need for urban search and rescue operations. The rapid assessment phase of the building safety evaluation operation typically takes place after the urban search and rescue efforts are complete. ATC has expressed the view that carrying out the Overall Damage Survey in a step-by-step way, as occurred on the first day after the February earthquake, was very efficient and effective.

2.3.2.2 Rapid assessments

Carrying out rapid assessments is the next step in the building safety evaluation process. The rapid assessment phase is made up of two assessments:

- the Level 1 Rapid Assessment; and
- the Level 2 Rapid Assessment.

Level 1 Rapid Assessments are typically carried out by building control officials from territorial authorities, volunteer structural and civil engineers, or other suitably qualified people including architects. Level 1 Rapid Assessments are typically a 10–20 minute inspection of the structural damage visible from the outside of the building. Level 1 Rapid Assessments are normally carried out on buildings up to four storeys.

Level 2 Rapid Assessments should be carried out by structural, geotechnical or territorial authority engineers. They are usually carried out on larger, more complex buildings, but will include critical facilities such as hospitals. They are also carried out on buildings that have had a Level 1 Rapid Assessment that has resulted in a recommendation that evaluators carry out a Level 2 assessment. The Level 2 Rapid Assessment is a more detailed visual assessment lasting from one to four hours, examining both the interior and exterior of the building.

Level 1 and Level 2 Rapid Assessments are summarised in the following flow charts.

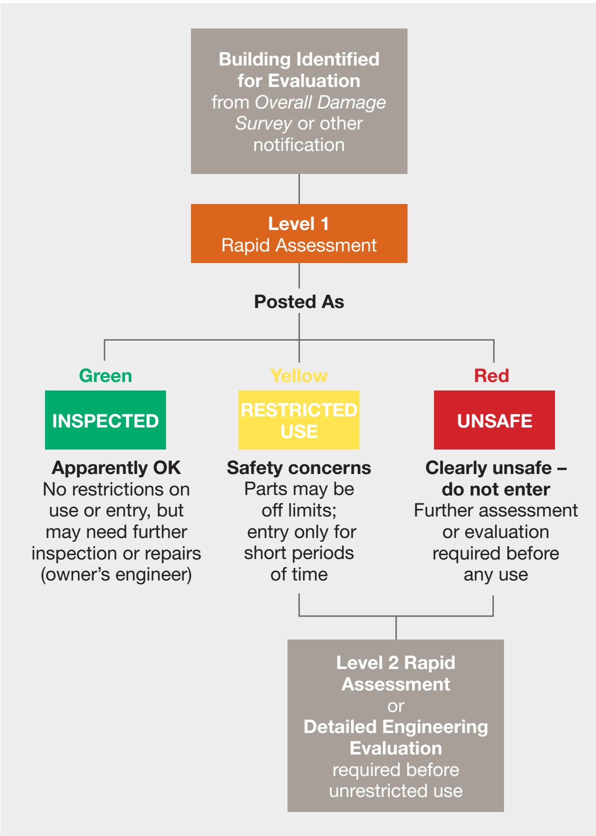


Figure 2: Level 1 Rapid Assessment (source: NZSEE Guidelines, 2009)

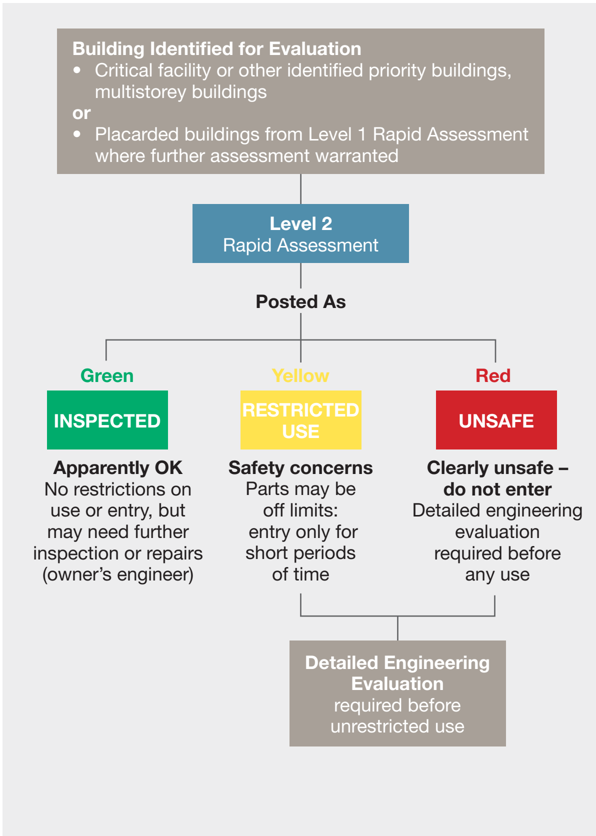


Figure 3: Level 2 Rapid Assessment (source: NZSEE Guidelines, 2009)

Both Level 1 and Level 2 Rapid Assessments are intended to give a short-term indication of the condition of a building. Rapid assessments give an early indication of whether the building is an immediate danger to the people using it, or to the public in the vicinity. In this phase of the building safety evaluation process, evaluators place red, yellow or green placards on buildings to indicate their status following assessment. They may limit entry to buildings and recommend the erection of cordons to restrict access to the area around the building.

2.3.2.3 Detailed Engineering Evaluations

The third step in the building safety evaluation process is to undertake a DEE. This is carried out by structural and/or geotechnical engineers as appropriate. DEEs involve accessing and considering all of the information available on the building, carrying out thorough exterior and interior inspections and performing calculations if required. They can take from one day to one week or more. Building owners are expected to take responsibility for obtaining a DEE by engaging their own engineers, and ensuring the safety of the public and occupants. This evaluation is not, normally, undertaken by local authorities.

2.3.2.4 Sequences of the building safety evaluation process

During a local or national state of emergency, the Overall Damage Survey and the rapid assessments should be carried out under the authority of a civil defence Controller. Because DEEs take longer to complete, they are more likely to be carried out after a state of emergency has ended, and the relevant Civil Defence and Emergency Management Act 2002 powers are no longer applicable.

2.3.3 Overview of the building safety evaluation operations after the Canterbury earthquakes

The reports received by the Royal Commission describe how the CCC and the Waimakariri and Selwyn District Councils each implemented their own building safety evaluation operation after the September earthquake. These operations were broadly based on the NZSEE Guidelines. Each territorial authority carried out a rapid assessment operation, which then transitioned from civil defence to normal building management arrangements. CCC's building safety evaluation process also included Project East, a rapid assessment operation that assessed residential buildings in Christchurch's eastern suburbs.

2.3.3.1 The rapid assessment teams

CCC's rapid assessment teams were a mix of building control officials and engineers. These rapid assessment teams were typically made up of a minimum of three people:

- a council building control officer or civil defence response team member;
- a structural engineer; and
- an Urban Search and Rescue technician.

Level 2 Rapid Assessment teams had one more building control officer and/or engineer join these teams. These teams were expected to include at least one engineer.

2.3.3.2 Managing the building safety evaluation operation

CCC's civil defence Building Evaluation Manager organised building control officials and volunteers into informal teams to carry out the Overall Damage Survey as they arrived at the Emergency Operations Centre from 5:30am on 4 September 2010. Over the course of the day, civil defence workers at the Emergency Operations Centre gradually pieced together an overview of the level of damage caused by the earthquake.

2.3.3.2.1 Completing Level 1 Rapid Assessments

The reports we received note that CCC sent out 29 rapid assessment teams to carry out rapid assessments on the morning of 5 September. Level 1 Rapid Assessments were carried out by 23 of the 29 rapid assessment teams. These teams were assigned to one of 25 CBD grids. The grids were planned out by CCC staff, workers from the former Department of Building and Housing, and the Urban Search and Rescue Engineering Team Leader. When the rapid assessment teams were sent out on the morning of 5 September, six teams were assigned to immediately carry out Level 2 Rapid Assessments on critical facilities and buildings that the Overall Damage Survey had identified as needing more detailed assessment than Level 1. The CCC had completed most of the Level 1 Rapid Assessments by the evening of 5 September. This was a remarkable effort.

2.3.3.2.2 Completing Level 2 Rapid Assessments

The Level 2 Rapid Assessments of Christchurch's CBD buildings began on the morning of 6 September. The CCC developed a process that established which of the Level 1 assessed buildings would receive a Level 2 Rapid Assessment. It also developed a process for prioritising when these buildings would be assessed.

As a general rule, green placard buildings that were recommended for further assessment were prioritised above red and yellow placard buildings. This was because red and yellow placard buildings had already been vacated as they were regarded as potentially dangerous. The CCC had completed some, but not all, of the proposed Level 2 Rapid Assessments by the end of the state of emergency on 16 September. The CCC then re-evaluated the buildings that had been assessed during the state of emergency when the building safety evaluation process transitioned to normal building management arrangements.

2.3.3.3 The building safety evaluation operations in later earthquakes and aftershocks

After the Boxing Day aftershock, the CCC decided on 27 December not to declare a state of emergency. The CCC categorised buildings as either red or green, and placed notices issued under section 124 of the Building Act 2004 instead of affixing placards. The Boxing Day aftershock did not cause significant damage in Waimakariri or Selwyn districts.

The building safety evaluation operation carried out in Christchurch after the February earthquake differed from that used after the September earthquake because of the search and rescue operation. The immediate response to the February earthquake focused on locating and rescuing trapped people. Christchurch's CBD was locked down while Urban Search and Rescue operations were in progress. Reports to the Royal Commission from the NZSEE[3] and the CCC[4] describe how civil defence workers planned the rapid assessment process on 23 and 24 February before sending out teams on 25 February. CCC building control officials led this planning, supported by engineers who had taken leadership roles after the September earthquake. This group incorporated some of the lessons learned in the response to the September earthquake in their plans. Between 22 and 25 February, the CCC carried out rapid assessments on suburban commercial buildings and other premises suitable for welfare centres; this rapid assessment operation was known as Operation Shop. The CCC then began Operation Suburb, which assessed residential buildings. After an initial check, Waimakariri and Selwyn District Councils decided not to carry out large-scale building safety evaluation operations after the February earthquake because the buildings in these areas did not suffer significant damage.

Following the 13 June 2011 aftershock, the Canterbury Earthquake Recovery Authority (CERA) sent out 12 engineers to carry out rapid assessments in Christchurch's CBD Red Zone. The Red Zone at this time covered about 24 blocks. These engineers identified buildings that were now dangerous, or more dangerous, due to the aftershock. No damage was recorded in Waimakariri or Selwyn.

2.4 The development and maintenance of the building safety evaluation process

The Royal Commission has identified matters that may lead to improvement of the building safety evaluation process. This section discusses the objectives for the management of buildings after earthquakes and whether there is a need to establish a legislative mandate for the building safety evaluation process. We discuss who should be responsible for developing and maintaining this process, and the methods, frameworks and assumptions engineers use when carrying out assessments. We also consider how New Zealand mobilises skilled building safety evaluators, what their numbers should be and barriers to developing a sufficient core of skilled evaluators.

International approaches to building safety evaluations are not subject to international benchmarking or codification. Nevertheless, the NZSEE[3] has identified several key indicators of good planning for a building safety evaluation process. These indicators include:

- setting out an appropriate legal mandate for the process;
- identifying a central government focal point to which the process belongs;
- making sure that territorial authorities plan appropriately before the event;
- siting the plans and procedures for the building evaluation process after a disaster within the civil defence and emergency management operation;
- establishing the criteria and process for the reoccupation of buildings;
- developing information management systems to record information, produce maps, and transfer the information collected into the wider territorial authority information management systems; and
- planning how to mobilise trained people at a national and local level.

2.4.1 Objectives of building management after earthquakes

The Royal Commission has heard evidence that the objectives of the building safety evaluation process are not well understood by the public and building safety evaluators.

The rapid assessment operation is designed to identify the visible structural damage to buildings after an earthquake or other disaster and to prioritise how to treat these buildings based on the severity of the damage to them. Buildings are assessed for damage to ensure that they do not pose an immediate threat to the safety of the people using them. Clarity is required regarding the purpose of the building safety evaluation process in comparison with the subsequent need to manage buildings after a disaster. Getting the city moving again and deciding when and under what conditions reoccupation of a building may occur are not part of the rapid assessment process.

Ensuring public safety following a disaster is the main objective of the building safety evaluation process. The management of buildings after earthquakes must deal with the competing objectives of public safety and the economic imperative of reactivating the commercial life of the city. The New Zealand Historic Places Trust notes that the unnecessary loss of heritage due to poorly-informed, rushed decision making has been observed in other countries after earthquakes and other disasters. It suggests ensuring the immediate safety of the public by carrying out make-safe works, or shoring and erecting cordons around the damaged building, and then taking the time to consider all the factors that affect the decision to repair or demolish the building. In its submission, the New Zealand Society for Risk Management states that adopting one objective to the exclusion of others is overly simplistic and does not reflect reality. It favours setting objectives for each stage of the building safety evaluation process, from the initial response through to the recovery phase.

The Royal Commission confirms that life safety should be the one, overarching objective for the management of buildings after earthquakes. However, we also consider it appropriate to have different secondary objectives at different times. In the short-term, the Royal Commission considers that life safety should be the objective that is most emphasised in the rapid assessment phase of the building safety evaluation process. As the civil defence and emergency management response moves into recovery, it may be appropriate to consider other objectives such as the reoccupation of damaged buildings and recovery of the community and local businesses. However, we consider it important that these objectives remain secondary to the main objective of life safety.

Recommendation

We recommend that:

111. Life safety should be the overarching objective of building management after earthquakes as communities both respond to and recover from the disaster.

2.4.1.1 Scope of the building safety evaluation process

An important issue is whether the building safety evaluation process should only be used after earthquakes, or whether it can be used after other disasters. The NZSEE Guidelines indicate that the process is broadly applicable to any disaster that may cause large numbers of buildings to be severely damaged. Likely causes are earthquakes, floods, slips, landslides, coastal hazards, wind and volcanic activity.

In practice the building safety evaluation process is primarily a structural assessment focused on earthquake damage. The Royal Commission has received evidence that the rapid assessments after the February earthquake did not adequately cover geotechnical matters. Structural engineers did not understand why the geotechnical team had assessed the building as dangerous, and the placard did not say it was assessed for geotechnical reasons. This meant that evaluators had to revisit and replace placards at some dangerous sites.

The Ministry of Business, Innovation and Employment supports using the building safety evaluation process for other disasters. If it can be used after a range of disasters, particularly floods, it becomes more cost effective to develop and maintain this process; 70 per cent of emergency declarations since 1963 have been flood-related. The Royal Commission accepts that the building safety evaluation process should be applied to a range of disasters.

Recommendation

We recommend that:

112. The building safety evaluation process should be used following a range of disasters.

New Zealand's building safety evaluation framework does not have a specific legislative mandate in either the Civil Defence and Emergency Management Act 2002 or the Building Act 2004. However, the general provisions contained within the Civil Defence and Emergency Management Act 2002 allow Controllers to authorise a rapid assessment operation. We now explore whether the current legislative arrangements are sufficient.

2.4.2 Legislative mandate and responsibility for the building safety evaluation framework

The NZSEE[3] contends that setting out an appropriate legal mandate for a building safety evaluation process that authorises its implementation in a range of circumstances is a feature of international best-practice. The placing, maintaining and removing of the placards should also have a clearly defined legal basis. Establishing a legal mandate for the process should involve specifying the lead agency responsible for it. The NZSEE states that establishing a central government focal point responsible for the building safety evaluation process is a feature of international best-practice. The central government agency would also guide the preparation of territorial authority plans, and develop and maintain core elements of the building safety evaluation process, together with common tools such as training materials. Having a central government focal point would give the building safety evaluation process a formal structure and provide resources to support territorial authority plans. Territorial authority plans are another feature of international best-practice for building safety evaluation processes.

The NZSEE[3] reports that since the introduction of their Guidelines in 1998, the uptake has been low. It attributes the low uptake to the lack of specific legislative mandate for the process. Territorial authorities have no legislative or regulatory obligations to use the NZSEE Guidelines and the latter cannot be enforced.

In addition, currently it is not clear who is responsible for developing New Zealand's building safety evaluation framework or any associated guidelines. Since Works Consultancy Services developed New Zealand's first building safety evaluation guidelines in 1991, responsibility for any guidelines has been shared informally between government agencies and the NZSEE. The NZSEE essentially took responsibility for developing New Zealand's building safety evaluation process in 1998, when it released its Guidelines. However, in 2008 the former Department of Building and Housing also took up a supporting role when it established the reference group to participate in the NZSEE's review. Both the Ministry of Business, Innovation and Employment and the Ministry of Civil Defence and Emergency Management now have a role in the current review of the NZSEE Guidelines.

The reports received by the Royal Commission support the view that current legislation already provides for a building safety evaluation process. The NZSEE[3] maintains that the Civil Defence and Emergency Management Act 2002 provides a legal basis for the building safety evaluation process despite not containing a specific legislative mandate. Under the Civil Defence and Emergency Management Act 2002, Controllers can:

- issue and control the use of signs (section 18(2)(c));
- carry out inspections (section 92);
- evacuate people and exclude them from any premises or places (section 86); and
- prohibit or restrict access to public roads and places to prevent or limit the extent of the emergency (section 88).

In addition, a Civil Defence and Emergency Management Group may require the securing or otherwise making safe of dangerous structures under section 85(1)(a)(iii) of the Civil Defence and Emergency Management Act 2002.

The Royal Commission considers that collectively these provisions authorise a rapid assessment operation such as those carried out after the September and February earthquakes during the state of emergency. For these reasons, the Royal Commission does not consider that there is a need to make further provisions for the building safety evaluation process in legislation.

The Ministry of Business, Innovation and Employment has indicated that it wishes to take on responsibility for developing and maintaining New Zealand's building safety evaluation process. It proposes that new emergency risk management provisions be incorporated into the Building Act 2004. The new provisions would establish a mandate for carrying out a building safety evaluation operation within a new emergency management building system. They would set out the authority and process for placing, changing and removing placards; they would also establish an appropriate penalty regime for carrying out these activities without authority. This new emergency management building system would be applicable to a range of disasters, not just earthquakes.

Although the new emergency management building system would be mandated under the Building Act 2004, the response to the disaster as a whole would remain coordinated through the Civil Defence and Emergency Management Act 2002. This means the building safety evaluation system would be designed at a national level, with territorial authorities planning its execution. To support the development and execution of the new emergency management building system, the Ministry of Business, Innovation and Employment would take on a role within New Zealand's national civil defence and emergency planning arrangements. The Ministry of Civil Defence and Emergency Management and CERA both support these proposals.

The Royal Commission has concluded that the Civil Defence and Emergency Management Act 2002 provides for New Zealand's building safety evaluation process. However, in principle, we endorse the Ministry of Business, Innovation and Employment's proposal that it assume responsibility for the building safety evaluation process and we support the incorporation of new provisions in the Building Act 2004 that would establish an emergency building management system. This is because this proposal may address some of the problems that occurred when the building safety evaluation process transitioned from civil defence to the building control arrangements governed by territorial authorities. We note that these proposals would also specifically mandate New Zealand's building safety evaluation process. Issues with the transition from civil defence to normal building management arrangements and the options for addressing these issues are discussed in section 2.6 of this Volume. The Royal Commission favours undertaking more policy work on the merit and detail of these proposals to ensure that they are robust, flexible, efficient and effective.

2.4.2.1 Building safety evaluation operations are confined to a state of emergency

A rapid assessment operation is usually only carried out when a state of emergency is declared. Civil defence and emergency management Controllers can only exercise the wide-ranging powers that allow them to authorise a building safety evaluation operation during a state of emergency. In practice, this means that a rapid assessment operation that results in placards being placed on a building cannot take place outside of a state of emergency. We discuss the problems this caused throughout this section.

To address these problems, several submitters suggest that territorial authorities should be able to carry out a building safety evaluation operation and place placards outside of a state of emergency; they suggest placing emergency management provisions that provide for this in the Building Act 2004.

Sections 4 and 68 of the Civil Defence and Emergency Management Act 2002 set out the criteria that civil defence and emergency management use when deciding whether or not to declare a state of emergency. Section 4 of the Act states that an:

> **emergency** means a situation that—
>
> (a) is the result of any happening, whether natural or otherwise, including, without limitation, any explosion, earthquake, eruption, tsunami, land movement, flood, storm, tornado, cyclone, serious fire, leakage or spillage of any dangerous gas or substance, technological failure, infestation, plague, epidemic, failure of or disruption to an emergency service or a lifeline utility, or actual or imminent attack or warlike act; and
>
> (b) causes or may cause loss of life or injury or illness or distress or in any way endangers the safety of the public or property in New Zealand or any part of New Zealand; and
>
> (c) cannot be dealt with by emergency services, or otherwise requires a significant and co-ordinated response under this Act[.]

Section 68(1) of the Act states that an authorised person:

> …may declare that a state of local emergency exists in the area for which the person is appointed if at any time it appears to the person that an emergency has occurred or may occur within the area.

The Royal Commission considers that a building safety evaluation operation should only be triggered by a state of emergency. This is because the wide-ranging powers Controllers have under the Civil Defence and Emergency Management Act 2002 significantly reduce the rights of property owners. The civil defence and emergency management framework recognises that this is appropriate when the safety and well-being of the public is compromised after a disaster. However (leaving aside issues that arise during the transition from the state of emergency to the normal legislative framework), removing the rights of property owners outside of a state of emergency is not appropriate.

We consider that if the impact of the event warrants carrying out a building safety evaluation operation, then it is likely to be significant enough to warrant a declaration. For these reasons, the Royal Commission does not believe that there is a problem with the existing civil defence and emergency management framework or its empowering legislation that needs to be specifically addressed: it is the local authority's decision whether or not to declare a state of emergency.

Recommendations

We recommend that:

113. Legislation should provide that a building safety evaluation operation should only be commenced during a state of emergency.

114. The Ministry of Business, Innovation and Employment should progress its proposals to incorporate new emergency risk management provisions into the Building Act 2004 to:

    - make the Ministry of Business, Innovation and Employment responsible for the development and maintenance of New Zealand's building safety evaluation process;
    - make territorial authorities responsible for delivering a building safety evaluation operation; and
    - give the Ministry of Business, Innovation and Employment a formal role within national civil defence and emergency planning arrangements.

115. The Ministry of Business, Innovation and Employment should continue working with the Ministry of Civil Defence and Emergency Management on the detail of the above proposals.

2.4.3 How evaluators assess buildings in rapid assessments and detailed engineering evaluations after earthquakes

As well as considering the process of building safety evaluation, the Royal Commission considered the way in which engineers evaluate buildings when carrying out rapid assessments and DEEs after earthquakes. Consideration of the methods, frameworks and assumptions used by engineers is important because different skill sets are needed to assess the damage to different types of buildings and structures. The Royal Commission has heard evidence about assumptions made as a result of inspections and about when engineers should be expected to:

- examine the interior of the structure;
- consult plans and drawings;
- carry out calculations;
- pull linings off the walls, floors and ceilings to check the structural elements underneath;
- use invasive methods such as boring holes and taking samples to test; and
- move from a damage-based assessment to one that indicates the building's (residual) seismic capacity.

2.4.3.1 Damage-based assessments

Most countries with comparable building safety evaluation systems first assess the visible damage that an earthquake or other disaster has done to the building. The purpose of a damage-based assessment is to identify those buildings that are obviously unsafe and therefore at risk of collapse in an aftershock. Rapid assessments are clearly damage-based assessments based on visible damage. DEEs tend to begin as damage-based assessments.

Most countries also assess the danger from the non-structural parts of a building; for example, parapets that could fall on passers-by in an aftershock. The building safety evaluation processes in some countries look at the danger a building might pose to its neighbours. Several countries also consider whether other hazards like broken utility lines, asbestos or chemicals are present. Some researchers suggest that evaluators use particular models and methods when carrying out damage-based assessments: for example, several propose grading a building and giving it a number depending on the intensity of the damage described.

From October 2010, damage-based assessments in Christchurch were carried out by evaluating visible evidence as to whether the earthquake resistance capacity of the building was no worse than it was before the September earthquake. This is the approach engineers in Japan take when they assess the capacity of the building to withstand aftershocks through assessment of observed damage and calculation of residual seismic resistance. Future aftershocks were assumed to be events with an order of magnitude one less than the damaging event. Some local authorities in California also allow building owners to restore their building back to the condition the building was in before the earthquake if the observed damage is not considered substantial.

2.4.3.2 Seismic capacity assessment

Calvi et al.[12] discuss how seismic vulnerability assessment methodologies have developed over the past 30 years, including how to assess the residual capacity of buildings after an earthquake. In Turkey, the rapid assessment of reinforced concrete buildings after recent earthquakes there has led to some researchers proposing building safety evaluation methods that define the lateral load resistance systems using mathematical modelling. The researchers Calvi et al. suggest in their paper that these methods could help civil defence workers' decision making, such as prioritising which buildings need a more detailed engineering assessment, and determining when to allow people to reoccupy a building after an earthquake. However, Calvi et al. also believe that the potential for the use of such methods in large-scale seismic risk models is limited because evaluators still need to consider buildings individually, for repair and reoccupation.

2.4.3.3 Seismic capacity assessments within a damage-based assessment

Instead of replacing the damage-based assessment, the building evaluation systems in Greece, California and Japan all recommend assessing the (residual) seismic capacity of buildings damaged in an earthquake within a damage-based approach. This is because it is not generally easy to fully identify the residual capacity a building has to withstand aftershocks quantitatively from quick inspections. Engineers would primarily carry out a damage-based assessment, but include some calculations and other analyses of a building's (residual) seismic capacity.

In practice, most methodologies follow a stepped process, where an engineer would carry out a range of qualitative and quantitative assessments set on a continuum. The simple, inexpensive qualitative assessments are at one end of this continuum; more complex calculations and invasive investigative methods (like boring holes into walls) are at the other. A rapid assessment would be the first qualitative step, to locate potential fall hazards and identify buildings in urgent need of further attention from the point of view of public safety. This should be followed by more detailed engineering assessments appropriate to the circumstances. We discuss the nature and content of such assessments in section 2.6.2.2.1 of this Volume. Engineers move from qualitative to quantitative methods, and from simpler to more complex analyses, depending on the damage they observe at each step. Evidence to the Royal Commission indicates that there is usually visible evidence of cracking or displacement of wall or floor linings if structural elements have yielded or lost their structural capacity. We accept that is so.

In such cases wall linings, floor coverings and ceiling tiles should be removed to enable examination of the damage. There are some cases where damage may not be apparent before the collapse condition is reached. The PGC and the CTV buildings are examples of this situation, where there was no significant damage evident prior to collapse, but because the structures of these buildings did not possess resilience through ductile detailing they subsequently failed in a brittle manner.

In assessing the percentage of ULS (we prefer to refer to the ULS (ultimate limit state) rather than to NBS (new building standard) for the reasons explained in section 6.2.4 of Volume 4), it is essential to consider the capacity of the building to sustain gravity loads under seismic shaking. The strength of the building is only part of the consideration that is needed: it is essential to consider also the deformation capacity and the rate at which strength will degrade with additional seismic shaking.

In their evidence to the Royal Commission, Mr David Brunsdon and Mr John Hare illustrated the significance of strength degradation with reference to Figure 4.

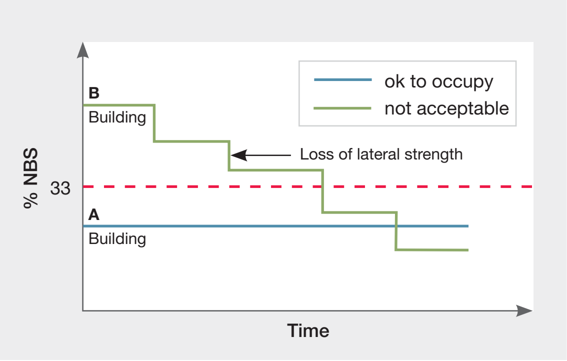


Figure 4: Building status and reoccupation (source: adapted from evidence to the Royal Commission by D. Brunsdon, September 2012)

The notional building B in the figure may initially have a strength in excess of 33 per cent of NBS, but due to damage occurring at non-ductile zones its strength can degrade in aftershocks of significantly smaller intensity than the original ground motion. Such a building may lose its strength in a non-ductile manner due to a critical structural weakness or weaknesses, without any apparent damage in an initial earthquake. The Royal Commission saw examples of such non-ductile behaviour in the failure of the PGC and CTV buildings (see the discussions in section 2.8.2.2. of Volume 2 and Volume 6) and the non-ductile failure of a number of other structural elements discussed in Volume 2.

The notional building A in Figure 4 may have a low lateral strength, which may be below 33 per cent of the strength of a new building but, due to ductile behaviour of the potential plastic regions and the lack of damage in other locations, it will continue to perform in a safe manner in aftershocks.

Identifying a critical structural weakness that limits the displacement capacity of the structure is more important than determining the lateral strength. This aspect needs to be considered in determining the percentage ULS.

2.4.3.4 Accounting for aftershocks

The Royal Commission has heard evidence that the rapid assessments in the building safety evaluation process in New Zealand are based upon an assumption that a building should be able to withstand an aftershock of one magnitude less than the main shock if it has not been significantly damaged in the main shock. Building safety evaluation best-practice does not plan for the situation seen in Christchurch, where increased ground accelerations from a near aftershock damaged buildings more than the main shock, even though its magnitude was one order less. This was an unforeseen circumstance.

The view that a building should withstand an aftershock of one magnitude less than the main shock developed after researchers in several countries studied the performance of buildings after earthquakes. The Federal Emergency Management Agency (FEMA)[13] in the United States undertook the seminal research on this topic; this major research project examined how buildings performed in aftershocks. Researchers found that if the structural elements in a building had been damaged, but did not suffer strength degradation, then the building generally had the same capacity as it did before the earthquake. FEMA recognises that this may seem counterintuitive, stating that:

> … it is natural to assume that [a building] is worse off than if the damage had not occurred. It seems likely that the maximum displacement in the future, larger earthquake would be greater than if it had not been damaged. Extensive nonlinear time-history analyses performed for the project indicated otherwise for many structures. This was particularly true in cases in which significant strength degradation did not occur during the prior, smaller earthquake. Careful examination of the results revealed that maximum displacements in time histories of relatively large earthquakes tended to occur after loss of stiffness and strength would have taken place even in an undamaged structure. In other words, the damage that occurs in a prior, smaller event would have occurred early in the subsequent, larger event anyway.

In section 2 of Volume 1 of this Report, we discuss the characteristics of the Canterbury earthquakes. It is clear that the February earthquake had much greater ground accelerations that the main September event though the aftershock was of a lesser magnitude. As we noted in section 2.7.1.8 of Volume 1, the comparatively high magnitude of the aftershocks in the Canterbury earthquakes sequence is not the norm. The epicentre of the February event was much closer to the Christchurch CBD than that of the September earthquake, and more shallow, and this greatly increased the intensity of the shaking in Christchurch's CBD. Consequently, we do not consider that the theoretical underpinning of the building safety evaluation process should be abandoned as a result of the Canterbury earthquakes sequence.

The Royal Commission nevertheless considers that building safety evaluators must look at other factors when considering how a building might perform in an aftershock. Where the earthquake is generated on a distant fault, aftershocks may generally be expected to be of shorter duration and lower intensity than the main shock. Where the fault is close to the city, there is a greater likelihood of subsequent aftershocks being closer to the city than the initial earthquake. Such an event may result in a greater intensity of shaking and the possibility of the directions of the major components of shaking being different from those of the initial earthquake. The result may be to cause major damage to buildings not severely damaged in the initial earthquake. Where the earthquake was on a local fault, a greater level of care in the assessment is required with more conservative judgements being made due to the possibility of aftershocks with a greater intensity and with different principal directions of shaking.

Recommendations

We recommend that:

116. The Ministry of Business, Innovation and Employment, the Ministry of Civil Defence and Emergency Management, GNS Science, the New Zealand Society for Earthquake Engineering and other engineering technical groups should research how and when building safety evaluators should account for aftershocks.

117. The building safety evaluation process should set out the factors evaluators need to take into account when considering how a building will respond in an aftershock, including:

   - how close the main shock was to an urban centre that could be affected by an aftershock;
   - the direction of the main shock and any likely aftershocks; and
   - how soil, ground conditions and any other relevant factors may affect the intensity of the ground motions in an aftershock.

2.4.4 Mobilising a sufficient number of skilled building safety evaluators

The ability to carry out an effective building safety evaluation operation depends on the number of skilled evaluators available. For this reason, effective plans for the mobilisation of trained professionals at national and local levels, and for events of different magnitudes, are important.

2.4.4.1 Model based on volunteers

New Zealand's building safety evaluation framework relies on volunteers. The process was developed by the NZSEE, a volunteer organisation. We have heard evidence that CCC building control officials and other council staff are required to support the civil defence and emergency management response to a disaster as part of their job description. However, other evaluators such as engineers, architects, and members of the construction industry are generally volunteers.

In New Zealand, professional bodies like the Institution for Professional Engineers New Zealand (IPENZ) and the Building Officials Institute of New Zealand encourage their members to assist after a disaster. IPENZ led the mobilisation of volunteer engineers from the rest of the country after the September and February earthquakes; some engineers also volunteered of their own accord. Local Government New Zealand mobilised workers from other territorial authorities to support local council staff.

2.4.4.2 Availability of building safety evaluators after the Canterbury earthquakes

Approximately 250 volunteers carried out rapid assessments in Christchurch during the state of emergency declared after the September earthquake. About 75 of these volunteers were engineers who worked in the rapid assessment teams alongside 24 Urban Search and Rescue engineers. Urban Search and Rescue engineers were able to join the rapid assessment teams and carry out other tasks to support the local civil defence response because there were no casualties and they did not need to carry out a rescue operation.

After the February earthquake, civil defence planners identified the need for up to 100 engineers and a further 50 building control officials to make up the rapid assessment teams going into Christchurch's CBD. Approximately 350 engineers were involved in the rapid assessments carried out during the national state of emergency.

2.4.4.3 Constraints caused by the number of building safety evaluators available after the Canterbury earthquakes

After the September earthquake, the number of available engineers limited the number of rapid assessment teams carrying out evaluations in Christchurch's CBD to 29. The limited number of available engineers particularly affected Waimakariri District Council, which used its own building control officials to carry out rapid assessments until structural engineers and people with more technical expertise became available on 7 September.

There were significant issues with the availability of people to carry out building safety evaluations after the Boxing Day aftershock. Because the aftershock occurred in the holiday season, many local engineers and CCC staff were on holiday and had left the city. Further problems with mobilising the volunteer engineers arose when the CCC did not declare a state of emergency. This is because there are difficulties with utilising volunteer engineers outside of a state of emergency declared under the Civil Defence and Emergency Management Act 2002. We discuss these issues further in section 2.4.5.1 of this Volume.

The number of available building control officials also constrained the rapid assessment operation after the February earthquake. Not every rapid assessment team had a warranted officer to support placing the placards because Operation Suburb, an extensive evaluation of suburban residences, reduced the number of building control officials available. At its peak, Operation Suburb deployed up to 1,000 building control officials, welfare representatives and Earthquake Commission staff each day. This reduced the number of building control officials available for the rapid assessment operation in Christchurch's CBD. The CCC therefore decided to give temporary warrants to the building safety evaluation team leaders, who were almost exclusively Chartered Professional Engineers.

The response to the February earthquake incorporated some of the lessons learnt about staffing issues after the September earthquake. The reports received by the Royal Commission note that the building safety evaluation management team was better resourced than its September equivalent. They suggest that this, along with a formal roster to keep staff alert, allowed the building safety evaluation management team to support a wider range of activities conducted in parallel.

2.4.4.4 Options for mobilising a sufficient number of building safety evaluators

The main questions are whether volunteer evaluators should be paid or unpaid, and how many evaluators New Zealand needs to carry out rapid assessments after a disaster.

The Royal Commission has heard evidence that the mobilisation of volunteers after the Canterbury earthquakes was timely and well-organised. For this reason, we consider the current arrangements are appropriate, provided matters of liability are resolved.

The Ministry of Business, Innovation and Employment and CERA suggest establishing a core team of trained, registered and warranted building safety evaluators. This team of building safety evaluators would be a national resource that could be called in by the Chief Executive of the Ministry of Business, Innovation and Employment to carry out building safety evaluation operations. The Ministry would decide when and where to deploy this team in conjunction with the civil defence and emergency management Controller after a state of emergency had been declared. CERA supports this concept. It has observed that a relatively small group of experienced, well-trained engineers could be more effective in completing rapid assessments over a number of buildings than a larger group of engineers with less training or experience. CERA contends that this group should be supplemented by a pool of evaluators for larger-scale events.

The NZSEE[3] also favours using a tiered model. It suggests developing three groups of trained evaluators:

- a small group of experts;
- a larger group of trained building safety evaluators; and
- the largest group of potential evaluators who have received basic training.

This model is illustrated below.

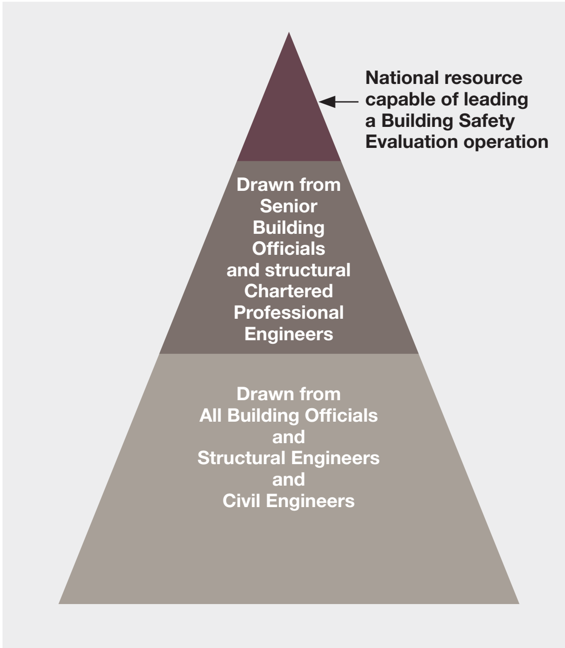


Figure 5: Building evaluation resource (source: NZSEE, 2011)

Currently, the Urban Search and Rescue engineers and other engineers who have developed expertise by assisting in the response to overseas disaster events, form the smallest group. The middle group would be drawn from senior building officials and chartered structural engineers who wish to become building safety evaluators. The largest group is made up of potential building safety evaluators drawn from all building officials, structural engineers and civil engineers.

The building safety evaluators who assessed buildings after the Canterbury earthquakes comprised a small group of experts and volunteers drawn from all building officials, structural engineers and civil engineers. The middle group of senior building officials and structural Chartered Professional Engineers who could be called on to supplement the small group of building safety evaluation experts did not exist when engineers mobilised to respond to the Canterbury earthquakes.

The Urban Search and Rescue engineers and the engineers who have significant expertise gained from their participation in the response to overseas disaster events could become the Ministry of Business, Innovation and Employment's core team. The middle group would supplement this group of experts in larger building safety evaluation operations. The largest group is made up of the potential building safety evaluators who would only be brought in for very large operations.

The Royal Commission considers that establishing a core team of building safety evaluators supplemented by two larger pools of potential evaluators is conceptually sound. It recognises that, notwithstanding the experience of Christchurch, earthquakes in New Zealand will not generally significantly impact on major urban centres. The Ministry of Business, Innovation and Employment's core team of building safety evaluators should be sufficient to respond to a smaller centre, such as Gisborne. The middle group could be called in to assist this core team when an event occurs in a larger provincial centre. If a territorial authority needs to carry out a large-scale, urban building safety evaluation operation, it could call upon all three groups of potential evaluators. We discuss the training needs of the middle group of building safety evaluators in section 2.4.5.2.4 of this Volume.

Recommendations

We recommend that:

118. The Ministry of Business, Innovation and Employment should progress their proposal to establish a core team of building safety evaluators that the Ministry could call on.
119. The Ministry of Business, Innovation and Employment should carefully consider the merits and detail of any proposals about the size of this group of building safety evaluators.
120. The ability to supplement this team with more evaluators who have received basic training should be maintained.

2.4.5 Barriers to obtaining skilled building safety evaluators

2.4.5.1 The liability waiver for building safety evaluators

The reports received by the Royal Commission record that when the NZSEE Guidelines[10] were reviewed from 2004 to 2009, engineering consultancies made it clear that they would not volunteer their workers for a building safety evaluation operation without a waiver of liability. They wanted a waiver to recognise that engineers would be volunteering on a "best endeavours" basis in an emergency situation: engineers would normally evaluate buildings more thoroughly.

To find a way forward, the NZSEE convened a large group made up of government, industry and technical engineering societies to discuss the liability issues. This group concluded that section 110 of the Civil Defence and Emergency Management Act 2002 was the best way to manage engineers' concerns about liability for building safety evaluations. Section 110 gives civil defence workers protection from liability for damages or loss during a state of emergency, unless they acted in bad faith or were grossly negligent. It states:

110 Protection from liability

(1) Except as provided in sections 107 to 109, there is no cause of action against the Crown, or a Civil Defence Emergency Management Group, or an officer or employee or member of any of them, or against any other person, to recover damages for any loss or damage that is due directly or indirectly to a state of emergency.

(2) Subsection (1) applies whether the loss or damage is caused by any person taking any action or failing to take any action, so long as the act or omission occurred in the exercise or performance of his or her functions, duties, or powers under this Act.

(3) No person is exempted from liability under subsection (1) for any act or omission to act that constitutes bad faith or gross negligence on the part of that person.

This liability waiver was carried through into the recovery phase after the February earthquake. Section 83 of the Canterbury Earthquakes Recovery Act 2011 sets out a comparable liability waiver:

> 83 Protection from liability
>
> (1) Except as otherwise provided in this Act, no action lies against the Crown, or an officer or employee or Minister of the Crown, or against any other person,—
>
> (a) to recover any damages or other amount for any loss, damage, or adverse effect that is due directly or indirectly to any action taken under this Act; or
>
> (b) to require any work to be carried out or other action to be taken in order to remedy or mitigate any loss, damage, or adverse effect that results directly or indirectly from any action taken under this Act.
>
> (2) No person who takes any action under this Act is liable under the Resource Management Act 1991 for any fine, costs, or expenses in respect of that action, except as otherwise provided in this Act.
>
> (3) Subsection (1) applies whether the loss, damage, or adverse effect is caused by any person taking any action or failing to take any action, so long as the act or omission occurred in the exercise or performance, or intended exercise or intended performance, of his or her functions, duties, or powers under this Act.
>
> (4) No person is exempted from liability under subsection (1) for any act or omission to act that constitutes bad faith or gross negligence on the part of that person.

Submitters suggest that providing a liability waiver for building safety evaluations is necessary and desirable because it recognises that these evaluations are carried out in special circumstances. Turner's[14] analysis of the building safety evaluation processes in several countries indicates that evaluators have liability protection in California and Japan; evaluators in Italy and the European Union do not have liability protection.

The unwillingness of some engineers to carry out building safety evaluations after the Boxing Day aftershock without the protection of a liability waiver clearly illustrates that having a waiver incentivises individual behaviour. The reports received by the Royal Commission describe how some engineers withdrew as evaluators when the CCC decided not to declare a state of emergency. Griffiths and McNulty[5] contend that this is because the CCC's contracting management system could not resolve their concerns about potential liability outside of a state of emergency. This suggests that the standard contracting arrangements used by human resourcing departments may not be sufficient to address any concerns about liability for work done under special circumstances, such as after a disaster. If engineers are not given a liability waiver when they volunteer as building safety evaluators, they may carry out more thorough assessments, or alternatively, not provide their services. In either case, the recovery from the disaster is likely to be delayed. It was made clear to the Royal Commission by some of those who suffered personal loss that they held those involved in the assessments responsible. Taking these considerations into account, the Royal Commission considers it is both prudent and reasonable to provide a liability waiver for building safety evaluators.

It is important to consider whether a building safety evaluation operation can continue outside of a state of emergency because civil defence and emergency management best-practice is to move from response to recovery as soon as possible. A large-scale rapid assessment operation may not be complete before a state of emergency ends. The Ministry of Business, Innovation and Employment suggests aligning the liability waiver with the building safety evaluation process rather than whether or not a state of emergency is declared. This would allow territorial authorities and other decision makers to carry out building safety evaluation operations in a range of circumstances. It may also remove the need for a mechanism that transitions the process from civil defence to normal building control arrangements governed by territorial authorities: we discuss this transition in section 2.6 of this Volume. The Royal Commission therefore considers that the liability waiver for building safety evaluators should be associated with the process itself, not when it takes place.

Recommendations

We recommend that:

121. Legislation should continue to provide for a waiver of liability for building safety evaluators carrying out rapid assessments.

122. The liability waiver for building safety evaluators should be aligned with the building safety evaluation process instead of being restricted to an operation carried out in a state of emergency.

2.4.5.2 The skills of building safety evaluators

In addition to constraints caused by the availability of engineers, the skill sets and abilities of the evaluators may also affect the efficiency and effectiveness of a building safety evaluation operation. International literature on building safety evaluations indicates that the quality of assessments produced by evaluators can be inconsistent. The Royal Commission has heard evidence that the quality of both the DEEs and rapid assessments in Christchurch varied. We have also heard evidence that geotechnical engineers had to reassess properties in the Port Hills that were incorrectly given a green placard by structural engineers who did not identify the fall hazards from the surrounding cliff faces. Some submitters stated that, overall, they thought that the poorer-quality rapid assessments tended to be too conservative. International literature on building safety evaluations also suggests that rapid assessments tend to be conservative. However, the Royal Commission has found that this was not the case with evaluations of unreinforced masonry buildings. In section 4 of Volume 4 we discuss the individual buildings that caused the deaths of 42 people when they failed in the February earthquake. These buildings were nearly all unreinforced masonry or brick or block structures. We note several examples where engineers carried out less cautious assessments, such as those on 7 Riccarton Road.

2.4.5.2.1 The skill sets engineers require

International literature indicates that many engineers may not be skilled enough to carry out good quality evaluations of buildings damaged in an earthquake. The NZSEE[15] recommendations on how to assess whether a building is potentially earthquake-prone also express concerns about the ability of engineers to assess existing buildings before an earthquake.

This is because the processes used to assess the structural performance of a building in an earthquake are different from those an engineer would use when designing a building. In addition, Saito and Thakur[16] note it can be particularly difficult to assess moderate damage to a building; it is easier to identify when a building is severely damaged or hardly damaged at all. Engineers assessing a building's structural performance in an earthquake need to assess the way in which individual structural elements affect the overall response of the building. This requires considerable judgement by the engineer, who needs a thorough understanding of the underlying theory and its empirical justifications to adequately identify and assess the observed condition of the building. For this reason, the NZSEE[15] recommends that only Chartered Professional Engineers with experience in earthquake engineering determine whether a building is potentially earthquake-prone. The Royal Commission has heard evidence that the number of engineers with this experience before the September earthquake was small.

2.4.5.2.2 Guidance on carrying out DEEs after earthquakes

The Royal Commission has received evidence that engineers carrying out DEEs for building owners were expected to use their own knowledge and refer to guidance documents produced in New Zealand and the United States if necessary. We note advice that some of these overseas guidance documents are not directly applicable to New Zealand. Engineers were not familiar with what needed to be included in a DEE after an earthquake. Some engineers effectively repeated a Level 2 Rapid Assessment: they did not seek out plans, identify any critical structural weaknesses or adequately determine the structural load paths in the building. Owners confused them with a DEE because they were provided by a Chartered Professional Engineer.

After looking at how engineers carried out DEEs in Christchurch following the Canterbury earthquakes, the Ministry of Business, Innovation and Employment[17] began developing guidelines for engineers to use when carrying out DEEs after earthquakes. We consider that these DEE guidelines should be finalised as soon as possible to assist building owners and other decision makers in the rebuild of Christchurch.

Recommendation

We recommend that:

123. The Ministry of Business, Innovation and Employment should work with the New Zealand Society for Earthquake Engineering, the Structural Engineering Society New Zealand and others with appropriate experience and expertise to finalise guidelines for Detailed Engineering Evaluations as soon as possible.

2.4.5.2.3 Guidance for entering dangerous buildings after earthquakes

In section 4.16.4.2 of Volume 4, we discuss the circumstances in which workers entered the damaged Durham Street Methodist Church and lost their lives in the February earthquake. We highlight the lack of clear guidelines for engineers and others in assessing the risk of entering what was essentially a dangerous building.

The Royal Commission has heard evidence that building safety evaluators checking buildings in the CBD Red Zone in Christchurch were nearly caught in them during the second June 2011 aftershock. In addition, engineers carrying out detailed engineering evaluations in red or yellow placard buildings may need to enter them to assess the building. Urban Search and Rescue engineers receive training on assessing the risks to themselves and their team when entering a building. For this reason, they accompanied the rapid assessment teams working in Christchurch's CBD after the February earthquake, to make sure that these teams were carrying out their work in a safe way.

The Royal Commission considers that guidelines should be developed to assist building safety evaluators to assess when and how to enter a damaged building. These guidelines should be based on the Urban Search and Rescue training. We consider that they should be attached to the guidelines for carrying out DEEs after earthquakes that the Ministry of Business, Innovation and Employment are currently developing.

Recommendations

We recommend that:

124. Guidelines should be developed that assist building safety evaluators to assess when and how to enter a damaged building.

125. These guidelines should be based on the Urban Search and Rescue training on when and how to assess entry to a damaged building.

126. These guidelines should be attached to the guidelines the Ministry of Business, Innovation and Employment is developing on the way in which engineers should carry out Detailed Engineering Evaluations after earthquakes.

2.4.5.2.4 Training for building safety evaluators

The lack of specific training for building safety evaluators and the wider engineering community contributed to the variable quality and inconsistencies in both rapid assessments and DEEs after the earthquakes, which were reported to the Royal Commission. Many of the Urban Search and Rescue engineers who carried out rapid assessments after the September earthquake were familiar with the building safety evaluation process: they had supported overseas operations and had received pilot NZSEE training in 2010. However, few of the volunteer engineers had received direct training on this process, or had previously used the NZSEE Guidelines. This meant that a consistent brief for these engineers on the building safety evaluation process was desirable before they carried out rapid assessments.

From 5 September 2010, members of the rapid assessment teams received a briefing of about 30 minutes on the NZSEE Guidelines and the process they were to follow. However, because of when they arrived and were deployed, not everyone received this briefing. New Zealand has yet to develop a field manual for building safety evaluators to take out with them.

This does not mean that these engineers received no support in carrying out building safety evaluations. The Royal Commission has heard evidence that building safety evaluators would hold informal debriefs with each other at the end of the day. Participants commented on how valuable these conversations were, because more experienced evaluators shared their knowledge about how and why they assessed damaged buildings the way they did.

The NZSEE has been developing a training programme for building safety evaluators for some time. In 2005 and 2006, the NZSEE developed drafts of the following:

- an Information Sheet,
- Training Modules;
- Induction materials; and
- a Field Guide.

However, work on these drafts stalled in 2007. By 2009, work on the development of a field guide had progressed. Pilot training modules had also been developed to accompany the revised version of the NZSEE Guidelines[10]. These pilot training modules focus on managing the building safety evaluation process, with participants split into groups to work through case studies where they assess damaged buildings. This training was delivered to building control officials and local council engineers. Only six territorial authorities, including the CCC, had received this training in 2009 and 2010. Most of the CCC engineers and building control officials carrying out building safety evaluations after the September earthquake had undergone this training.

Like the pilot training materials, the NZSEE Guidelines focus on how to plan for and manage a building safety evaluation operation. The guidelines in countries with similar building safety evaluation processes tell engineers and other evaluators what methods, frameworks and assumptions they should use. Their building safety evaluation guidelines typically describe the characteristics and the damage that evaluators are likely to observe in different types of buildings. These countries usually develop specific training programmes to supplement their guidelines.

In section 2.4.5.2.1 of this Volume, we discuss the need for engineers to have specialised training and experience in order to successfully evaluate the performance of an existing building in an earthquake. For these reasons, the Royal Commission considers New Zealand's building safety evaluation process should include guidelines for evaluators about what methods, approaches and assumptions they should use when assessing the damage to a building. Although this will make the guidelines considerably larger, we consider that these guidelines should be incorporated into the main guidance documents, instead of being published separately. This will ensure that they reach all building safety evaluators.

The Royal Commission has heard evidence that building safety evaluators would have found it useful to have a field manual summarising the damage to look for in particular building types. We consider that the draft NZSEE field guide should be finalised and provided to all building safety evaluators.

Recommendations

We recommend that:

127. New Zealand's building safety evaluation guidelines should incorporate detailed guidance to engineers about the way they should assess the damage to particular building types.

128. The field guide for building safety evaluators should be finalised.

Submitters discussed how much training engineers need before becoming a building safety evaluator, and who should provide this training. The NZSEE[3] contends that not all building safety evaluators need the same level of training to successfully carry out rapid assessments. Using the model set out in Figure 5, Figure 6 illustrates the level of training each group of evaluators needs.

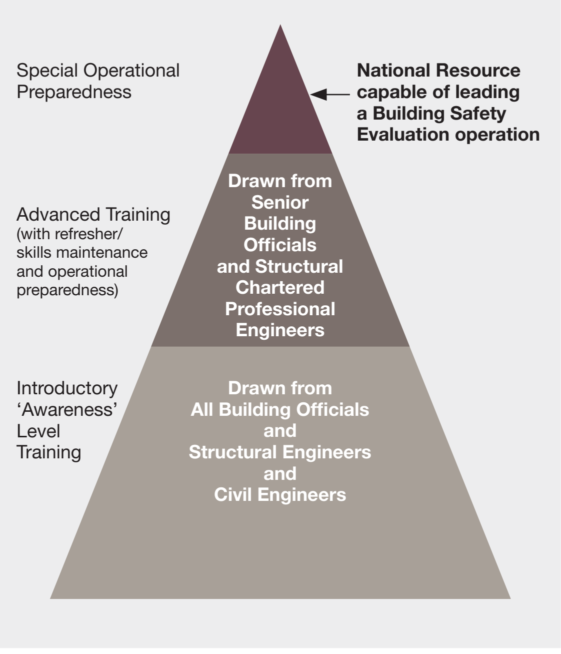


Figure 6: Building evaluation resource and training capability objectives (source: NZSEE, 2011)

The training for each of these groups is what is needed to maintain their ability to carry out rapid assessments of buildings after earthquakes. Each group would receive a different level of training. The smallest group is the most highly trained, attending presentations on the management of disasters and participating in visits to disaster scenes overseas. This group of experts would assist with training those in the middle group of structural Chartered Professional Engineers and senior building officials who are building safety evaluators in the methods, frameworks and assumptions they should use when they carry out rapid assessments. The middle group would maintain their preparedness through this advanced training, which would be supplemented by refresher courses. They would keep up to date with lessons from disaster events, and the structural engineers who wish to become building safety evaluators could undertake optional training as part of their preparation to become a Chartered Professional Engineer. The largest group of building safety evaluators would develop a basic awareness of the building safety evaluation process through engineering conferences and seminars, such as the "Learning from Earthquakes" seminars given by the Urban Search and Rescue engineers returning from overseas events.

The Royal Commission considers that New Zealand's building safety evaluation process and guidelines should be supplemented by a training programme. This training should explain what the building safety evaluation process is, and show evaluators how to assess the significance of damage to different types of buildings and structures. We consider that the Ministry of Business, Innovation and Employment should be responsible for developing and delivering this training programme. The assessment of damage observed in a building after an earthquake requires engineering judgement, and this judgement is usually garnered through experience. Developing and delivering training helps engineers to acquire the skills needed to carry out a building safety evaluation process because it provides a forum where engineers can learn from their more experienced peers. We consider that New Zealand should develop training for engineers on how to assess damaged buildings based on the NZSEE model illustrated in Figure 6. As well as identifying and assessing the damage to buildings caused by earthquakes, training on the building safety evaluation process could cover how to assess buildings damaged by other disasters.

Recommendations

We recommend that:

129. The building safety evaluation process should incorporate a training programme for all building safety evaluators.

130. Such training should cover:

- what the building safety evaluation process is and how it works; and
- how to identify and assess the damage evaluators observe in buildings after an earthquake.

131. This training programme should be developed using the New Zealand Society for Earthquake Engineering's building evaluation resource and training capability objectives framework, in which building safety evaluators are split into three different groups and each group receives a different level of training.

2.4.5.3 Indicating that the pool of building safety evaluators has the right skills

Several submitters favour developing a way to indicate that building safety evaluators have the right skills and experience. They contend that when building safety evaluation managers know what skills and experience their volunteers have, they are better able to decide where to send them. Some submitters proposed a training and warranting system for building safety evaluators similar to the system used in California. Several discuss whether or not building safety evaluators need to be chartered professionals. Some submitters suggest that the pool of available evaluators should be assigned to assess different types of structures based on their particular skills and experience.

2.4.5.3.1 A registration and warranting scheme for building safety evaluators

In contrast to New Zealand, volunteers in California must be formally registered and warranted as building safety evaluators (with the California Safety Assessment Program). Their registration as evaluators must be renewed every five years and they must attend training to keep it current. The Ministry of Business, Innovation and Employment suggests that the proposed core team of building safety evaluators should be registered and warranted.

The Royal Commission has received evidence that the mobilisation of engineers and other building safety evaluators after the Canterbury earthquakes was fast, efficient and largely effective. However, the reports we received recognise that pre-planning for how to mobilise volunteer evaluators was poor. We understand that the efforts of IPENZ and Local Government New Zealand in mobilising volunteer engineers and building control officials from other councils were largely responsible for the successful mobilisation. There is no reason to assume that such efforts would not be repeated after another major disaster. Consequently, we do not consider it necessary to register and warrant building safety evaluators to assist mobilisation.

However, it is important that these evaluators keep their skills current. The Royal Commission therefore considers that the training should be compulsory for the core team of building safety evaluators that forms a national resource capable of leading a building safety evaluation operation. We also consider that this training should be compulsory for those Chartered Professional Engineers, structural engineers and senior building officials who wish to be able to carry out rapid assessments. These building safety evaluators should regularly attend compulsory refresher courses to keep their training up to date. The Royal Commission does not consider that it is necessary for the largest group of building safety evaluators, drawn from all building officials, structural engineers and civil engineers, to attend compulsory training as they will rarely be called upon to assist after a disaster. Only trained evaluators should participate in a building safety evaluation operation, unless the circumstances of a particular disaster make this impractical and the largest pool of potential evaluators is mobilised. Should the need to call upon the largest group of potential evaluators arise, we consider that, wherever practicable, these evaluators should carry out rapid assessments under the supervision of those evaluators who have attended the compulsory training and therefore possess a greater level of preparedness.

In section 2.4.2 of this Volume, we suggest that building safety evaluation operations should be delivered by territorial authorities. Consequently, we consider it particularly important that territorial authority staff with civil defence and emergency management responsibilities attend the compulsory training. This should be considered part of the job training for this group.

Because the training for the core team that forms a national resource capable of leading a building safety evaluation operation and the building safety evaluators who actively maintain their preparedness would be compulsory, the Ministry of Business, Innovation and Employment would be able to keep a list of people who have attended the training. The Ministry of Business, Innovation and Employment should make this list available to territorial authorities' civil defence and emergency management planners.

2.4.5.3.2 Should building safety evaluators be Chartered Professional Engineers?

Some submitters suggest that using non-chartered professional engineers could lead to poorer quality rapid assessments because these engineers are typically less experienced than their chartered peers.

Turner[14] outlines who can be building safety evaluators in California, Greece and Japan. Engineers registering as building safety evaluators in California must be the equivalent of a Chartered Professional Engineer. Civil engineers in Greece carrying out evaluations should have four to five years' experience. Building safety evaluators in Japan must be trained and registered first or second class authorised architects; the legislation governing the authorisation to architects applies to both architects and building engineers. In Japan, architects receive substantial training in structural engineering.

After the February earthquake, only Chartered Professional Engineers were allowed to join the building safety evaluation teams working in the CBD Red Zone. Because of their greater experience, civil defence management believed that they would be better able to assess the damage to a building, and therefore the risk to their team and ultimately the wider public, from ongoing aftershocks.

However, allowing only Chartered Professional Engineers to become building safety evaluators would significantly reduce the pool of people available to carry out rapid assessments. Further, volunteer building control officials, architects and members of the construction industry can be valued members of a rapid assessment team. In addition, the Ministry of Business, Employment and Innovation contends that while only Chartered Professional Engineers should carry out DEEs after earthquakes, suitably trained building control officials could produce rapid assessments of consistent quality. We accept that this is so, and consider that all building safety evaluators do not need to be Chartered Professional Engineers.

2.4.5.3.3 The assignment of specific tasks to evaluators with specific qualifications and experience

Another way of indicating that building safety evaluators have the right skills and experience is to organise for different groups of evaluators to assess particular types of buildings and structures depending on their qualifications, training, and/or experience.

The 1998[18] version of the NZSEE Guidelines took this approach. So do the Californian building safety evaluation guidelines[11] on which the NZSEE Guidelines are based. These documents suggest that building control officials, architects and members of the construction industry carry out Level 1 Rapid Assessments. The engineering resource is reserved for Level 2 Rapid Assessments. This is because Level 2 Rapid Assessments are more thorough and therefore take more time (note, however, that Level 2 Rapid Assessments are still only a basic evaluation of the condition of the building).

The New Zealand Historic Places Trust expands on this idea. It proposes developing a core group of specialist heritage building safety evaluators because considerable experience is needed to assess the damage to heritage buildings, particularly unreinforced masonry buildings.

After the February earthquake, civil defence and emergency management introduced targeted building safety evaluation teams to assess sections of the city or issues important to the community. As well as evaluating suburban commercial buildings in Operation Shop and residential properties in Operation Suburb, specialist evaluators assessed shopping malls (so that the public could access food and other necessities), critical buildings (including those six or more storeys high), the CBD, when and where cordons were needed, and what buildings needed immediate demolition. ATC[6] suggests that this approach may have some advantages over the block-by-block method usually used internationally: civil defence and emergency management in Christchurch were able to move more rapidly to open up entire segments of the community. California[19] has therefore added this concept to the operational plans used by the state agency that supports local authority delivery of the building safety evaluation process.

Based on how efficient and effective the building safety evaluation operations were overall after the Canterbury earthquakes, the Royal Commission does not believe that it is necessary to formalise who should carry out what assessments based on the qualifications, skills and experience of the evaluator. As Operations Shop and Suburb proved, it is possible to informally manage a building safety evaluation operation this way if necessary. Nevertheless, we consider that non-chartered professional engineers and more experienced evaluators drawn from building control officials, architects and other suitably qualified people should primarily carry out Level 1 Rapid Assessments. Where possible, only Chartered Professional Engineers should carry out Level 2 Rapid Assessments.

Recommendations

We recommend that:

132. The core group of building safety evaluators who are a national resource capable of leading a building safety evaluation operation, and those Chartered Professional Engineers, structural engineers and senior building officials who wish to be building safety evaluators, should be required to attend compulsory training.
133. Only trained building safety evaluators should be authorised to participate in a building safety evaluation operation unless the circumstances of a particular disaster make this impractical.
134. If the scale of the emergency requires the mobilisation of the largest group of potential building safety evaluators, who have not received the compulsory training, these evaluators should work, wherever practicable, under the supervision of those evaluators who have attended the compulsory training.
135. Territorial authority staff with civil defence and emergency management responsibilities should be required to attend the compulsory building safety evaluator training as part of their job training.
136. The Ministry of Business, Innovation and Employment should keep a list of the people who complete the compulsory training for building safety evaluators and should make this list available to all territorial authorities.
137. Where available, only Chartered Professional Engineers should carry out Level 2 Rapid Assessments.

2.4.6 Building safety evaluation models

The Royal Commission considered it important to look at whether or not the current system is the right approach or model. Researchers are developing technology-based building safety evaluation models. We also looked at building safety evaluation models based on building type, private contracting and the Indicator Building system that developed in Christchurch after the September earthquake.

Option 1: Technology-based building safety evaluation models

International literature on building safety evaluations suggests that cities adopt technology-based building safety evaluation models as the main building safety evaluation process. If adopted widely, these methods could develop into a building safety evaluation process that is fully automated. Researchers contend that this will result in better quality rapid assessments because raw data of each building's performance will be available, and these models reduce the number of evaluators needed for a building safety evaluation operation.

Vidal et al.[20] identifies several technology-based building safety evaluation models. Scenario modelling involves looking at the characteristics of the buildings in an area and modelling what would happen in various disasters before a potential event. Aerial surveying (increasingly carried out using high-resolution satellite imagery), laser scanning and damage mapping determine the extent of the damage caused by the earthquake by comparing photographs, laser images or information from sensors with baseline images or data. These sensors are placed throughout locations and/or in individual buildings. Some of these tools were used in Christchurch after the Canterbury earthquakes. A number of buildings were assessed using laser scanning. GNS Science also used laser scanning to monitor movement in the cliff face in the Port Hills. Building safety evaluators used remote reconnaissance by a small unmanned aerial vehicle with a camera mounted on it and a New Zealand Army robot to assess the damage to the Cathedral of the Blessed Sacrament in Barbadoes Street.

Generally, these methods tend to be less accurate when applied to a single building. Consequently, these building safety evaluation models tend to work better in places where there has been extensive building collapse; aerial surveying and damage mapping have been used in Haiti, China and Turkey. In addition, technology-based building safety evaluation approaches rely on high-quality digital information about the area or individual buildings being available before and after a disaster. Although territorial authorities in New Zealand may have semi-automated building record systems, the Royal Commission has received evidence that territorial authorities may struggle to provide this information in a format that building safety evaluators can use.

Option 2: Status quo – local reconnaissance teams

New Zealand's building safety evaluation framework uses local reconnaissance teams to assess the damage a disaster causes to an area's buildings. In section 2.3.2 of this Volume, we describe how it is characterised by teams placing colour-coded placards on buildings after assessing the damage to them. This approach was first developed in Europe in the early 1980s. It is used by the United States, Japan, Indonesia, Greece, Italy, the wider European Union, Colombia and Mexico.

Option 3: Privately contracted building safety evaluators

Rather than implementing a building safety evaluation operation managed by public agencies, New Zealand could encourage or require building owners to contract their own engineers to check their buildings after a disaster. San Francisco developed a building safety evaluation model based on this concept; this is the voluntary Building Occupancy Resumption Program (BORP).

There are precedents for developing a model based on using privately contracted building safety evaluators in New Zealand. Lifeline utilities typically contract engineering consultancies to carry out a baseline evaluation of the utility and then check it after a disaster; Telecom has contracted Opus to do so, for example. The Royal Commission has heard evidence that building owners also contacted engineers and asked them to check their buildings immediately after the September earthquake. However, if this system is adopted building owners and engineers may need to renegotiate the assessment contract every time the building is sold or engineers move on. The Royal Commission therefore considers that it would not be feasible to rely solely on privately-contracted building safety evaluators. However, we encourage owners to be aware of the likely seismic performance of their buildings.

Option 4: Evaluating buildings based on their building type

Building safety evaluation literature and some submitters suggest determining what placard to assign to a building based on its building type, particularly its age and construction. This approach involves identifying the key structural weaknesses associated with each particular building type and the key damage patterns it is likely to experience in an earthquake. This idea would require certain processes to be followed in relation to particular kinds of buildings without regard to the extent to which they had been damaged by the earthquake. We do not favour this approach as it would unnecessarily restrict access to undamaged buildings.

2.4.6.1.1 Conclusions

The Royal Commission considers that improvements should be made to our current process instead of looking for an entirely different model. This is because New Zealand follows current international best-practice and we have not found any viable alternative. Although some of the semi-automated systems have merit, it may be some time before they can be adopted in a systematic way throughout the country due to the limitations of the current technology and the base information.

On the other hand, the Royal Commission considers that the management of buildings after earthquakes should incorporate separate procedures and assessments for different kinds of buildings. This issue is discussed in section 2.6.2 of this Volume.

2.4.6.2 The Indicator Building system

According to the reports we received, the Indicator Building system was first used after the September earthquake. After the February earthquake, this model was expanded and formalised. The Indicator Building system is designed to assess the effects of aftershocks on buildings. The relevant authority identifies examples of different types of buildings whose structural elements were damaged in the main shock, but are not close to collapse: these are the Indicator Buildings. It then monitors the new damage that an aftershock causes to see if it falls within expected limits. If the Indicator Buildings are sufficiently damaged, or the damage observed in them is greater than expected, the authority may decide to carry out a building safety evaluation operation in respect of the class of building that the indicator building represents.

Figure 7: An Indicator Building in Christchurch after the February earthquake (source: draft ATC Reconnaissance Team report, 2012)

The NZSEE[3] states that this model proved invaluable for determining how to use the resources available to carry out building safety evaluations in Christchurch's CBD after significant aftershocks. CERA has also communicated to the Royal Commission that the model has been an effective tool in their management of buildings after aftershocks. In January 2012, California[19] amended the operational plans used by the state agency that supports local authority delivery of the building safety evaluation process to incorporate New Zealand's Indicator Building system. This is because the Indicator Building system provides a rational decision making tool for civil defence and emergency management and territorial authority staff.

We consider that the Indicator Building system is particularly useful when an area is experiencing an earthquake swarm or a prolonged aftershock sequence. For this reason, the Royal Commission considers that the Indicator Building system should be incorporated into New Zealand's building safety evaluation process.

Recommendation

We recommend that:

138. The Indicator Building model should be incorporated into New Zealand's building safety evaluation process.

2.5 Delivery of the building safety evaluation process

The Royal Commission has heard evidence that planning for a building safety evaluation process (prior to the September earthquake) in Canterbury had only just begun when the earthquake occurred. However, as our international expert, Mr Bret Lizundia, pointed out in his evidence to the Royal Commission, New Zealand overcame this lack of planning with considerable efficiency and innovation. He discussed how impressed California's ATC were with New Zealand's quick mobilisation of extra help and resource, and the way procedures were developed, and that volunteers came forward and carried out the necessary tasks efficiently. ATC[6] expresses the view that "officials did an outstanding job" at improvising on an urgent basis after the February earthquake. Mr Lizundia particularly notes the creative use of shipping containers for propping and as barricades, how well temporary utilities were organised and that portable sanitary facilities were provided that allowed people to shelter in place.

The Royal Commission therefore considers that despite some problems, overall, the building safety evaluation operations after the Canterbury earthquakes were well delivered: for example, the NZSEE[3] reports that most of the rapid assessments of 1236 commercial buildings and 6686 residential buildings were completed during the first week following the September earthquake. In our Report, we make recommendations about how to improve the building safety evaluation process. The Royal Commission considers that relevant plans should be flexible and adaptable, rather than prescriptive rules that must be followed. Because they will be applied in an emergency, they need to be flexible enough to allow innovative responses to unusual situations.

We now discuss the more significant issues we have identified with the delivery of the building safety evaluation operations after the Canterbury earthquakes.

2.5.1 Processes developed at the time

The NZSEE Guidelines[10] suggest that territorial authorities need to plan the building safety evaluation process before the event. This is also international best-practice; building safety evaluation literature stresses pre-planning the implementation of a building safety evaluation process.

It is not clear how much CCC, Waimakariri District Council and Selwyn District Council had pre-planned for carrying out a building safety evaluation operation before September 2010. All three territorial authorities had taken steps to implement the NZSEE Guidelines by this time. On the morning of 4 September, the Urban Search and Rescue Engineering Team Leader and a civil defence and emergency management consultant worked with the CCC to plan and set up the building safety evaluation process used after 5 September. The Urban Search and Rescue Engineering Team Leader suggested using draft revised Guidelines, developed in 2010, to take advantage of the improvements introduced from the lessons learnt in the Indonesian and Italian earthquakes in 2009.

Time is needed to explain these new arrangements to people. Even though CCC staff had recently received training on the 2009 version of the NZSEE Guidelines, they would have been unfamiliar with the draft 2010 revision.

The NZSEE[3] contends that many territorial authorities believe that they can pick up the NZSEE Guidelines on the day and use them to run their building safety evaluation process. We consider it important that local authorities should plan for the process in advance. This should occur as part of their civil defence responsibilities. This requirement should be set in legislation.

Recommendations

We recommend that:

139. The Ministry of Business, Innovation and Employment should provide guidance to territorial authorities to support their plans to carry out a building safety evaluation process.

140. Territorial authorities should be required to plan their building safety evaluation process as part of their civil defence and emergency management plans.

2.5.2 Development of multiple processes

After the September earthquake, parallel building safety evaluation processes developed as engineers engaged by owners carried out evaluations of varying detail alongside the official operations. Privately contracted engineers are not required to undertake the same process as official building safety evaluators. There is no legal requirement to follow the NZSEE Guidelines. The Royal Commission has heard evidence that these engineers carried out the equivalent of Level 1 and Level 2 Rapid Assessments, DEEs, or assessments that fell between one or other of these categories. Some building owners and engineers changed the official placard placed on the building, or posted their own placards on the basis of these evaluations. We consider the processes used to change the placards in section 2.5.3.2 and discuss the development of multiple placard systems further in section 2.5.3.1 of this Volume.

Building owners and their engineers are not legally required to share the information in these evaluations with their local authority and there was no system in place to integrate them into the building's record. However, these reports sometimes contained information that would have triggered a change in a building's status. For these reasons, CCC introduced procedures to consider the reports on red and yellow placard buildings generated by a building owner's engineer.

Some submitters suggest formalising the parallel building safety evaluation process that developed after the Canterbury earthquakes and integrating it with the official process. Other submitters note the confusion the parallel building safety evaluation process caused and question whether it can be successfully integrated.

The Royal Commission supports building owners, their property managers and tenants taking the initiative to check out the condition of their building after an earthquake or other disaster. Nevertheless, we consider that there should be one rapid assessment process that is managed and implemented by officials with a clear mandate and authority. Building owners should understand the need for DEEs of their building and should engage their own engineers to carry out this service. They should also be required to give a copy of this evaluation to the relevant authority. This would eliminate much of the confusion that arose after the Canterbury earthquakes and ensure that authorities have access to all of the information that could affect the status of a building.

Recommendation

We recommend that:

141. Only official building safety evaluators should be authorised to place, change or remove placards, and to carry out rapid assessments for this purpose.

2.5.3 Issues with the placards

We have reproduced the placards used after the September earthquake in Appendix 2 of this Volume. The reports we received, international literature on building safety evaluations and submitters agree that the public, and some building safety evaluators, do not understand the meaning of the placards; in the same way, some do not understand the objectives of building management after earthquakes. These sources contend that the wording and the colour of the placards is unclear and confusing. A failure to understand the wording and meaning of the placards is an issue because the placard is often the main way that tenants or the wider public know whether a building can be entered and used. In particular, green placards are frequently interpreted as meaning that the building is "safe" and needs no further inspection. The development of placard systems in addition to the official process contributed to this confusion. Issues also arose when the status of the building and the placard on the building needed to be changed.

The Royal Commission, in the progression from red, to yellow, to green, notes that the placards become more wordy and less understandable. We consider the following sections of the green placard to be less clear than is desirable:

> This building has received a brief inspection only. While no apparent structural or other safety hazards have been found, a more comprehensive inspection of the exterior and interior may reveal safety hazards…
>
> Owners are encouraged to obtain a detailed structural engineering assessment of the building as soon as possible. Report any unsafe conditions to the Territorial Authority. Subsequent events causing damage may change this assessment. Re-inspection may be required. Secondary damage (partition, windows, fittings and furnishings) may be hazardous. Electrical and mechanical equipment, gas connections, water supplies and sanitary facilities have not been inspected.

Put simply this means:

- there has been a quick visual inspection of your building;
- no obvious structural problems were found after a quick look over your building;
- this does not mean that it is not damaged;
- this does not mean that it is completely safe;
- you need to organise for someone to look at it more thoroughly;
- if aftershocks cause more damage, the placard on your building may need to be changed;
- tell the council if you find anything that could be dangerous; and
- the role owners have in regard to the future safety of occupants and the public is important.

The Royal Commission considers that the wording of the placard should be changed to a plain English format along these lines. This would be easier to read and understand in an emergency situation, when people are stressed. The messages on the placards could be more clearly emphasised, so that people notice its text as well as its colour.

Recommendation

We recommend that:

142. The placards placed as a result of the building safety evaluation process should be rewritten in a plain English format.

New Zealand's building safety evaluation process uses red, yellow and green colour-coded placards to indicate the status of the building; this type of system is known as the "traffic light model". Examples of where it is used include project planning, risk management and prioritising medical treatment in emergency situations.

Part of the appeal of the traffic light model is that the general public is likely to have a basic understanding of the meaning of the colours. However, this can also become a disadvantage. People associate red with "stop", yellow with "caution" and green with "no issues", or "go". The green placard's colour may reinforce the commonly held view that the building is "safe" and does not need to be checked further. The CCC, the NZSEE, Mr David Brunsdon and Galloway and Hare[21] propose changing the colour of the green placard to white.

They contend that people are less likely to think that no further action is needed if the placard is not green.

In principle, the Royal Commission favours changing the colour of the green placard to white. However, we have heard evidence that changing the colour of the green placard to white could make New Zealand's building safety evaluation process less compatible with other countries' systems. The traffic light system is international best-practice and this change could result in confusion when evaluators assist in New Zealand or our evaluators help overseas. For these reasons, the Royal Commission considers that any decision to change the colour of the placards should be made after consulting with the wider international building safety evaluation community.

Recommendation

We recommend that:

143. In principle, the colour of the green placard should be changed to white. The Ministry of Business, Innovation and Employment should consult with the international building safety evaluation community about the merits and detail of the change before deciding whether or not to do this.

2.5.3.1 Multiple placard systems

Some engineers engaged by building owners developed and used their own building safety evaluation forms and placards during and after the state of emergency. Typically, these were adapted from the templates in the NZSEE Guidelines, or the ones used by the CCC and/or in the civil defence response. This led to the growth of multiple placard systems after the Canterbury earthquakes. As Figure 8 illustrates, by late November 2010, a building could stickered with:

- the (red/yellow/green) rapid assessments placards placed under a civil defence warrant;
- the placards developed by engineers engaged by building owners, placed during and/or after the state of emergency;
- the red section 124 Building Act notice placed by their territorial authority after the state of emergency;
- a variety of general engineering assessment notices; and/or
- notices placed by lifeline utility operators.

Figure 8: Multiple placards on the same building (source: the Applied Technology Council)

The large, red "Danger" notice in Figure 8 is an example of an assessment notice developed by building owners, their engineers, or other groups. Figure 8 also illustrates the problems that arose because the placards were not printed onto colourfast materials that faded over time. It became particularly difficult to tell the difference between a green and yellow placard as both faded to a pale yellow colour.

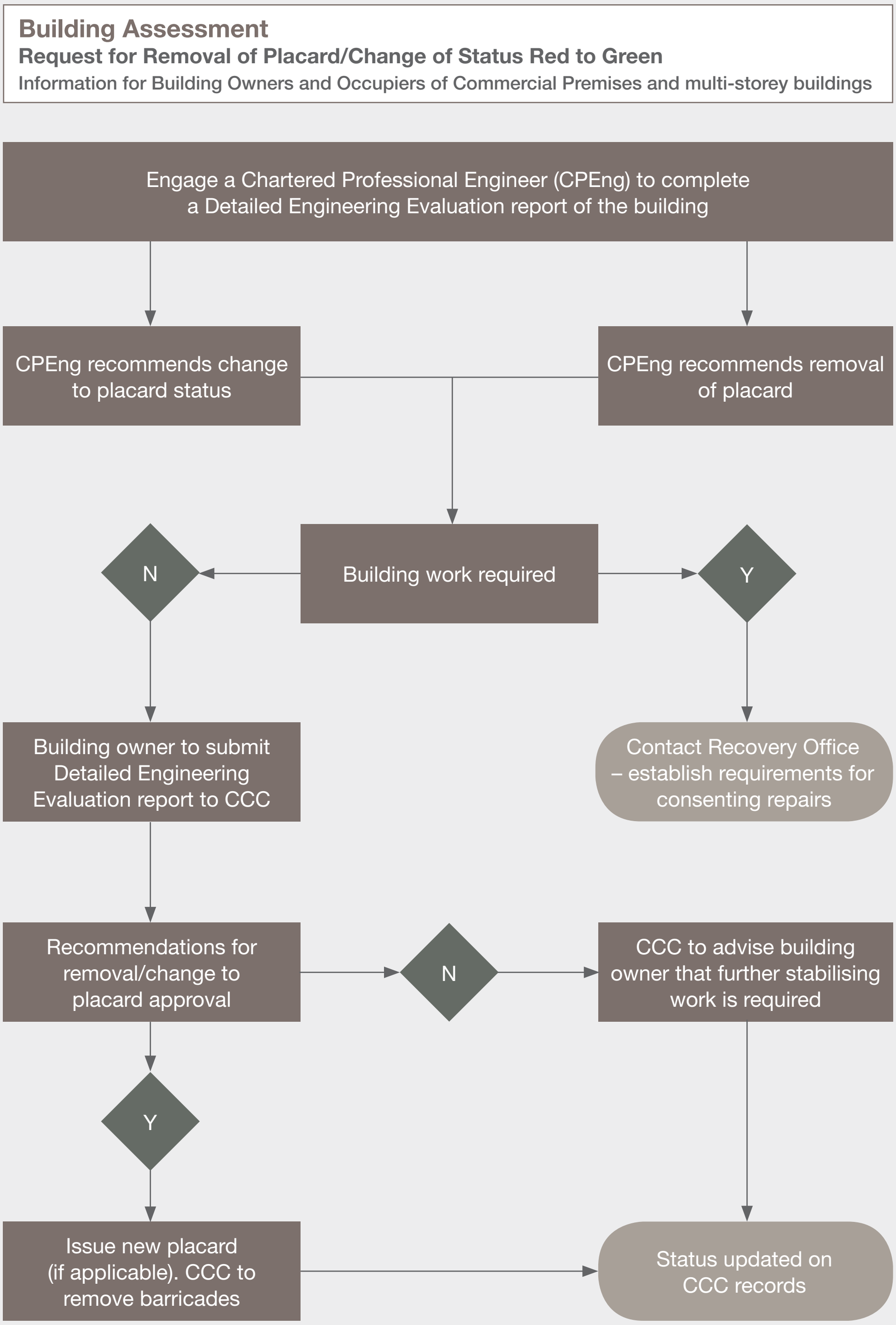
Placing several different placards on a building made it difficult for building owners, tenants and the general public to know what the status of the building was. The Royal Commission considers that only the relevant authorities should place, change or remove placards.

2.5.3.2 Changing the placards

The Royal Commission has heard evidence that building owners found the processes for changing a building's placard unclear. During the state of emergency after the September earthquake, some engineers engaged by building owners filled in the official Level 2 Rapid Assessment forms, which they obtained from the Emergency Operations Centre. Others provided their completed report to the Centre. In both cases, civil defence and emergency management would arrange for a placard to be placed on the building. The reports received by the Royal Commission contend that some building owners and their engineers did not realise that their evaluation would not automatically result in a change of placard. As well as placing multiple placards on buildings, some building owners or their engineers would remove placards without authorisation in both the response and recovery phases.

After the transition from civil defence to normal building management arrangements, the CCC developed processes to be followed before changing a red or yellow placard to a green placard.

These processes are set out in Figures 9 and 10.



The Building Act (2004) still applies. A building consent for urgent building work can be obtained at the Recovery Office based in the new City Council buildings in Hereford Street. These consents will be subject to safe practice conditions such as disconnecting the power and drains, along with appropriate health and safety practices. Heritage conditions will apply.

Use IPENZ engineer referral service, phone 0800 2424 4357 or refer to page 415 in the Christchurch Yellow Pages for a structural or civil engineer.

Figure 9: Process for changing a placard from red to green after the state of emergency in 2010 (source: CCC, 2011)

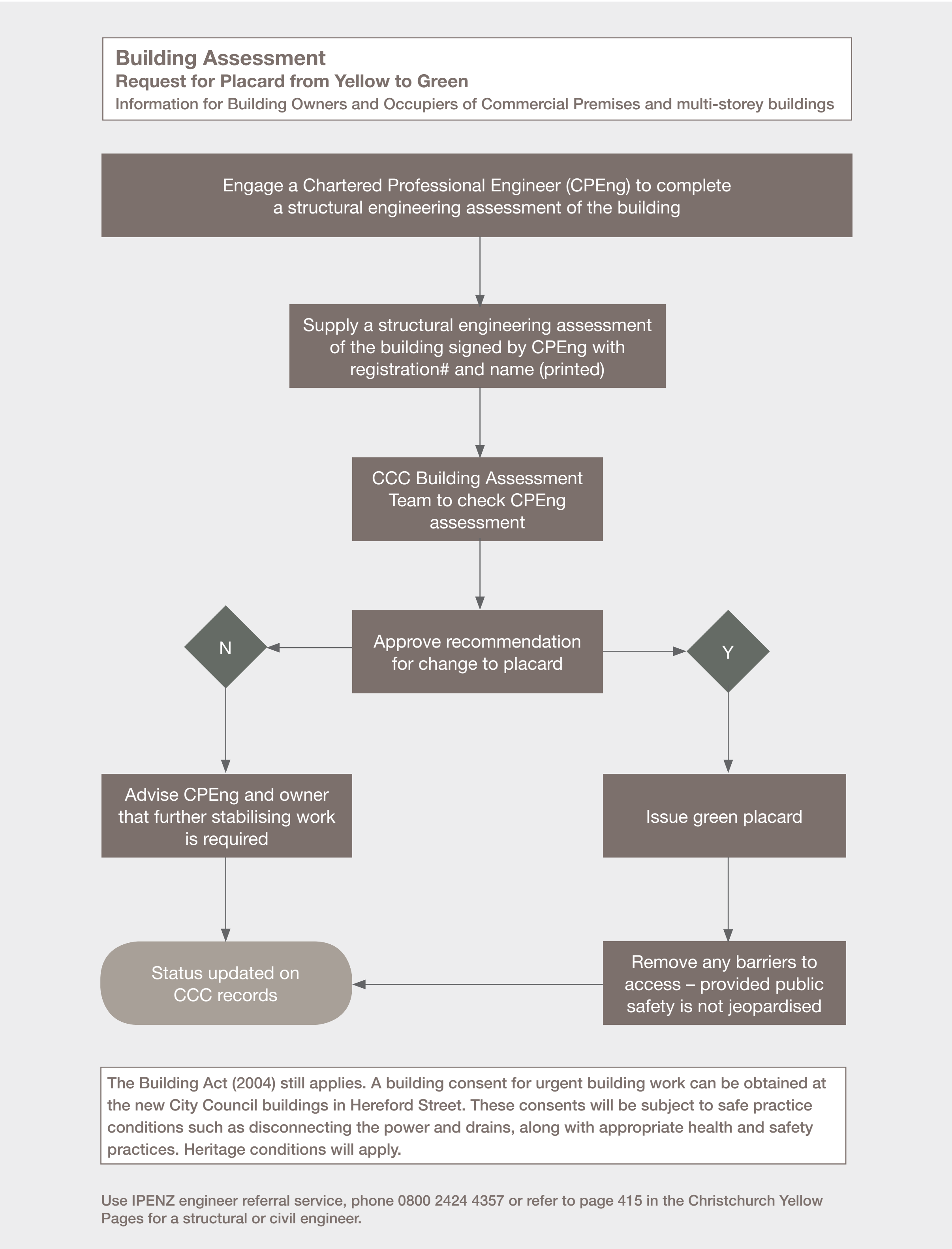


Figure 10: Process for changing a placard from yellow to green after the state of emergency in 2010 (source: CCC, 2011)

Initially, the CCC requested that building owners submit a DEE completed by a Chartered Professional Engineer. We have heard evidence that the level of detail in these reports varied. Griffiths and McNulty[5] contend that, as a result, the CCC effectively became peer reviewers for DEEs after earthquakes.

2.5.3.2.1 The CPEng Certification Form

To clarify and facilitate change procedures, the CCC introduced a new certification form that Chartered Professional Engineers submitted to request a change of placard. This form, reproduced in Appendix 3 of this Volume, is known as the CPEng Certification Form.

This form assured the CCC that the building was safe for occupancy and posed no further hazard to people or property, before the status of a red or yellow placard could be changed. It specifically recognised the danger falling hazards posed to public safety and the potential danger from damage to adjacent buildings, with the engineer stating that these dangers had been addressed. CCC staff discussed when and how to change a building's status with the certifying engineer if they needed to consider additional factors like removing cordons.

The CPEng Certification Form contemplated that a building was suitable for reoccupation if the structural integrity, and performance of the building had been restored "to at least the condition that existed prior to the earthquake of 4 September 2010". This meant that the building did not have to be made stronger than it had been prior to the September earthquake, before reoccupation could occur. Consequently, if a damaged building was earthquake-prone before the September earthquake, then it could be reoccupied even though it was still earthquake-prone after repair. The statement assumes that people were happy to take on the same risk associated with the building as they had prior to the earthquake. We discuss issues of risk and understanding in section 7.8 of Volume 4.

Submitters suggest developing procedures setting out when and how to change the status of a building and its placard. The Royal Commission also considers that formal procedures for changing the status of a building and its placards should be developed as part of the building safety evaluation process.

Recommendation

We recommend that:

144. Formal procedures should be developed that set out when and how the status of a building could be changed. The placard on a building should only be changed if the formal procedures are followed.

2.5.4 Communication tools

Civil defence and territorial authorities used a variety of communications tools to let the public know:

- what the building safety evaluation process was;
- what the placards meant;
- the responsibilities of building owners; and
- how to deal with their damaged buildings.

These tools included a mix of print, electronic media and public meetings. In addition to using flyers and posters, the CCC also set up a web-based newsletter. People had to register to receive this newsletter, which reduced its reach. Despite this, the media, building owners, engineers and the public did not fully understand what the building safety evaluation process was or the meaning of its placards.

The Royal Commission considers that the Ministry of Business, Innovation and Employment should be the lead agency responsible for any public communications about how to manage buildings after earthquakes and other disasters. It should be responsible for this during and after the state of emergency. The Ministry of Business, Innovation and Employment should develop communications material before it is needed and release this information as soon as possible after the disaster. This material should include information about:

- the extent of the risk posed by the damage the disaster has caused;
- the implications of aftershocks; and
- the roles and responsibilities of building owners.

The Royal Commission also considers that GNS Science should develop protocols and plans to ensure that it is ready to advise the Ministry of Business, Innovation and Employment, other government agencies, local authorities and the wider public after an earthquake.

Recommendations

We recommend that:

145. The Ministry of Business, Innovation and Employment should be responsible for developing and releasing public communication materials about building management after earthquakes and other disasters during and after the state of emergency.

146. GNS Science should develop protocols and plans to ensure that it is ready to advise the Ministry of Business, Innovation and Employment, other government agencies, local authorities and the wider public after an earthquake.

2.5.5 Information sharing

As well as problems with how authorities communicated with the public, the Royal Commission has heard evidence of communication problems between people and organisations after the Canterbury earthquakes. People and organisations failed to share information about the damage to a building with others who needed to be involved in decisions about its use, repair or demolition. When discussing information sharing within a civil defence context, Doyle and Johnston[23] contend that effective teams under high pressure commonly adopt a communication style characterised by expecting people to tell them the information they need to know, rather than team members specifically asking for it.

The Royal Commission has heard evidence that after the Canterbury earthquakes, networking was a key tool in obtaining and disseminating information about the damage to a building and its status. This was particularly important for green placard buildings, as territorial authorities had no way of finding out information about these buildings after the state of emergency ended.

Several submitters have suggested that mechanisms that allow different people and organisations to share information more easily should be developed. The Royal Commission discusses and makes recommendations about information sharing in section 7.5.3 of Volume 4.

2.5.6 Information management

Civil defence and emergency management literature suggests that access to good quality information is a key component of making initial assessments of the situation and informing ongoing decision making. The NZSEE[3] recommends developing a database to receive and record information gathered in rapid assessments.

The information management system used after the September earthquake, based on an Excel spreadsheet, was developed by the Urban Search and Rescue Engineering Team Leader, CCC and a civil defence and emergency management consultant on 4 September. This spreadsheet became the basis of the information management system that developed when the building safety evaluation process transitioned to the CCC.

Griffiths and McNulty[5] describe how this information management system designed for the building safety evaluation process did not interface well with CCC's own systems. The Royal Commission has heard evidence that there were other problems with how information on damaged buildings was gathered and managed after the September earthquake. Inefficient information recording meant that civil defence management, territorial authority staff and building owners had problems knowing the status of a building at a given point in time. Middleton and Westlake[2] contend that sometimes the only way to find out if the status of a particular building had changed was to carry out a visual check. In addition, sometimes official records would note a change to the building's status, but a new placard was not placed on the building.

Several submitters propose using information technology tools to collect and analyse data on damaged buildings. They suggest integrating a variety of tools, such as portable personal computers (e.g., tablets and notebooks), GPS and cellular telephones. Shibayama and Hisada[24] found that their electronic information management system, which was based on these tools, was more efficient than using conventional paper-based information gathering methods. This is despite practical issues with obtaining good quality digital maps and using portable personal computers; technological advances should address these issues.

The Royal Commission has heard evidence that engineers and building owners were not able to access records as they were held in the CCC's earthquake-damaged building. Consequently, several submitters suggest digitising building records and storing them offsite. Like technology-based building safety evaluation approaches, electronically-based information management systems need to interface with existing electronic records to work effectively. This may not be possible, even in first world countries. Although some territorial authorities in New Zealand have certain building control records on microfiche or in digitised formats, not all records are kept electronically and stored offsite. This means that it may not be possible to directly download or access existing building records, even if the technology to do so was available.

Nevertheless, the Royal Commission considers that digitising building control records and storing them offsite is good business continuity planning and should be encouraged. We have heard evidence that the CCC is encouraging other territorial authorities to do so based on their experiences after the Canterbury earthquakes and that the Ministry of Business, Innovation and Employment proposes establishing a national database of building records with several access points. The Royal Commission understands that this goal may not be achieved for some time because of the cost to territorial authorities to digitise their records. However, we consider that the Ministry of Business, Innovation and Employment and territorial authorities should progress their plans to achieve this.

Recommendations

We recommend that:

147. Information management systems should be developed as part of planning for New Zealand's building safety evaluation process.

148. The Ministry of Business, Innovation and Employment should work with territorial authorities and other relevant agencies to develop a way for territorial authority building records to be electronically recorded and stored off-site.

2.5.6.1 Identifying buildings

The Royal Commission has also heard evidence of the problems that arose because records for each building appear to have been kept according to its postal address. If a building has several entry points and/or multiple tenancies, then the territorial authority may have alternative addresses for the same structure. Alternatively, territorial authorities could have decided to identify a particular building by one particular address, even though different people and organisations may use several addresses. These addresses may not be the same as the postal address or the street address for the building and/or tenancy. The Royal Commission has heard evidence that this led to issues with identifying buildings.

Some submitters suggested looking at establishing a national unique address system. Middleton and Westlake[2] note that the United States is exploring how to develop a unique address system based on mapping coordinates.

Territorial authorities are responsible for allocating road names and numbering in New Zealand. When they name a road, they are required to advise Land Information New Zealand, which keeps an official national record of all properties in New Zealand.

Land Information New Zealand has recently introduced several initiatives to improve how people access property information via addresses. In 2011, it began work on a Spatial Data Infrastructure project that pulls together geospatial data; this project incorporates information on identifying individual properties. It has also introduced a new section on "Property Addressing" on its website. These webpages provide information on why addressing properties properly is important, who is responsible for allocating road names and numbering in New Zealand, addressing standards and address data. In addition, Land Information New Zealand now allows public access to the Authoritative Streets and Places database. This database provides:

- up-to-date nationwide listings of street names and place names that may potentially be used as part of an address, referenced against the territorial authorities and their electorates;
- nearby place names to provide locational context; and
- historical records of former names (since late 1992).

The Royal Commission considers that a clear system for identifying individual buildings should be developed and included in the plans for a building safety evaluation process. This needs to be set out in the general training about the building safety evaluation process, the induction evaluators receive before they are assigned to a rapid assessment team, and the assessment forms, so that evaluators know immediately how they are to indicate which building they are assessing. Clear instructions will avoid some of the inconsistent information recording seen in Christchurch. The Royal Commission considers that Land Information New Zealand should continue to develop consistent national addressing protocols, working with territorial authorities, and make this information available to the general public.

Recommendations

We recommend that:

149. A clear system for identifying individual buildings should be developed and included in the plans for a building safety evaluation process.

150. Land Information New Zealand should continue to work on initiatives that develop consistent national addressing protocols and make this information available to the general public.

2.6 Transition from the civil defence response to the recovery phase governed by territorial authorities

The reports received by the Royal Commission indicate that there were significant issues in the transition of responsibility for the building safety evaluation process from civil defence to normal building management arrangements governed by territorial authorities after the Canterbury earthquakes. We have heard evidence from Mr Bret Lizundia that this is an issue that United States engineers have not encountered before: he considered that it negatively impacted on the building safety evaluation operation after the Canterbury earthquakes. This is also the Royal Commission's view.

This section considers the need for a transition mechanism, the NZSEE Guidelines recommendation, and the mechanism used after the Canterbury earthquakes. We examine how territorial authorities should manage buildings after earthquakes, the roles and responsibilities different decision makers have in this, and the management of cordons. We also consider the barriers building owners faced when they sought to repair or demolish their damaged buildings.

2.6.1 The need for a transition mechanism

The initial building safety evaluation operation takes place during a state of emergency under civil defence and emergency management arrangements. The placards placed on buildings in the rapid assessment phase of this operation only have legal status during a state of emergency. To be able to manage necessary building work after the state of emergency ends, there needs to be a transition mechanism.

2.6.1.1 The transition mechanism recommended in the NZSEE Guidelines

The NZSEE Guidelines[10] recommend placing a notice issued by the territorial authority under section 124 of the Building Act 2004 before the end of the state of emergency. Section 124 states:

> **124 Powers of territorial authorities in respect of dangerous, earthquake-prone, or insanitary buildings**
>
> (1) If a territorial authority is satisfied that a building is dangerous, earthquake prone, or insanitary, the territorial authority may—
>
> (a) put up a hoarding or fence to prevent people from approaching the building nearer than is safe:
>
> (b) attach in a prominent place on, or adjacent to, the building a notice that warns people not to approach the building:
>
> (c) give written notice required work to be carried out on the building, within a time stated in the notice (which must not be less than 10 days after the notice is given under section 125, to—
>
> (i) reduce or remove the danger; or
>
> (ii) prevent the building from remaining insanitary.
>
> (2) This section does not limit the powers of a territorial authority under the Part.
>
> (3) A persons commits an offence if the person fails to comply with a notice under subsection (1)(c).
>
> (4) A person who commits an offence under this section is liable to a fine not exceeding $200,000.

In this context, a section 124 notice requires the building owner to reduce or remove the danger the building poses to its occupants or the wider public. Reducing or removing the danger associated with a building can include removing the part of the building that is dangerous, securing or repairing the building, or demolition. An example of a section 124 notice used after the Canterbury earthquakes is attached as Appendix 4 of Volume 7.

2.6.1.2 The transition after the Canterbury earthquakes

It is unclear what pre-planning had been done to manage the transition of the building safety evaluation process from civil defence to normal building management arrangements after the September earthquake. CCC[4] contends, and we accept, that the large number of buildings damaged after the September earthquake meant that it was not possible to place section 124 notices on all red or yellow placard buildings before the state of emergency ended: the large number of damaged buildings meant that the workload of its Enforcement Team was much greater than the approximately 65 complaints a year about buildings alleged to be dangerous that it usually processes. The CCC developed its policies and procedures about how to treat red and yellow placard buildings after the state of emergency ended. In 2008, Brunsdon[25] noted that it would be difficult to issue section 124 notices before the end of a state of emergency in a building safety evaluation operation larger than Gisborne's.

The Canterbury Earthquakes (Building Act) Order 2010, which extended the status of the red and yellow placards for a further 60 days, was intended to respond to this difficulty. Clause 8 deemed them to be section 124 notices. It provided that:

> (2) A red card is deemed to be a notice issued under section 124(1)(b) of the Act that warns people not to approach the building.
>
> (3) A yellow card is deemed to be a notice issued under section 124(1)(d) of the Act as modified by clause 9.
>
> (4) Any restrictions on use that are described on a yellow card are deemed to be requirements of a notice issued under section 124(1)(d) of the Act as modified by clause 9.

Note that Clause 9 inserts paragraph (d) into section 124(1) of the Building Act 2004.

As well as extending the status of the red and yellow placards for 60 days, Clause 9 also required that building owners take action within five days of receiving written notice (or having a notice placed on their building) setting out the need to reduce or remove the danger their building posed. Normally under section 124 building owners have no less than 10 days before they must take action.

Extending the status of the red and yellow placards gave the CCC time to develop the procedures it needed to transition the building safety evaluation process into its building control arrangements. The CCC established the Building Evaluation Transition team and the Building Recovery Office to manage this process.

The Building Evaluation Transition team operated from 20 September 2010 to the end of November 2010. This team audited the placards of approximately 580 commercial properties in October 2010 to maintain an accurate schedule of building safety evaluations. It developed a process for incorporating the reports generated by engineers engaged by building owners and for changing the status of placards on a building. The team also carried out inspections of dangerous or unstable buildings, maintained cordons and arranged for section 124 notices to be placed on buildings.

CCC established the Building Recovery Office on 13 September 2010. The Building Recovery Office was the main point of contact for building and home owners. It responded to queries about the building evaluation process, answering questions about the meaning of the placards, what the Building Act notices meant, and what building owners needed to do to change the status of their building. As the main point of contact for building owners, the Building Recovery Office was where owners registered the need for demolition work, major repairs or rebuilds, obtained property records, and obtained any consents needed to proceed.

From 28 November 2010, a new Building Recovery Office was established that combined the functions of the old Building Recovery Office with those of the Building Evaluation Transition team. The new Building Recovery Office was responsible for the case management of all remaining dangerous buildings, both in the CBD and other areas. It also responded to customer service requests about dangerous buildings.

Most building owners had until the end of January 2011 to address the danger associated with their buildings, unless they were particularly dangerous or impeded traffic flow or public access. Evidence the Royal Commission has heard indicates that work to follow up on the status of these buildings was ongoing when the February earthquake struck. Owners' actions were compromised while they waited for insurance company decisions before committing to costly make-safe or demolition decisions. This issue and other barriers to the repair or demolition of buildings damaged in the Canterbury earthquakes are discussed in section 2.6.4 of this Volume.

2.6.2 Managing buildings after an earthquake

The need for a transition mechanism is part of a larger issue with the management of buildings after earthquakes. After a significant earthquake or other disaster, it is necessary to prioritise how to treat buildings based on the severity of the damage to them. However, there is also a need to consider all buildings that may have been damaged, even if the damage appears minor. Even if a building has a green placard, it may be appropriate to assess it further. This is important because the rapid assessments are only designed to indicate the condition of the building as an interim measure until a more detailed evaluation can be arranged by the owner. Rapid assessments are not thorough. They are appropriate for a basic sifting method, but a brief assessment of the damage to a building is unlikely to identify the capacity it has left to withstand damage from further aftershocks or its suitability for long-term reoccupation.

Because the process is designed to prioritise which damaged buildings to focus on, buildings fall out of the system as soon as a green placard is applied. Green placard buildings were not considered further during the rapid assessment phase unless their Level 1 Rapid Assessment form noted the need for a Level 2 Rapid Assessment. Because the Canterbury Earthquakes (Building Act) Order 2010 only dealt with the status of red and yellow placard buildings, green placards had no status after the state of emergency ended. The Royal Commission has heard evidence that after the September earthquake civil defence workers and building control officials did not have a formal mechanism for the further assessment of a building that was able to be used, but remained in need of repair.

2.6.2.1 Need for further engineering evaluations

The NZSEE Guidelines[10] make it clear that New Zealand's rapid assessment process is not designed to provide an engineering assessment service for building owners and insurers. This is because the result of rapid assessments are inevitably indicative only. Building owners and other decision makers need better information to decide what short-term repairs are needed, when to carry these out, and the long-term future of the building. For these reasons, the NZSEE Guidelines envisage that DEEs will be carried out on all buildings after the state of emergency. These Guidelines state that building owners are responsible for organising DEEs for their buildings. Building owners remain responsible for the safety of their buildings.

We have heard evidence that many building owners did not act on the green placard's recommendation to obtain "a detailed structural engineering assessment" of their building. It is not known how many owners did authorise engineers to carry out full evaluations of their buildings. Middleton and Westlake[2] suggest that territorial authorities were able to require DEEs from owners after the September earthquake. However, the CCC[4] states that it could not legally require building owners to order a DEE of their building. The Royal Commission agrees with this view.

The Royal Commission considers that building owners have the primary responsibility to ensure that buildings are safe to occupy and owners should therefore carry out the appropriate engineering assessments after the rapid assessment phase of the building safety evaluation process.

Submitters discussed whether or not to require DEEs after earthquakes, particularly before allowing the short- or long-term reoccupation of the building. There was some debate among submitters about what level of assessment should be required before people are allowed to reoccupy buildings after a disaster. They discussed what the appropriate triggers for the short-term reoccupation and for the long-term reoccupation should be.

The Royal Commission has received evidence that establishes that a full engineering evaluation, using the methods and approaches engineers employ in normal circumstances, is both costly and time-consuming. There would be very significant economic and social impacts if completion of such evaluations was required before allowing reoccupation, and the Royal Commission considers that would be both undesirable and unrealistic.

However, we consider that in many cases a rapid assessment will not be sufficient for reoccupation without a further evaluation of the building, because it is a short, coarse inspection. The NZSEE Guidelines also take this view. In particular, we consider that the Level 1 Rapid Assessment is not sufficient to ensure the safety of the building's occupants or the wider public. By contrast, a DEE would confirm that the building is safe for long-term reoccupation. Under section 51 of the Canterbury Earthquake Recovery Authority Act 2011, CERA can compel building owners to obtain a DEE of their building before its reoccupation and provide this information to CERA.

In practice, CERA recognised that some buildings only had minor damage after the Canterbury earthquakes and it might not be appropriate to restrict their reoccupation while their owners arranged for a full DEE. CERA developed a process to determine whether a building can be occupied before a full engineering evaluation is carried out on it; this process is called the Interim Use Evaluation (IUE). Japan's Post-Earthquake Damage Evaluation and Rehabilitation guidelines are an international example of a process that is specifically designed to determine how a building can be used temporarily after repair but before full, long-term earthquake strengthening.

In their evidence to the Royal Commission, Mr John Hare and Mr David Brunsdon discussed the IUE. It involves examining the structural drawings to identify the locations of critical structural weaknesses and potential plastic zones. Having established these locations, the building is examined with the appropriate wall and floor linings and ceiling tiles removed to enable the critical zones to be inspected and the level of damage assessed. If the damage is seen in other locations the drawings and foundations should be further assessed until a satisfactory explanation is obtained for the observed damage. If the level of damage is acceptable, the building contains no critical structural weaknesses and is judged to have an acceptable level of ductility and redundancy, the building may be opened to the public for interim use. Figure 11 demonstrates how this process works in practice:

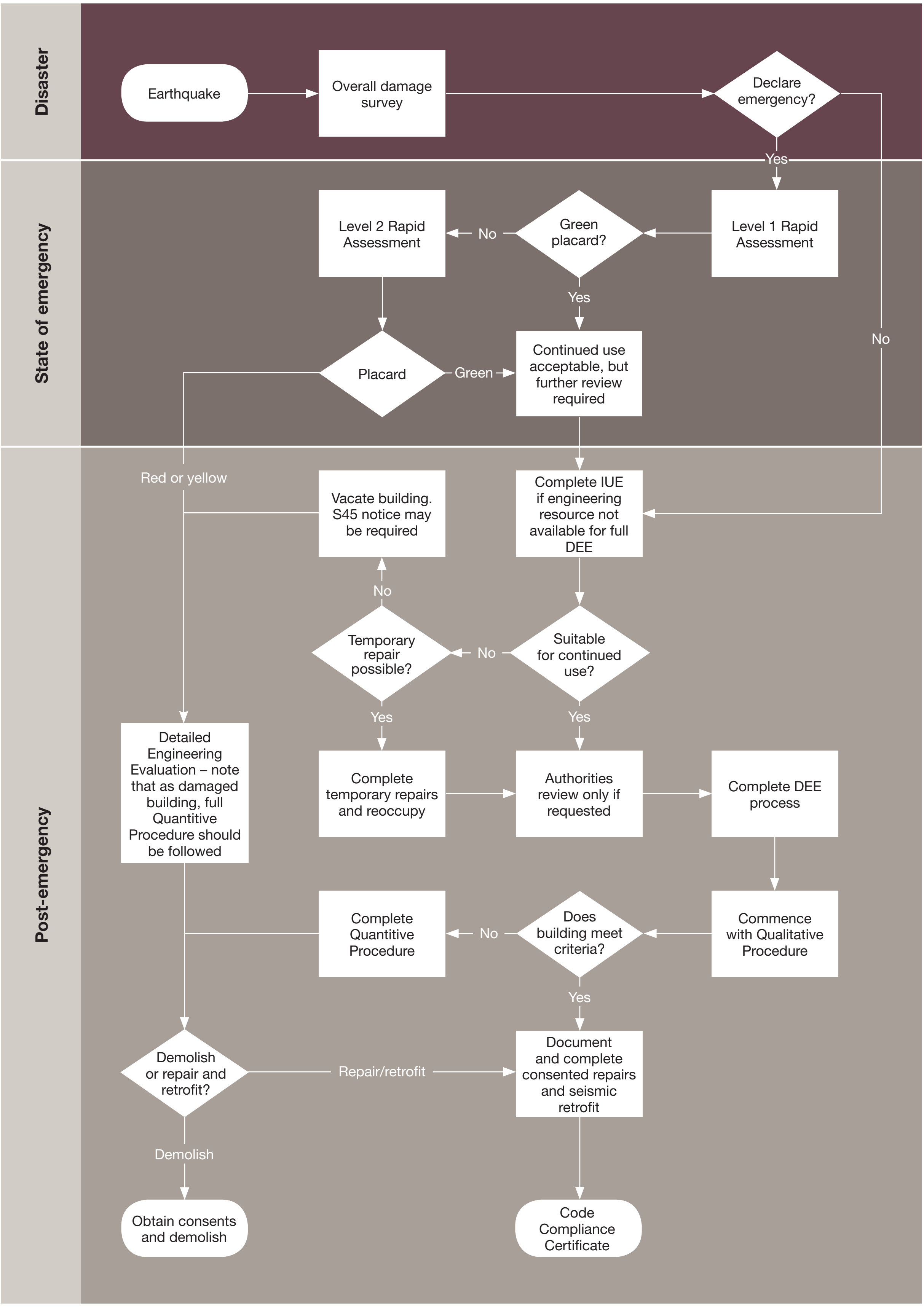


Figure 11: Simplified building safety evaluation and use decision making framework (source: adapted from email from John Hare to the Royal Commission, 1 September 2012[26])

We note that in June 2012, the former Department of Building and Housing[27] released guidance on how to carry out an IUE.

2.6.2.2 The Royal Commission's proposals

As has been seen, the Terms of Reference require us to examine the legal and best-practice requirements for the assessment of buildings after any earthquake, having regard to lessons from the Canterbury earthquakes. As a result of considering the performance of buildings in the Canterbury earthquakes, the Royal Commission has identified a number of factors that engineers need to consider when deciding how best to facilitate the return of a city to an operational state after an earthquake.

2.6.2.2.1 Practical assessment considerations

We have already dealt with practical considerations that need to be taken into account in the assessment of individual buildings. We set out several factors that engineers need to note when assessing buildings that are not constructed from unreinforced masonry in section 6.2.5 of Volume 4. Examples of these factors include:

- allowing for the effect of flexural cracking on the stiffness of structural members;
- allowing for accidental torsion;
- considering how the inter-storey drifts should be calculated;
- ensuring that there are valid load paths for seismic forces and gravity loads through the building and through details such as beam-column joints; and
- the attachment of floors to lateral force resisting elements.

Volume 2 and section 6.3.8 of Volume 6 of this Report address the vulnerabilities of different building types we observed from buildings in Christchurch (including the CTV building). These should also be taken into account. The Royal Commission considers that there is a lack of adequate guidance given in New Zealand Standards on the design forces required to tie floors on to lateral force resisting elements. This aspect of the design is of concern where the primary source of lateral force resistance is provided by structural walls or braced frames located on the perimeter of the building. In such cases, we propose that, where practicable, structural drawings should be examined to check that the floors are adequately tied into the lateral force resisting elements. This check should be made in the case of all buildings to which this consideration is applicable.

The Royal Commission considers that these matters should be incorporated into the Ministry of Business, Innovation and Employment's draft guidelines[17] on carrying out detailed engineering evaluations after earthquakes.

We note that in the following sections we outline the concept of a "Plans-Based Assessment" (PBA), and its role in the assessment of buildings after a major earthquake. We observe here that the PBA concept could also be adapted for use in the assessment of buildings prior to an earthquake.

2.6.2.2.2 The post-earthquake assessment system

The focus of this section of the Report is mainly on the overall system that should be adopted following the occurrence of a major earthquake that has resulted in the declaration of a state of emergency. Following a significant earthquake, international best-practice is to carry out an Overall Damage Survey to identify areas where appreciable damage has occurred so that appropriate steps can be taken to direct assistance to locations where help may be required to free people trapped in buildings and provide assistance to those that have been injured. A decision on whether to declare a state of emergency is one outcome from this survey.

This step should be followed by the rapid assessment of individual buildings to locate potential fall hazards and identify buildings that are in urgent need of further attention from the point of view of public safety. Subsequent steps should be based on a number of considerations which include the extent of the damage, the characteristics of the earthquake, the likely intensity of subsequent aftershocks (as advised by GNS Science), the manpower available for the assessment of buildings and the mix of building types and ages in the city.

The system that we are proposing envisages that in the area in which the state of emergency applies all buildings should be assessed prior to reoccupation. That process would commence with Level 1 and 2 Rapid Assessments. Where the rapid assessment process has identified the need for further evaluation of an individual building, the reoccupation of the building would then depend on assessments that vary according to the building's structural type and the nature of the earthquake event. Assessments after the rapid assessments would include a PBA or, at the most thorough level, a DEE. The concept of a PBA is similar to that of the IUE discussed above.

We envisage that a PBA would involve examining the structural drawings to identify the locations of plastic zones and other locations where high strain may be induced. In addition it would involve identifying critical structural weaknesses, including assessing the level of ductile detailing in columns, beams, beam-column joints, structural walls, braced frames (concentric and eccentric) and the way in which the floors are tied into the lateral force resisting elements. Ideally in a PBA these locations in the building should be examined to identify the extent of the damage. This would require the removal of areas of ceilings and wall and floor linings to allow the level of damage to be assessed. Where damage is located in other parts of the building, the drawings and foundations should be re-examined until the damage can be satisfactorily explained. The objective of the PBA is to identify whether the building has any critical structural weaknesses that could result in sudden and/or non-ductile behaviour, such as occurred in the CTV and PGC buildings. Any calculations involved in a PBA are envisaged as being approximate in nature and sufficient to determine the order of strength or ductility of a detail or structural element. We address below the situations in which the PBA would be carried out. We recommend that the Ministry of Business, Innovation and Employment further develop the PBA concept, in consultation with the NZSEE and the Structural Engineering Society New Zealand.

The following discussion also refers to a DEE, which should include the calculation of the percentage of ULS of the damaged structure. The concept of the DEE is discussed in sections 2.3.2.3 and 2.4.5.2.2 of this Volume.

Where the initial earthquake is generated by a distant fault, aftershocks may be expected to be of shorter duration and lower intensity than the main shock. Where the fault is close to the city there is the possibility of subsequent aftershocks being closer to the city than the initial earthquake. In such an event the ground shaking may be more intense than the initial earthquake and there is also the possibility that the directions of the major components of shaking will be different from those of the initial earthquake. Both of these factors can potentially cause damage to buildings not significantly damaged in the initial earthquake.

We therefore propose that a more conservative approach is taken to the assessment of buildings when the rupture causing the earthquake is on a local fault line rather than on a distant fault line. The Royal Commission considers that if significant structural damage has been observed in a significant proportion of the multi-storey buildings, then all buildings of three or more storeys (provided in the case of residential buildings that they contain three or more household units) should be subjected to a DEE in the months following a major earthquake.

2.6.2.2.3 Categorisation of buildings

To allow for the changes that have occurred in design practice over the years, we propose that buildings are divided into four groups, namely:

Group 1: non-unreinforced masonry buildings that do not have a known critical structural weakness, and either:

- in the case of concrete buildings, were designed to NZS 3101:1995[28] or later editions of that Standard; and
- in the case of structural steel buildings, were designed to NZS 3404:1992[29] (informed by the Heavy Engineering Research Association guidelines[30] published in 1994) or later editions of that Standard;

or have been subject to an evaluation that has shown that the building has 67% ULS or greater (we discuss the term “ULS” in section 6.2.4 of Volume 4);

Group 2: buildings designed between 1976 and the mid-1990s, but not included in Group 1;

Group 3: buildings designed before 1976, but not included in Group 1; and

Group 4: unreinforced masonry buildings.

The extent of post-earthquake assessment of a building in each group should depend on the extent of the damage it has sustained, having regard to the assessment considerations that we have addressed in section 2.6.2.1.1 above.

Buildings used for residential purposes that are three or less storeys in height should be excluded from Groups 2 and 3. In the case of those buildings, a pragmatic approach needs to be taken to assessment and occupancy, which balances the need for shelter with safety considerations. In our view other commercial and residential buildings should not be occupied until that is approved in the process outlined below.

The assessment process should also reflect the characteristics of the earthquakes, the proximity of the fault and the nature of the soils in the affected area. We are not able to be precise about these matters in advance. The discussion that follows reflects the understandings that we have developed as a result of our consideration of the performance of buildings in the Canterbury earthquakes, which had the characteristics we set out in Volume 1 of our Report. It must be understood that the assessment process following future earthquakes will inevitably need to be adapted to the circumstances that then apply. However, we consider that the assessment process and decisions about occupancy should be informed by an understanding of the characteristics of the earthquake and the potential for aftershocks. The civil defence Controller (and the territorial authority after the state of emergency has come to an end) should be responsible for obtaining authoritative advice about those matters, and making the information available so that those involved in the assessment process are aware of it.

2.6.2.2.4 Other considerations

The Royal Commission considers that the civil defence Controller and the Ministry of Business, Innovation and Employment (as the agency that deploys the core team of building safety evaluators) should decide the timeframe in which building owners should obtain a PBA and a DEE considering the circumstances and extent of the disaster.

Given the problems with information sharing, which we discuss in section 2.5.5 of this Volume, we consider that building owners should be required to provide a copy of any PBA and DEE obtained to the territorial authority.

In section 7.4.2 of Volume 4, we recommend that the Building Act 2004 should be amended to require and authorise territorial authorities to ensure completed assessments of all unreinforced masonry buildings within their district within two years from the enactment of the Amendment, and of all other potentially earthquake-prone buildings within five years of enactment. We note that this would require each territorial authority to develop a database listing all of the earthquake-prone buildings in its district. We consider that the information gained and recorded in that exercise should be supplemented by information classifying buildings of three or more storeys into the groups that we have discussed above. The database thereby produced, which can be prepared in anticipation of a future earthquake, could be used to guide the assessment process that would be appropriate after the rapid assessment operation following a major earthquake.

2.6.2.2.5 Occupation

As with the assessment process, the decisions made about the occupation of buildings following a significant earthquake should reflect the nature of the buildings, the characteristics of the earthquake, the proximity of the fault and the nature of the soils in the affected area. The following proposals reflect the experience of the Canterbury earthquakes.

The September earthquake produced shaking in Christchurch of a level comparable to the design level for the ultimate limit state. However, the duration of strong ground shaking was on the low side of what might be expected in other parts of the country. The February earthquake produced shaking with an intensity that was unusually high and such an event is rare. In our opinion, the experience gained from the September earthquake gives a better guide to what is required for the assessment of buildings for reoccupation after an earthquake for other locations in New Zealand. Where the geological situation is such that an aftershock may occur on a fault line closer to or within the CBD, as occurred in Christchurch with the February earthquake, additional precautions should be taken.

The Royal Commission considers that, following Level 1 and Level 2 Rapid Assessments, occupation should be based on the outcome of the assessment process set out below:

a) For Group 1 buildings:
   - where no significant structural damage was seen, a Level 2 Rapid assessment;
   - where significant structural damage was seen, a PBA for a lower levels of structural damage and a DEE for higher levels of structural damage.

b) For Group 2 buildings:
   - where no significant structural damage was seen, a PBA;
   - where significant structural damage was seen, a DEE.

c) For Group 3 buildings:
   - for all levels of damage, a DEE.

d) For Group 4 buildings:

- where no significant structural damage was seen and the building has been retrofitted to 67% ULS or greater, a PBA;
- where significant structural damage is apparent and where the building has not been retrofitted to 67% ULS or greater, a DEE.

Where the earthquake is located on a fault that is close to the city or where there is a possibility of an aftershock or new earthquake closer to the CBD, a higher level of assessment should be made.

Decisions about the occupancy of buildings should be made once the appropriate level of assessment has been carried out, and forwarded to the Civil Defence Controller (while the state emergency continues) and to the territorial authority when it is completed, for their approval.

Recommendations

We recommend that:

151. After an earthquake that has given rise to the declaration of a state of emergency, buildings should be assessed in accordance with the following process:

    a all buildings should be subject to a rapid assessment process;

    b for the purposes of subsequent steps, buildings should be placed in the following categories:

        i) Group 1: non-unreinforced masonry buildings that do not have a known critical structural weakness, and either,

            - in the case of concrete buildings, were designed to NZS 3101:1995 or later editions of that Standard;
            - in the case of structural steel buildings, were designed to NZS 3404:1992 (informed by the Heavy Engineering Research Association guidelines published in 1994) or later editions of that Standard;

        or have been subject to an evaluation that has shown that the building has 67% ULS or greater (we discuss the term "ULS" in section 6.2.4 of Volume 4);

        ii) Group 2: buildings designed between 1976 and the mid-1990s, but not included in Group 1;

        iii) Group 3: buildings designed before 1976, but not included in Group 1; and

        iv) Group 4: unreinforced masonry buildings;

    c buildings used for residential purposes that are three or less storeys in height should be excluded from Groups 2 and 3. In the case of those buildings, a pragmatic approach needs to be taken to assessment and occupancy, which balances the need for shelter with safety considerations. Other commercial and residential buildings should not be occupied unless approved for occupancy in accordance with the process outlined below;

    d legislation should require territorial authorities to classify buildings in their districts in accordance with the preceding Recommendation within the timeframes established under Recommendation 82 in Volume 4 of our Report (Recommendation 82 requires the assessment of earthquake-prone and potentially earthquake-prone buildings);

    e where the rapid assessment process had identified the need for further evaluation of a building in one of these defined Groups, the building should not be occupied until the Civil Defence Controller or the territorial authority (as appropriate) has approved the occupancy of the building after the following assessments:

        i) for Group 1 buildings:

            - where no significant structural damage was seen, a Level 2 Rapid Assessment;
            - where significant structural damage was seen, a Plans-Based Assessment for lower levels of structural damage and a Detailed Engineering Evaluation for higher levels of structural damage;

ii) for Group 2 buildings:

- where no significant structural damage was seen, a Plans-Based Assessment;
- where significant structural damage was seen, a Detailed Engineering Evaluation;

iii) for Group 3 buildings:

- for all levels of damage, a Detailed Engineering Evaluation;

iv) for Group 4 buildings:

- where no significant structural damage was seen and the building has been retrofitted to 67% ULS or greater, a Plans-Based Assessment;
- where significant structural damage is apparent and where the building has not been retrofitted to 67% ULS or greater, a Detailed Engineering Evaluation;

f arranging for the Plans-Based Assessments and Detailed Engineering Evaluations should be the responsibility of the owner of the buildings concerned; and

g the Ministry of Business, Innovation and Employment should further develop the Plans-Based Assessment concept, in consultation with the New Zealand Society for Earthquake Engineering and the Structural Engineering Society New Zealand, and set out the Plans-Based Assessment in published guidelines.

152. Plans-Based Assessments and Detailed Engineering Evaluations should include checking the vulnerabilities observed after the Canterbury earthquakes that the Royal Commission describes in Volume 2, section 6.2.5 of Volume 4, and section 6.3.8 of Volume 6 of this Report.

153. Any Plans-Based Assessment and Detailed Engineering Evaluation of a building after an earthquake should begin with a careful examination of the building's plans.

154. The Plans-Based Assessment and Detailed Engineering Evaluation should confirm that all known falling hazards and other vulnerabilities have been assessed and secured or removed.

155. A copy of the Plans-Based Assessment and the Detailed Engineering Evaluation should be given to the relevant authorities.

2.6.3 Confusion of roles and responsibilities

The NZSEE[4] suggests that pre-prepared building safety evaluation plans should describe the roles and responsibilities of key personnel responsible for delivering the building safety evaluation process.

A number of units within CCC worked on building recovery activities after the September earthquake. For this to be successful, these units had to work together in an integrated way. Griffiths and McNulty[5] suggest that the Building Recovery Office and the Building Transition Evaluation Team did not work together in a coordinated way, resulting in some information sharing problems, owners being told incorrect information about their buildings, and a number of inaccurate or contradictory messages being released to the media and wider public.

The Royal Commission has heard evidence that an engineer engaged to evaluate a building became a point of contact for many of the people who had an interest in the building; often, this was not something that was clearly articulated or clearly required of the engineer. Property managers were another group who took on a similar role. These groups could be encouraged to take up a coordinating role after an earthquake or other disaster. We have also heard evidence that engineers found it difficult when they had to consider how their advice about the building could affect the safety of the wider public, a role that they took on for the good of society, while contracted and liable, however, only to the building owner.

In addition, the Royal Commission has heard evidence that the responsibilities of building owners were not clear following the Canterbury earthquakes. Ultimately, building owners are responsible for confirming that their building is safe after a disaster. We have heard evidence that there were issues with the way the responsibility for a damaged building transferred from the CCC to building owners. Normally building owners are responsible for emergency repairs on a building and any barricades erected while this work is ongoing. However, after the September earthquake civil defence emergency management and territorial authorities organised for assessments of buildings and the setting up of cordons.

Some building owners waited for civil defence or council workers to evaluate their buildings, assuming that these authorities would inform them if any problems existed. Griffiths and McNulty also describe how the Building Evaluation Transition team carried out activities that were normally the responsibility of the building owner: for example, clearing rubble from major arterial routes and designing propping to enable the cordons around a building to be removed.

2.6.3.1.1 Cordon management

The Royal Commission has heard evidence that it was not clear who was responsible for setting up and maintaining cordons after the state of emergency ended. Mr Stephen McCarthy of the CCC told us that normal building practice is for building owners to organise safety fencing around their properties if they are carrying out works on them. Building owners must gain permission from their territorial authority to do so, but the owners or their contractors erect and manage these barricades until the work on the site is complete. During the state of emergency in September 2010, civil defence workers set up a cordon around Christchurch's CBD. Civil defence workers then set up cordons around particular buildings or areas as they slowly reopened access to the wider CBD.

After the state of emergency ended, the CCC decided when and where cordons were to be placed, moved or dismantled. However, evidence the Royal Commission has heard indicates that building owners may have been expected to take over some responsibility for maintaining the cordons around their buildings, especially when they were carrying out repairs to the building but using council barricades and cordons. When and how this change over was to occur was not clear to the CCC or to building owners.

We have also heard evidence that indicates that cordons were not wide enough to ensure public safety in the February earthquake. We consider that public pressure to keep access to streets and businesses open may have contributed to this. There is clearly a need to balance such considerations with public safety, which nevertheless should be the main consideration. Best-practice indicates that cordons should be set to allow for a fall zone of one and a half times the height of the building. The Royal Commission saw examples of cordons having been set up around an individual building that failed causing death with a fall zone considerably less than this.

We received evidence from Mr Peter Smith, who analysed the failure of each individual building causing death, that even if the cordon was set up to protect the public from a particular fall hazard, such as a parapet, when parapets fell in the February earthquake they often took a considerable part of the exterior wall with them. Sometimes, this meant that the cordon was inadequate and the building collapsed across the street.

The Royal Commission considers that territorial authorities should be responsible for placing, moving and removing cordons. Territorial authorities should take over the responsibility for maintaining any cordons set up during the response phase after the transition to normal building management arrangements. This is because territorial authorities are responsible for ensuring that people are safe in public areas, including, of course, streets and footpaths. We recognise that this may place a burden on territorial authorities when building owners take time to make a decision about the repair or demolition of their damaged building. The Royal Commission therefore considers that territorial authorities should be able to recover the costs of maintaining any cordons set up due to the damage to a particular building from the building owners after a reasonable period, which we would assess as three months.

The Royal Commission considers that the wider roles and responsibilities of statutory authorities, other decision makers and building owners should be set in the plans for the building safety evaluation process. These plans should set out their roles and responsibilities during the response and recovery phases. We consider that such plans should keep a degree of flexibility, so that people and organisations are aware of their responsibilities but can respond to the disaster as appropriate within the circumstances and scale of the event.

Recommendations

We recommend that:

156. Civil defence and emergency management should be responsible for setting up and maintaining cordons during the state of emergency.
157. Territorial authorities should be responsible for maintaining any cordons that are in place at the end of the state of emergency until the public space or building they surround is made safe.
158. Territorial authorities should be able to recover the costs of maintaining any necessary cordons from the building owner after three months.
159. The roles and responsibilities of decision makers should be described in the building safety evaluation process. The roles and responsibilities should allow for flexibility of operation according to the circumstances and scale of the event.

2.6.4 Barriers to action

The Royal Commission has heard evidence that some building owners were motivated to address the damage to their building after the September earthquake, but were not able to carry out work on their buildings because of problems finding a contractor, insurance issues, or legislative barriers.

2.6.4.1 Meeting the requirements of insurers

We have heard evidence that problems settling their insurance claims caused delays for building owners attempting to repair their buildings after the September earthquake. These issues caused the reluctance of some owners to act in response to a section 124 notice on their building. Griffiths and McNulty[5] note that owners had little control over the time it would take to repair the buildings while still in negotiation with their insurers. The NZSEE[4] suggests that the level of insurance claims insurers are willing to meet makes the decision about the level of repair and strengthening territorial authorities require for a building after an earthquake more complex. Brunsdon[25] notes that issues about what work insurance policies covered also arose after the 2007 Gisborne earthquake. There is little that can be done to address these issues, since they involve rights that are under individual contracts of insurance.

2.6.4.2 Legislative barriers

Rotimi[31] contends that the Civil Defence and Emergency Management Act 2002, the Resource Management Act 1991 and the Building Act 2004, and their regulatory guidelines in particular, are a barrier to coordinated and unhindered recovery from a disaster. He also highlights the lack of cross linking between these statutes, and expresses the opinion that statutory powers to coordinate recovery efforts are inadequate.

Building consents for repairs to buildings damaged in the September earthquake would normally trigger requirements to ensure access to the building for people with disabilities and for escape from fire. The Royal Commission discusses and makes recommendations about this issue in section 7.5.5 of Volume 4.

The Royal Commission has heard evidence that section 124 notices issued under the Canterbury Earthquake (Building Act) Order 2010 did not override the need for a resource consent under the Resource Management Act 1991 (for example, to repair or demolish a heritage building). The timeframes for processing these consents were sometimes long. The Royal Commission discusses and makes recommendations about this issue in the case of buildings that could cause injury or death in section 7.7 of Volume 4.

The Canterbury Earthquake (Resource Management Act) Order 2010 let territorial authorities act immediately to fix a building without resource consent if they did the work themselves, by modifying section 129 of the Building Act 2004. In section 7.5.2.2 of Volume 4 we discuss how the CCC was reluctant to exercise this power. We discuss and make recommendations there for the conferral of a general legislative power to enable territorial authorities to take action where a building requires immediate demolition or repair as a result of an earthquake.

2.6.4.2.1 Buildings that act as one structure in an earthquake

The Royal Commission has heard evidence that problems can arise when buildings are divided into separate properties with different addresses separated by party walls, but nevertheless act as a single structure in an earthquake. The former Austral Buildings in Colombo Street, shown in Figure 12, are an example of such a structure.

Figure 12: Former Austral Buildings, 603, 605–613 Colombo Street before the February earthquake

Figure 12 shows how this structure can be one, large unreinforced masonry building that takes up most of a block. The party walls that divide each part of the building, while thicker and more substantial than other internal walls, are not built to be an external wall. Structurally, each property acts as a part of one building in an earthquake. As we saw in Christchurch, this often resulted in the façades of the entire row of separate properties collapsing onto the street. Figure 13 shows how first floor façades of the Austral Buildings, acting as one large façade, collapsed outward onto the Number 702 Red Bus and pedestrians, tragically causing death.

Figure 13: Former Austral Buildings, 603, 605–613 Colombo Street after the February earthquake

For this reason, such buildings should be assessed as one structure by building safety evaluators. Although the intent was that the whole of one structure be inspected and treated as one, and the placards placed on each tenancy or property accordingly, we have heard evidence of instances when that did not occur. Having separate properties that act as one structure also caused problems when attempting to repair the building, because each property was treated individually by engineers, building owners, territorial authorities and other decision makers. To address this issue, section 52 of the Canterbury Earthquakes Recovery Act 2011 allows CERA to direct the owners of two or more adjacent buildings to act together for their mutual benefit. CERA[32] advise that it has not implemented this provision because a reluctant owner is unlikely to see the action as being to their benefit. The owners of a row of properties in New Regent Street voluntarily acted together to repair and preserve their building.

The Royal Commission considers that it is important that these buildings are assessed as one structure by building safety evaluators. In section 7.5.4 of Volume 4, we discuss and make recommendations about the need for general legislative provision to ensure that all portions of such structures are able to be strengthened contemporaneously.

Recommendation

We recommend that:

160. The building safety evaluation process should direct evaluators to assess properties that act as one structure in an earthquake as one structure, rather than as separate buildings.

2.6.5 Options for a transition mechanism

Submitters propose developing formal transition mechanisms that set out the process and procedures to be used when shifting the building safety evaluation process from civil defence to the building management arrangements governed by territorial authorities. The Ministry of Business, Innovation and Employment and the Ministry of Civil Defence and Emergency Management contend that the new emergency risk management provisions proposed for the Building Act 2004 would ensure a seamless transition from response to recovery after a disaster.

Figure 14 describes the Ministry of Business, Innovation and Employment's proposed new emergency risk management provisions for the Building Act 2004.

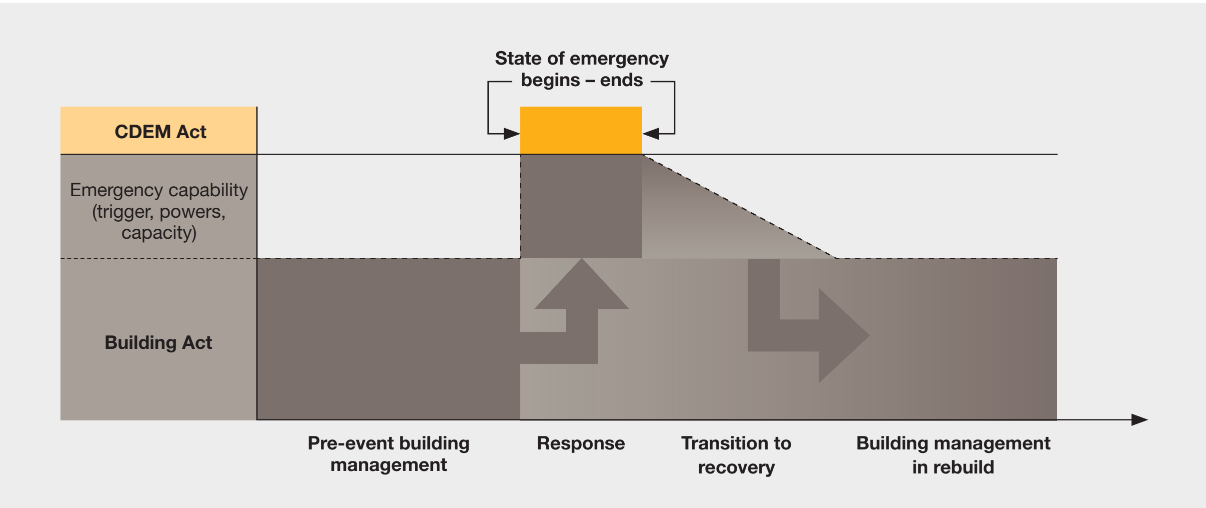


Figure 14: Proposal for Building Act 2004 emergency building evaluation arrangements integrated with normal building management arrangements (source: submission from the Ministry of Civil Defence and Emergency Management)

In contrast to the current legislative arrangements, the new provisions propose to build in a gradual shift from building management after earthquakes and other disasters to normal building management arrangements. Under these proposals, the responsibility for the building safety evaluation process and wider building management after earthquakes does not shift from the civil defence and emergency management framework into the building regulatory framework. Consequently, it is theoretically possible to manage the process end to end within the territorial authority's building management arrangements.

The Ministry of Civil Defence and Emergency Management discusses how placing emergency management provisions in the Building Act 2004 is consistent with New Zealand's civil defence and emergency management framework. It[33] encourages "clusters" of agencies to facilitate routine coordination of readiness planning on a daily, standard arrangements basis; these clusters may also be activated to carry out response and recovery activities. In its submission to the Royal Commission, it contends that each cluster or agency continuing to work through its primary mandate as far as practicable is a key principle that underpins New Zealand's civil defence and emergency management framework. Figure 15 demonstrates how national civil defence and emergency management plans are informed by and integrated with other legislative and planning frameworks.

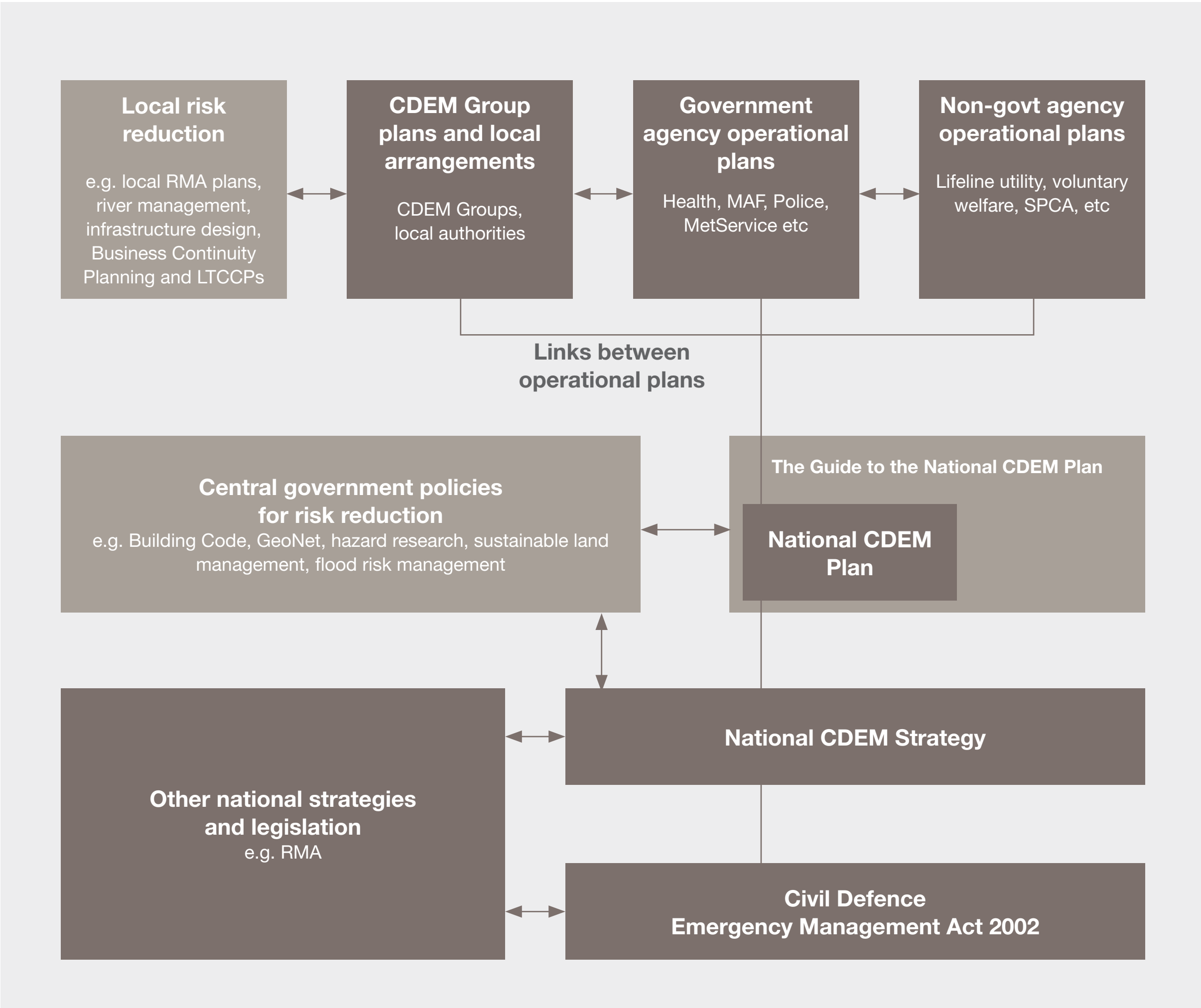


Figure 15: Linkage between national, regional and local operational plans and arrangements (source: *Guide to the National Civil Defence and Emergency Management Plan*, 2009)

The civil defence Controller is still in charge during a state of emergency. For example, after the February earthquake the Ministry of Social Development led the response of the welfare cluster under the authority of the civil defence Controller.

Developing a standard Order in Council that transitions the management of buildings from civil defence to normal building control arrangements could also address the problems with the legal status of the placards at the end of a state of emergency. Drafting a standard Order in Council in advance would allow the detail of any proposed changes to legislation, such as those contained in the Canterbury Earthquake (Building Act) Orders 2010 and 2011, to be carefully considered. Nevertheless, the Royal Commission considers that it would be difficult to guarantee many years in advance of an event that all of the relevant issues had in fact been covered. In addition, a standard Order in Council would still need to be authorised by a special legislative procedure.

The Royal Commission considers that the Ministry of Business, Innovation and Employment's proposal to introduce emergency risk management provisions into the Building Act 2004 has merit. The transition fully into standard processes will be less abrupt and is likely to be better planned than under the current legislative arrangements. We consider that there could be several advantages to this proposal once its details are further explored. For example, does this proposal establish a cluster, led by the Ministry of Business, Innovation and Employment, that deals specifically with building management after earthquakes and other disasters? Given that the clusters are encouraged to make their own arrangements within New Zealand's civil defence and emergency management framework, the Royal Commission considers that this could be one way to ensure that central and local government take up a formal role in developing building safety evaluation processes.

Regardless of where these mechanisms are placed, or what format they take, submitters clearly believe that it is important to develop these transition mechanisms before they are needed. We agree, and consider that the building safety evaluation process and wider building management after earthquakes (and other disasters) framework should be developed and provided for in legislation.

Recommendation

We recommend that:

161. The building safety evaluation and wider building management after earthquakes (and other disasters) framework should be developed and provided for in legislation.

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Section 3: Roles and Responsibilities

Under its Terms of Reference, the Royal Commission is required to inquire into 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 for the design, construction and maintenance of buildings to address the known risk of earthquakes. We are also required to make recommendations on 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. In this section we address relevant findings and conclusions from this part of our Inquiry

3.1 Introduction

In the course of our Inquiry, we identified some systemic issues relating to the regulatory framework for buildings, such as misunderstanding of the framework; a complex and sometimes confusing suite of regulatory documents; and quality assurance issues. We issued a discussion paper in July 2012, seeking comment on these matters. We received 29 submissions. At a public hearing held on 11 and 12 September 2012, we then heard evidence on building legislation, regulations and compliance methods, and also the roles and responsibilities that underpin the building and construction industry.

The key issues raised in submissions and at the hearing were the need for effective leadership of the regulatory requirements for building control and the need for assurance of the quality of structural design and construction of buildings that can be described as “complex”. The latter issue focuses on the design and construction of *new* buildings in that category. We have discussed the performance of *existing* buildings in Volumes 2 and 4 of this Report, and the emphasis in the Terms of Reference on central business district (CBD) buildings does not call for a consideration of new, simpler structures (for example, stand alone dwellinghouses).

This section begins with a brief explanation of the current “performance-based” building control framework as it relates to the issues noted above. (There is a fuller description of the history of building regulation to deal with earthquake risk in section 2 of Volume 4 of this Report.)

3.2 Current building control framework

The hierarchy of New Zealand building controls is illustrated in Figure 16 below. This shows the legislative framework – the Building Act 2004, Building Regulations and the Building Code – and the ways in which compliance with the Building Code may be demonstrated.

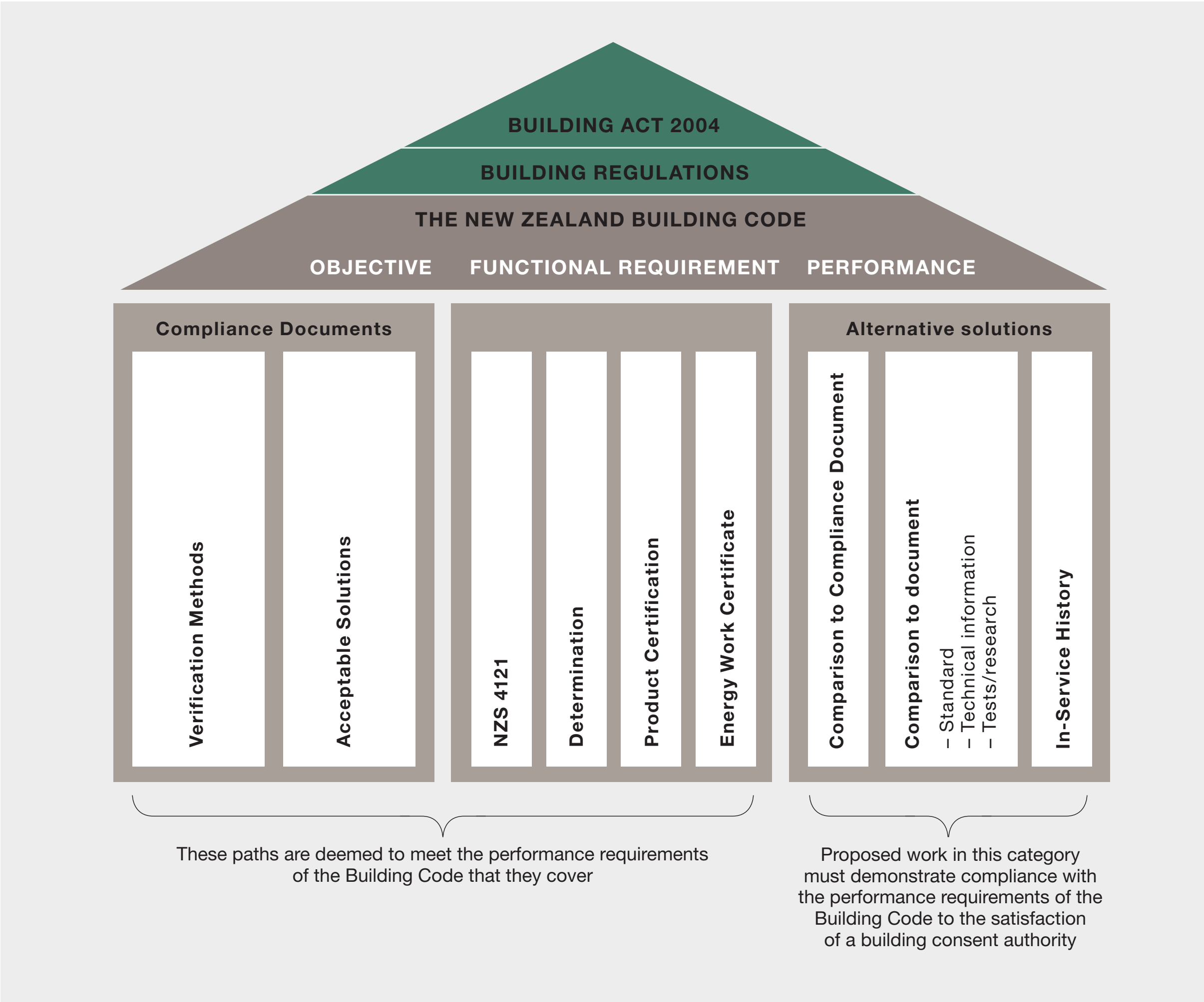


Figure 16: Hierarchy of New Zealand building controls (source: Department of Building and Housing, 2011[1])

3.2.1 Building Code

The Building Code (which is Schedule 1 to the Building Regulations 1992) sets out the minimum standards for all new building work. It states how a completed building and its parts must perform. It contains no prescriptive requirements stipulating that certain products or designs must be used. This "performance-based" approach is intended to allow development and innovation in building design, technology and systems.

The Building Code provides the requirements against which a building must perform to comply with the Building Code by prescribing the functional requirements for buildings and the performance criteria with which buildings must comply in their intended use, and outlines how compliance with the Building Code is achieved. All building work must comply with the Building Code whether or not a building consent is required in respect of that building work. A building owner has to achieve the minimum building performance criteria set out in the Building Code. To issue a building consent, a building consent authority (sometimes abbreviated as BCA) must accept evidence of compliance with the Building Code and/or a compliance document (see below), and/or a determination made by the Ministry of Business, Innovation and Employment (MBIE).

We make some other observations about the Building Code in section 2.2.3 of Volume 4 of our Report.

3.2.2 Compliance documents

Compliance documents provide rules about design that, if followed, result in compliance with the Building Code. They are published by MBIE, which is the government department responsible for the administration of the Building Act 2004. The two kinds of compliance documents are verification methods and acceptable solutions. Some 300 standards developed by Standards New Zealand are referenced in the compliance documentation of the Building Code.

Section 25 of the Building Act 2004 provides for compliance documents to be used in establishing compliance with the Building Code and section 25A provides for these to be available on MBIE's website. The chief executive of MBIE may place a notice in the Gazette that a compliance document has been issued that explains a specific method of compliance with the Building Code. Building work that complies with this document will be treated as having complied with the provisions of the Building Code to which the document relates.

A building must not be constructed, altered, demolished or removed without a building consent (section 40). An owner who intends to carry out building work must, before the building work begins, apply for a building consent to a building consent authority.

3.2.3 Verification methods and acceptable solutions

Verification methods are tests that prescribe one way to demonstrate compliance with the Building Code. They can include calculation methods, laboratory tests and tests in situ that may involve examination of plans and verification by test, where compliance with specified numbers, dimensions or locations is required.

Acceptable solutions are step-by-step instructions that show one way to comply with the Building Code.

3.2.4 The role of Standards in the performance-based building control framework

Within a performance-based system, Standards are needed for two reasons. First, to determine or evaluate the performance level of buildings, systems or products; and second, to give specific performance levels for buildings, systems or products that can be classified as a type of product standard.

These Standards are developed and approved by the national Standards-setting body, following international practice. In New Zealand, this is the Standards Council. Standards New Zealand is the operating arm of the Standards Council, which develops, reviews and updates Standards. The majority of Standards are developed in partnership with Standards Australia.

Standards often provide the links from the Building Act 2004 and regulations to the performance metrics for materials, products, and systems. Where Standards are referenced in verification methods, they provide data to be combined with judgement by a designer or regulator.

When Standards are referenced in acceptable (deemed to comply) solutions to demonstrate compliance with a performance level cited or referenced in regulation (i.e. the Building Code), these solutions must be accepted by a building consent authority when considering an application for building consent.

3.2.5 Recent changes to the Building Act 2004

The former Department of Building and Housing (DBH) undertook a review[2] of the Building Act 2004 in 2009/10. That review found that the building regulatory framework functions adequately, but that it is too costly and inefficient. In addition, the review identified:

- there are problems ensuring responsibility sits in the right place;
- there are weaknesses in consumer protection;
- the system is out of balance with undue reliance on building consent authorities; and
- a change in culture and behaviour across the system is needed.

The enactment of the Building Amendment Act 2012 is intended to:

- clarify accountabilities for the compliance of design and building work by designers, builders, building owners and building consent authorities; and
- provide for a risk-based consenting process where the amount of checking and inspection is aligned to the risk and complexity of the work and the skills and capability of the people doing the work.

We mention these changes because they are relevant to the issues we have noted above. In making our findings and recommendations on the issues discussed in this section, we have therefore taken into account the existence of these provisions, although they are yet to be brought into effect through regulation.

3.3 Quality assurance

The Royal Commission received submissions and heard evidence about the importance of quality assurance processes, and the need for these to be carried out by appropriately qualified and experienced persons. This is particularly the case for complex structures, where the design of the building is more complicated and requires particular knowledge and skill, and where the consequences of failure are potentially greater (for example, from higher rates of occupancy).

Quality assurance should occur at a number of points throughout the design and construction of complex buildings. At the design stage, a suitably experienced practitioner should carry out a rigorous examination of the design specifications including both the foundations and the structure above ground. There should be engagement at the outset between architects and engineering designers.

Quality assurance systems should ensure construction work is properly supervised and monitored by the design team, in addition to the inspection and monitoring by the building consent authority, to ensure that construction is undertaken in accordance with the design, that any design variations are properly documented and consented, and that accurate as-built plans are filed prior to the building consent authority issuing a code compliance certificate on completion of the building work.

3.3.1 Current functions of building consent authorities and territorial authorities

Building consent authorities are responsible for the regulation of building activity within the districts of territorial authorities. Under section 12(1) of the Building Act a building consent authority:

- issues building consents (except consents subject to a waiver or modification);
- inspects building work for which it has granted a building consent;
- issues notices to fix;
- issues code compliance certificates; and
- issues compliance schedules.

A building consent authority may be an independent organisation and not part of a territorial authority. An independent building consent authority performs the functions of a building consent authority, except that it must obtain a project information memorandum from the territorial authority, provide copies of all building consent documentation to the territorial authority and notify the territorial authority when it has issued a compliance schedule.

A territorial authority must perform, either in-house or through an independent or another building consent authority, the functions of a building consent authority for its own district. In addition to these functions, a territorial authority:

- issues project information memoranda, building consents where the consent is subject to a waiver or modification of the Building Code, certificates of acceptance and compliance schedules;
- enforces notices to fix;
- administers and enforces annual building warrants of fitness;
- decides the extent to which buildings must comply with the Building Code when they are altered, their use is changed, or their specified intended life changes;
- performs functions relating to dangerous, earthquake-prone or insanitary buildings;
- determines whether building work is exempt under Schedule 1 from requiring a building consent; and
- carries out any other functions and duties specified in the Building Act 2004.

Territorial authorities maintain records of all building consents including as built plans, usually within a document management system. These records are usually only directly accessible within the territorial authority.

3.3.2 Profile of building consent authorities

There are currently 66 registered and accredited territorial authority building consent authorities and three registered and accredited regional authority building consent authorities. Five private organisations providing contract services to local authorities have also been accredited to the building consent authority standards but are not registered private building consent authorities under the Act. They work under the jurisdiction and authority of the local authorities they are working for.

Building consent authorities have varying capability and capacity; typically this will be in direct relationship to the profile of building activity in their district. This activity will consist of different kinds, and quantities, of residential and commercial building work (both new buildings and alterations to existing structures).

A large proportion of consents issued by building consent authorities is for residential buildings. By value, non-residential[3] building consents comprise 35–45 per cent of all building consents issued nationally. For the large building consent authorities of Auckland, Wellington and Christchurch, the non-residential proportion increases to 50–55 per cent by value.[4] Ninety per cent of non-residential building consents comprise work less than $500,000 in value and include alterations and additions to existing buildings.

Estimates from MBIE indicate that the number of building consents in 2010 for complex new buildings was approximately 13 per cent of total new non-residential buildings (or one per cent of the total number of building consents).

Complex building consent applications are the highest risk, require the highest levels of competence for their assessment and are the most time-consuming to process. Metropolitan building consent authorities issue most of the complex commercial building consents, typically have more highly qualified and experienced staff, and regularly use specialist professional engineers (structural, geotechnical, etc.) where these are required to review complex commercial designs.

The Royal Commission has heard evidence that small to medium-sized building consent authorities do not have a sufficient volume of complex building work to maintain staff with the highest competency levels; rather, they have an accredited process to outsource the assessment of complex commercial consent applications either to another building consent authority that does have the appropriately qualified and experienced staff or to local professional engineers with the appropriate qualifications and experience.

3.3.3 Building consent authority accreditation

Building consent authorities must operate in accordance with regulations 5 to 18 of the Building (Accreditation of Building Consent Authorities) Regulations 2006 and be accredited every two years. Compliance with the Regulations is being required on a staged basis from 1 February 2007 through to 1 December 2013.

The accreditation of building consent authorities is undertaken by International Accreditation New Zealand (IANZ). IANZ is part of the Testing Laboratory Registration Council, an autonomous Crown entity established in 1972. To operate as an accreditation authority, IANZ must comply with the ISO/IEC 17011 *Conformity Assessment – General Requirements for Accreditation Bodies Accrediting Conformity Assessment Bodies*[5] Standard. IANZ also meets the requirements of the Asia Pacific Laboratory Accreditation Cooperation (APLAC) and those of the International Laboratory Accreditation Cooperation (ILAC). IANZ services include formally recognising the technical competence and management effectiveness of laboratories, medical testing and screening, inspection bodies, and radiology services, amongst others.

Mr Geoffrey Hallam is the Regulatory Affairs Manager employed by IANZ. In his evidence to the Royal Commission, he explained the two-yearly accreditation process for building consent authorities. This is a comprehensive review that includes reviewing the building consent authority's documentation systems to ensure compliance with the Regulations. IANZ assesses each building consent authority on-site over a 3–5 day period. All stages of building control are sampled, and the process includes a technical assessment of the review of building consent applications (building design and specifications) through to observation of building officers undertaking site inspections. At the end of the assessment, IANZ prepares a full written report and discusses any corrective actions required with the building consent authority.

Mr Hallam also explained the processes a building consent authority would follow in order to be able to issue building consents for complex buildings, as follows:

- Every application is allocated a level of building complexity.
- Every building official has been assessed for competence using the same complexity levels.
- The accreditation regulations require work to be allocated to persons assessed as having the necessary competence for the project.
- Applications for building consent are checked for completeness before acceptance (not technical).
- Building officials (or contracted experts) undertake detailed assessment of the submitted plans and specifications to establish compliance with every applicable clause of the Building Code.
- Further information is often required during this process.
- Formal peer review may also be requested.
- When compliance of an application with the Building Code is confirmed, a Building Consent is granted.
- During construction, building inspectors confirm that construction is in accordance with the consented plans and specifications.
- If construction is significantly different from the approved design, remedial action is required or approval of an amendment to the design is required.
- Records of who worked on each project are retained (building consent authority staff and contracted experts).
- Building consent authorities contract out work they do not have the competence to handle in-house. This is a managed process.

- Work may be contracted out to other building consent authorities or to appropriate professionals.
- Decisions made during processing and inspections are recorded as are the reasons for decisions.
- Engineered designs are, by definition, unique. Therefore consideration of the need for peer review of a design is case-by-case. Decisions should be risk based.
- IPENZ Practice Note 2 defines types and scope of peer review. When a peer review is requested, it must be clear what type of review is required.

From the submissions received from the building and construction sector, we conclude that there is a general consensus that building consent authority accreditation is a thorough process that has significantly improved the quality of building consent decision making over the past five years. We accept that is the case.

However, the currently large number of building consent authorities still results in inconsistent application requirements and consent decisions around the country. This adversely impacts the efficiency of national design and/or construction companies and poses risks to the quality of the review of structural design during the consenting process. However, we also heard evidence from Mr Nick Hill and Mr Peter Laurenson representing the Building Officials Institute of New Zealand (BOINZ). It was their view that the systems and competency levels of building consent authorities are continuing to improve. In addition, some building consent authorities are working in “clusters” to develop common processes and to share skilled and experienced staff. The Royal Commission supports such initiatives, which indicate it is likely that national consistency will continue to improve.

3.3.4 The competence of building consent authorities

Regulations 9 and 10 of the Building (Accreditation of Building Consent Authorities) Regulations 2006 require a building consent authority to establish and assess the competence of staff and allocate work in accordance with these competencies. MBIE has developed a National BCA Competency Assessment System to provide to the candidate and assessor a detailed specification of the knowledge and skills that are required for a person to be competent at a particular level. There are six competency specifications, one for each of the national competency levels (Residential 1–3 and Commercial 1–3). Each competency specification contains:

- competencies required by Regulation 10(3) of the Building (Accreditation of Building Consent Authorities) Regulations 2006;
- performance indicators to meet the competencies in Regulation 10(3); and
- guidance for assessors and candidates for meeting the performance indicators.

Regulation 18 will require staff to have appropriate qualifications, by 1 December 2013, that are commensurate with the complexity of the buildings they are assessing. Mr Hill gave evidence that building consent officers generally had qualifications at a trade level rather than degree level. He noted that MBIE had only very recently recognised eight qualifications applicable to building consent officers – six at degree level and two at diploma level. He considered these higher-level qualifications for building consent officers would help lead to a generational improvement in professionalism. BOINZ has worked with Otago Polytechnic to develop and provide the Diploma in Building Control Surveying. BOINZ also provides structured continuing professional development for its members, to ensure knowledge and skills are maintained. The Royal Commission considers the requirement for building consent officers to have formal qualifications to be an important step in continuing to improve the capability of the sector. The Commission also sees the provision of ongoing professional development provided by BOINZ as an important means of ensuring building consent officers remain current in their knowledge and skills.

It is appropriate to record that we were impressed by the effort that BOINZ is putting into the continuing professional development of building consent officers. We consider that they should continue to be supported by Local Government New Zealand and territorial authorities.

3.3.5 Review of the structural design of complex buildings

The Building Act 1991 required producer statements to be supplied by or on behalf of the applicant for a building consent (or by or on behalf of a person who had been granted a building consent). Such statements certified that certain work would be, or had been, carried out in accordance with the technical specification. Contrary to the position under the Building Act 1991, producer statements are not expressly provided for in the Building Act 2004.

However, a building consent authority could have regard to a producer statement or its equivalent in deciding whether it is satisfied on reasonable grounds that the provisions of the Building Code have been met.

A submission by Dr Barry Davidson of Compusoft Engineering discussed the common process of using producer statements for consenting the structural design of complex commercial buildings.

> Current Building Consent Process with Regards to Structural Design:
>
> (i) On application for a Building Consent by the owner or his/her agents, the structural designer usually provides two copies of the structural drawings, specification and calculations, and often a Producer Statement 1 – Design (PS1) stating that the design complies with the Building Code and all applicable structural Standards.
>
> (ii) Often depending on the size of the project, prior to issuing a Building Consent, the Territorial Authority (TA) may check the design documentation themselves, simply accept the PS1, or it may request that an 'independent' engineer carry out a design review, and when the reviewer is satisfied that the design complies with the Building Code, he/she will issue a Producer Statement 2 – Design Review, to that effect.
>
> Notes:
>
> (a) On many projects, there may be a number of PS1's issued by the design engineer, to cover a staged consent process that allows, for example, foundation construction to proceed before the design of the superstructure is completed. In addition, sub-contractors supplying the likes of precast floor systems and timber roof trusses will issue PS1's to cover their proprietary designs.
>
> (b) For more complex projects, discussion between the TA and the owner may take place at the beginning of the project to nominate a designer reviewer who can perform the review at stages during the development of the design, to match the staged consent process.
>
> (c) For many projects, staged construction starts before all of the design (and review) is completed, but each stage is supposed to be fully consented before it starts on site.

Notwithstanding the change made by the Building Act 2004, building consent authorities generally accept producer statements as suitable documentation for assessing compliance with the Building Code for complex building designs, and some building consent authorities require them. In fact, the evidence considered by the Royal Commission indicates that many building consent authorities rely on these documents as an effective means of collecting and recording information required to process an application for a complex building consent, and as a basis for peer review. However, because peer reviews and producer statements are not a requirement of the 2004 Act, there is some confusion over their standing.

3.3.6 Quality assurance issues raised in evidence

Submissions and evidence from the New Zealand Construction Industry Council (NZCIC), Dr David Hopkins, Mr John Scarry, and others identified issues with peer review and the consenting process for commercial buildings. These issues are summarised as follows.

- There are too few qualified and experienced engineers on the staff of the regulator (MBIE) and the building consent authorities.
- Most building consent authorities lack sufficient structural engineering resources to maintain technical oversight of complex commercial designs, especially for staged construction. Most simply do not receive the volume of consents to justify having these skills available in-house. Rather, they use the resources of a larger building consent authority, share such resources within a building consent authority "cluster"[6], or employ the resources of a professional engineer or engineering firm to undertake the review in accordance with their accredited process. Only the large metropolitan building consent authorities typically have such resources in-house. Submitters raising this issue also considered that there were too many building consent authorities, resulting in skilled resources being spread too thinly across the authorities and causing inconsistency in consent information requirements and decisions.
- Consenting by building consent authorities is focused more on process than on technical design (especially the structural integrity of the design).
- There are a variety of processes for documenting, reviewing and consenting complex commercial buildings, including:
  - widespread use of producer statements by designers and building consent authorities to assess the compliance of designs with the Building Code; and
  - the common use of a staged consenting process for commercial buildings, which requires appropriate knowledge and oversight to ensure the overall structural integrity of the building as a whole across the stages.

However, as Dr Davidson submitted:

> The Producer Statement process overlooks the demands of the commercial world and human nature, and many of the parties that now dominate the design and construction process are not structural engineers and have limited structural design knowledge.

- Designers often use building consent authorities in lieu of internal peer review processes to assess whether designs comply with the Building Code. There is also some "gaming" of the system to cut costs and/or manage missed client deadlines by submitting incomplete building consent applications and relying on the building consent authority to identify areas of non-compliance. Sometimes the building consent authority is then wrongly blamed for delays.
- Several submitters questioned whether the statutory 20 working day timeframe to issue a building consent is sufficient time for processing a building consent application for a complex commercial building. They question whether this could result in insufficient technical/structural review during the building consent process.
- There is a lack of personal and firm responsibility for design (and product use) failure.
- Insufficient resources are applied to research and education. Submitters considered research and education to be below the level needed to maintain adequate competence within the sector. As a result, building and product failures are not (or not sufficiently) investigated, particularly where there are confidentiality clauses in insurance settlements. This means that findings/issues from building failures (and product failures) are not publicised and lessons are not learned across the sector.
- Building information, such as as-built plans and specifications, are not readily accessible on a regional or national basis, which makes national analysis of trends and performance issues difficult, if not impossible.
- The relatively small size of the New Zealand commercial building sector means that reviewers are in many instances not independent of the designer or the owner or his agents. This can mean:
  - the same engineers regularly review the structural designs of the same designers (with a risk that they get "comfortable" with a "type" of building design);
  - a lack of independence;
  - potential for a conflict of interest; and
  - the designer is not involved in supervision/monitoring of construction due to "cost" or because of other client commitments.
- Not all designers have equal ability and knowledge. The current process of using the Chartered Professional Engineer (CPEng) quality mark assumes that designers with that qualification are capable of designing and/or reviewing the design of a complex structure. However, there have been cases where significant buildings have not been adequately designed. In addition, under the current process (when a designer repeatedly uses the same design reviewer), a common mistake is made in thinking that, because someone has designed one type of building on many occasions, they are expert at it. It is possible that a particular design/review team is consistently getting the design wrong. All designers make mistakes at some time.
- The insurance industry provides negative incentives to the process. Dr Davidson states in his submission that "the insurance industry negatively influences a positive long-term outcome for quality designs" because "after a building failure, the negotiation process between insurance companies ensures that information about the situation is buried" (through non-disclosure statements).

3.3.7 Addressing the issues raised

The Royal Commission heard suggestions for addressing many of these issues.

The NZCIC proposed a regulatory model supported by most submitters, including IPENZ. This model strengthens current processes by requiring (by regulation): (i) designers to observe construction and provide evidence that their designs have been correctly constructed; and (ii) builders/constructors to provide evidence in support of the application for a Code Compliance Certificate (in addition to the observation/inspection information collected by the building consent authority) to demonstrate that the building has been constructed in compliance with the design. The NZCIC model recognises three occupational groups – designers/architects, engineers and constructors – who need to be regulated differently to reflect their differing roles and responsibilities.

IPENZ noted in its submission the need to differentiate between building types.

> Residential buildings typically pose less risk to life than commercial buildings. The regulatory framework needs to acknowledge this by being more explicitly risk based.

The Building Amendment Act 2012 attempts to address this with new provisions for determining the approved risk profile for the proposed design and a quality assurance system that will apply to building work.

The New Zealand Registered Architects Board (NZRAB) provided the Royal Commission with an interim report by a working party it established to consider the implications of the Canterbury earthquakes for the architectural profession. This report made a series of specific recommendations particularly focusing on the need to include greater involvement of structural engineers in projects, particularly at an early stage, as follows:

> - Encourage architects to advise their clients of the benefits of engaging a structural engineer at an early stage of project design;
> - Review the relationship between architects and structural engineers to achieve adequate structural design input at an early stage of the design. The structural engineer should be engaged at the same time as the architect;
> - Ensure architects request structural engineers to advise of inter-storey deflections at the serviceability and ultimate limit states early in the design process;
> - Ensure that architects work closely with structural engineers in designing seismic load transfer elements in multi-storey buildings;

We consider that these recommendations are sensible.

Dr David Hopkins and others recommended a review process that specifically includes a design features report[7]. (An example of a Design Features Report that he provided is set out in Appendix 5 of this Volume.) In his submission, Dr Hopkins expressed the opinion that a design features report "is a very good discipline for design engineers, plays an important part in quality assurance and can give building consent authorities a good starting point for their consent process".

The Building Amendment Act 2012 may resolve some of these issues with the current review process by requiring building consent authorities to approve a risk profile for the building work and the quality assurance system that will apply to the building work before a building consent application is submitted. Regulations will be developed based on the results of two pilots currently in progress. At a high level the two approaches do not appear incompatible. A design features report could form part of the risk profile of the building work.

Mr John Scarry reminded us that design features reports and peer reviews do not compensate for a lack of structural experience of the original designer. However, he suggested that peer reviews should be a two stage process – once, early on, at the what he called the "butter paper, thick marker" concept stage, and then at the end of the design process.

3.3.8 Discussion – quality assurance

3.3.8.1 Key issues to be addressed

In summary, we have heard and accept evidence that:

- Building consent authority performance and staff competencies have improved significantly over the past five years through a comprehensive accreditation process. However, with 69 building consent authorities, there is still inconsistency of consent processes and decision making around the country.
- Building consent authorities have insufficient numbers of experienced structural engineers reviewing the structural integrity of designs at a detailed, technical level.
- There is sometimes a lack of involvement of structural engineers at an early stage in the design of a building.
- Not all CPEng qualified engineers are necessarily capable of designing, or reviewing, complex structures.
- There is insufficient external peer review by independent, experienced structural engineers.
- Where peer review occurs, there is sometimes no express assurance about the independence of the reviewer.

The Royal Commission agrees that these key issues need to be addressed in respect of buildings whose design may involve challenges for the designer, and whose failure in an earthquake may have serious consequences in terms of the safety of their occupants and the public. In the discussion that follows we propose that "complex structures" should be the subject of a special process designed to give greater assurance about the quality of their design than is currently the case.

3.3.8.2 Complex structures

It is difficult to lay out a precise description of what constitutes a "complex structure". However, we are satisfied that such structures would normally involve common features which, alone or in combination, could result in the structure being considered complex. These would include matters such as building irregularity, complex gravity or lateral load paths, the need for complex analytical methods in the design process, eccentricity, and particular site considerations, including soil structure (requiring special care in the design of foundations), combined with considerations of scale and design occupancy numbers. Given the importance of the changes we are suggesting, we recommend that MBIE should develop criteria to be applied in determining whether a structure is complex for these purposes, in consultation with the Structural Engineering Society of New Zealand (SESOC), the New Zealand Society for Earthquake Engineering (NZSEE), the New Zealand Geotechnical Society (NZGS) and other relevant groups, including building consent authorities. When developed, the criteria should be given regulatory force.

The classification of any particular structure as complex should be based on a two-stage process. The first stage would essentially be a preliminary filter that resulted in the exclusion of many buildings as not needing any consideration as potentially complex in nature. The second stage would involve a consideration of a Structural Design Features Report that would be required for any building not excluded in the first stage. A decision would be made at the second stage as to whether the building should be treated as complex and therefore subject to the special consenting processes that we propose for complex buildings.

The first stage can be based to some extent on the "importance levels" for buildings, set out in Table 3.2 of AS/NZS 1170.0:2002, *Structural Design Actions Part O: General Principles*[8]. We consider that all buildings in categories 3, 4 and 5 in that Standard should be subject to the new process that we propose. These categories are set out in the following table, extracted from Table 3.2 in AS/NZS 1170.0:2002.

Table 2: Building Importance Levels – extract from Table 3.2 in AS/NZS 1170.0:2002, *Structural Design Actions Part O: General Principles*

Importance Level	Comment	Examples
3	Structures that as a whole may contain people in crowds or contents of high value to the community or pose risks to people in crowds	Buildings and facilities as follows: (a) Where more than 300 people can congregate in one area (b) Day care facilities with a capacity greater than 150 (c) Primary school or secondary school facilities with a capacity greater than 250 (d) Colleges or adult education facilities with a capacity greater than 500 (e) Health care facilities with a capacity of 50 or more resident patients but not having surgery or emergency treatment facilities (f) Airport terminals, principal railway stations with a capacity greater than 250 (g) Correctional institutions (h) Multi-occupancy residential, commercial (including shops), industrial, office and retailing buildings designed to accommodate more than 5,000 people and with a gross area greater than 10,000 m^2 (i) Public assembly buildings, theatres and cinemas of greater than 1000 m^2 Emergency medical and other emergency facilities not designated as post-disaster Power-generating facilities, water treatment and waste water treatment facilities and other public utilities not designated as post-disaster Buildings and facilities not designated as post-disaster containing hazardous materials capable of causing hazardous conditions that do not extend beyond the property boundaries
4	Structures with special post-disaster functions	Buildings and facilities designated as essential facilities Buildings and facilities with special post-disaster functions Medical emergency or surgical facilities Emergency service facilities such as fire, police stations and emergency vehicle garages Utilities or emergency supplies or installations required as backup for buildings and facilities of Importance Level 4 Designated emergency shelters, designated emergency centres and ancillary facilities Buildings and facilities containing hazardous materials capable of causing hazardous conditions that extend beyond the property boundaries
5	Special structures (outside the scope of this Standard – acceptable probability of failure to be determined by special study)	Structures that have special functions or whose failure poses catastrophic risk to a large area (e.g. 100km^2) or a large number of people (e.g. 100,000) Major dams, extreme hazard facilities

We would then add all residential and commercial building of three or more storeys in height, provided that, in the case of residential buildings, they contain three or more household units. In our proposal, all the buildings in the categories described would require the preparation of a Structural Design Features Report. The provision of such a report would not be onerous, when compared with other requirements of the application process. Our intent in casting the net reasonably wide, however, is to ensure that the complexity issue is addressed in respect of all buildings whose failure in an earthquake could have serious implications for the safety of the occupants or passers-by.

On receipt of the Structural Design Features Report, the building consent authority would make a judgement as to whether the proposed building should be regarded as complex, having regard to the considerations that we have outlined above. We expect that the majority of the buildings would not be regarded as complex after consideration of the Structural Design Features Report, and in that case, the building consent application could proceed and be processed from that point in the normal way. We propose a special process for the buildings that are considered complex at this second stage. This is discussed in section 3.3.8.4 below.

3.3.8.3 Structural engineering expertise

To address the issue of insufficiently experienced structural engineers designing complex structures and undertaking peer review of these structures, we propose a new category of structural engineer, to be known as a Recognised Structural Engineer. These senior, very experienced structural engineers would be required to certify the adequacy of the structural design of complex buildings. We discuss the qualification requirements for a Recognised Structural Engineer in section 4 of this Volume.

To address the issue of insufficient engineering input at an early stage of design, we consider that the structural engineer responsible for a design should be engaged at the same time as the architect (or other designer) of the complex building.

3.3.8.4 Building consent process

We have concluded that the design of complex buildings (as described above) requires a higher level of competence than the design of buildings that are more straightforward. We consider the appropriate regulatory procedure to ensure this occurs is the preparation and submission of a Structural Design Features Report at the outset of the building consent authority assessment of the building consent application.

This could be achieved with minimal change to the existing process. In making the recommendations that follow, we are aware of the requirements of the Building Amendment Act 2012 for commercial building consents, and that the supporting regulations are under development. Without seeing the regulations, we cannot be certain about the "fit" between the new legislation and the approach that we recommend. However, we do not see any necessary inconsistency between the provisions of the 2012 Act and the measures we are recommending. In any event, what we recommend here are provisions that we consider should apply.

The proposals that we make are summarised in the recommendations that we now set out.

Recommendations

We recommend that:

162. Building consent applications for:
    - buildings in importance levels 3, 4 and 5 in Table 3.2 of AS/NZS 1170.0:2002;
    - commercial buildings comprising three or more storeys; and
    - residential buildings comprising three or more storeys with three or more household units

    should be accompanied by a Structural Design Features Report, which describes the key elements of the design, including the foundations and gravity and lateral load resisting elements.
163. A structural Chartered Professional Engineer should be engaged at the same time as the architect for the design of a complex building.
164. After consideration of the Structural Design Features Report, the building consent authority should decide whether or not the structure should be regarded as complex.
165. The Ministry of Business, Innovation and Employment should develop criteria to be applied in determining whether a structure is complex, in consultation with the Structural Engineering Society New Zealand, the New Zealand Society for Earthquake Engineering, the New Zealand Geotechnical Society and other relevant groups, including building consent authorities. When developed, the criteria should be given regulatory force.

166. If the structure is determined to not be complex, the engineer who provided the Structural Design Features Report should certify the structural integrity of the building's design.

167. If the structure is determined to be complex, a Recognised Structural Engineer should be required to certify the structural integrity of the design.

168. On receipt of the building consent application, the building consent authority should decide:

   a whether it has the staff with the appropriate competency (qualifications and experience) to process the application in-house (including any decision as to whether the structure is complex and whether any additional peer review certified by a Recognised Structural Engineer should be required); or

   b whether it needs to refer the application to another building consent authority that has the staff with the appropriate competency (qualifications and experience) to process the application.

3.3.9 National consenting system

Several submissions discussed the idea of a centralised national consenting system. Another possibility discussed was providing for a fewer number of building consent authorities, organised on a regional basis.

We accept that reform along these lines would enable the creation of viable groupings of specialists, including experienced senior engineers, resulting in improved decision making, in terms of consistency and quality. Another likely benefit would be the creation of an improved career path for building control officers. Such a system would also have the benefit of facilitating the identification of emerging issues and trends.

However, the timely processing of building consents is also an important feature, which has received particular attention in recent years. It is important that the consenting system operate in a timely way. We consider that the consolidation of the building consent process into one national or several regional centres would inevitably lead to greater delays. Further, establishing a national system would be a major undertaking and would be difficult to administer. It would be a major change to the current building regulatory regime and would require more detailed consideration of the principles behind a locally-administered regulatory regime than we are required by our Terms of Reference to consider. Nor do we consider such a change is justified by the experiences of the Canterbury earthquakes and the evidence before us. We consider that the key matter for consideration, under our Terms of Reference and from what we have learnt in the course of our Inquiry, is the provision of assurance that complex structures are designed by appropriately qualified and experienced people. We consider the measures outlined above to be sufficient to address that key concern.

3.4 Leadership

3.4.1 The regulator

The overall leadership of the building and construction sector rests with the regulator, currently MBIE (formerly the Department of Building and Housing). The role of the regulator is to:

- set the policy and regulatory framework;
- issue and review compliance documents;
- publish guidance information on the requirements of the Building Act and the Building Code; and
- review the operation of territorial authorities, regional authorities and building consent authorities in relation to their functions under the Act.

The Act sets out the role (section 11) and responsibilities (sections 169 to 211) of the chief executive of the responsible department. This includes monitoring current and emerging trends in building design, building technologies and other factors that may affect the Building Code and compliance documents, and issuing guidance information to the sector. The chief executive also has the power to provide a warning about, or ban the use of, a building method or product (section 26) and to make a determination[9].

3.4.2 Other industry groups

Leadership is also provided by other groups within the building and construction sector. This includes:

- learned societies such as SESOC, NZSEE, NZGS, the New Zealand Concrete Society (NZCS), the Heavy Engineering Research Association (HERA) and the New Zealand Timber Design Society;

- professional societies and industry bodies such as IPENZ, the Association of Consulting Engineers New Zealand (ACENZ), NZRAB, and BOINZ, who maintain the qualifications, training and interests of the professionals, officials and trades that operate in the sector;
- research organisations, particularly the Building Research Association of New Zealand (BRANZ);
- NZCIC; and
- Standards New Zealand, which develops, reviews and updates New Zealand Standards and is the operating arm of the Standards Council.

3.4.3 Technical leadership

Lack of strong technical leadership from the regulator was a key issue raised in submissions. Many submitters argued that MBIE and the building consent authorities had limited structural engineering capability. Rather, MBIE is perceived as being focused on policy and regulatory tools (which are important) and as not providing sufficient focus on technical compliance requirements, particularly about the structural aspects of complex buildings.

The Royal Commission heard from Mr David Kelly, Director of Canterbury Rebuild and Recovery at MBIE, that two key leadership roles were established in 2008: Chief Engineer and Chief Architect. Mr Kelly explained that the role of the Chief Engineer is to:

- provide high-level technical leadership and advice to the Ministry;
- develop a critical understanding of future and current trends;
- provide strategic and technical advice to the sector;
- foster strong relationships with the sector; and
- facilitate the Engineering Advisory Group (which was established as a result of the Canterbury earthquakes and consists of highly experienced technical experts).

As discussed above, and in our discussion of the building failures in the Canterbury earthquakes in Volumes 2, 4 and 6 of our Report, structural design is of critical importance in ensuring the safety of building occupants in an earthquake.

We consider the role of Chief Engineer is critical for technical structural engineering leadership for the building and construction sector. We support the Ministry's initiative in creating this role. However, we consider the role should be further strengthened, and supported with additional capability, by:

- emphasising the structural engineering nature of the role – Chief *Structural* Engineer;
- focusing the role on complex building designs;
- collecting and analysing complex commercial building consent applications from building consent authorities to enable:
  - assessment and monitoring on a national basis to identify trends in design, structural engineering approaches and construction techniques;
  - identification of potential issues and risks associated with particular types of buildings or construction techniques identified from the analysis of consent information;
  - identification of the need for compliance information, guidance material and, in conjunction with IPENZ and the learned societies listed above, training requirements, particularly in relation to structural design, construction methods, site supervision and monitoring; and
- promoting, authorising and communicating to the building industry and the public standards for building design, construction and materials.

We also heard evidence that the current role of Chief Engineer appears to be under-resourced. Mr Kelly explained that, as a result of the Canterbury earthquakes, an Engineering Advisory Group consisting of highly regarded and experienced technical experts had been established to support the Chief Engineer. We agree that it is important that sufficient technical engineering expertise is provided to support the role and functions of the Chief Structural Engineer. We recommend the continuation of the Engineering Advisory Group as an ongoing function to provide expert advice to the Chief Structural Engineer. We also recommend that MBIE consult with the relevant learned societies about the membership of that group, on an ongoing basis. The membership should always include senior, practising structural engineers.

Recommendations

We recommend that:

169. The role of Chief Engineer should be renamed Chief Structural Engineer to reflect a greater focus on the structure of complex buildings and should be further strengthened and supported with additional capability.
170. The Chief Structural Engineer should have the statutory power to collect consent applications for complex structures (as part of the Policy and Regulatory Work Programme in Recommendations 173 and 174 below) for the purpose of analysing trends, identifying issues and risks, and sharing knowledge with the building and construction sector.
171. The Engineering Advisory Group should continue as an ongoing function to provide expert advice to the Chief Structural Engineer.
172. The Ministry of Business, Innovation and Employment should consult with learned societies, such as the New Zealand Society for Earthquake Engineering, the New Zealand Geotechnical Society and the Structural Engineering Society New Zealand, about the ongoing membership of the Engineering Advisory Group. The membership of the Group should always include senior practising structural engineers.

3.5 Clarity about roles and responsibilities

The majority of submissions received identified a lack of clarity in relation to the roles and responsibilities of participants within the building and construction sector.

Particular concern was expressed about not always having clear policy made centrally, such as whether protection of life should be the sole objective of building design or whether maintaining building serviceability after an earthquake should also be the goal. Dr Nicki Crauford of IPENZ noted in her evidence that "policy decisions should then inform legislation and regulations and flow through to the Building Code, Standards and guidance documents… and these policies need to be sufficiently comprehensive so compliance documents do not become policy by default". This is a valid point.

The Standards Council gave evidence that this lack of clarity has hindered the prioritisation and funding of the regular review and update of those New Zealand Standards referenced in the Building Code. The submissions from NZCIC and IPENZ pointed to the benefits of having a national policy and regulatory work programme for the building and construction industry covering a rolling 3–5 year period. Development of this work programme would be led by MBIE and set out:

- a clear statement as to what the regulatory framework aimed to achieve;
- the specific work programme and responsibilities for delivery;
- how participants would comply with the requirements of the regulatory framework; and
- how the success of the programme would be measured.

There was a general consensus among hearing participants that such a work programme should be established, led and funded by MBIE, in consultation with SESOC, NZSEE, NZGS and other relevant groups, including BRANZ, NZCIC and representatives of the building consent authorities. There was also general consensus that MBIE's role as the central regulator should be to have responsibility for developing building policy, including determining the level of risk that can be tolerated, and the Building Code and Standards needed to ensure the design and construction of safe buildings. It is important that the public have the opportunity to contribute to the formulation of building design policy.

3.5.1 Uncertainty about who should develop Standards and when

Evidence heard by the Royal Commission indicated uncertainty within the sector as to who should develop Standards, how frequently Standards should be reviewed, and how the review and availability of Standards should be funded.

A lack of clear responsibility and funding for the review and updating of Standards referenced in the Building Code has resulted in some Standards now being out of date. International guidance advises that Standards should be reviewed and, if needed, updated, every 5–7 years.

Dr Peter Mumford, a Director within the Economic Development Group at MBIE, gave evidence on the history of the funding of Standards. He explained that government originally subsidised the Standards Council by up to 50 per cent of its income; however, this approach came to an end in 1986 when it was agreed that an annual grant would be provided to the Council to contribute to its international activities and that "the Government [would] give favourable consideration to funding standards by designated grants proposed in departmental estimates". In other words the funding would come through the department responsible for the area of regulation and it was up to that department to determine funding priorities.

The funding model was moved to the current funding model in 1989/90. Dr Mumford said in evidence that there were three reasons for this shift.

> Firstly the need for the Council to operate a commercial model and, in this context, to achieve financial self-sufficiency and that's part of the objective. The second is the need for the Government to meet its international obligations in relation to standards. It has a set of international obligations with respect to Australia, and with respect to the WTO. And thirdly, and importantly in this context, the central role of regulators in determining whether a standard is required to support regulatory outcomes... I quote from the report to Government in 1986… "Individual public sector agencies have a responsibility for the public good in their respective areas and they are the qualified agencies to determine whether a standard is the appropriate method to provide public protection in their areas". So it put the responsibility with the government agencies that have the responsibility for, if you like, delivering on the public good.

For the 2012 financial year, Standards New Zealand received approximately $7.5m in revenue and incurred a deficit of approximately $250,000, which it funded from reserves. Revenue comes from the sale of Standards and from industry and government departments funding the development and maintenance of Standards. Standards New Zealand has meagre reserves and insufficient funding to self-fund the review and updating of Standards on a regular cycle.

Where Standards are in the public arena, the Standards Council encourages the relevant public agency to fund the review and update of the Standards, but it is the agency's decision based on funding priorities. Therefore the work priority of Standards New Zealand is driven by those organisations that are prepared to fund the work.

Overseas jurisdictions typically have more resources as a result of larger populations or government support. Standards Australia has a large investment fund of approximately $180 million and is able to fund the development and maintenance of Standards from the interest earned by the fund.

It is clear that designers, engineers and building officials place significant reliance on Standards as key compliance documents. Currently there are approximately 300 standards referenced in the compliance documents of the Building Code, thereby becoming part of the regulatory framework. The consequence of not updating critical standards is that developments in engineering understanding, such as those resulting from the Christchurch earthquakes, may not be incorporated in a timely manner.

Because of limited funding, Standards New Zealand typically manages the development, review and update of Standards using "volunteers". These are usually industry experts and academics who contribute to the review of a Standard in addition to their paid employment. This often results in lengthy timeframes for completion of the review, as business demands often take precedence.

The Royal Commission considers that Standards that are relied upon by structural engineers during complex building design should be reviewed and updated as a priority, and funded as part of MBIE's work programme undertaken by the Chief Structural Engineer.

A contributing issue identified in submissions was that the purchase price for New Zealand Standards creates a barrier to their accessibility and use. Standards referenced in a compliance document are freely available at MBIE offices. However, engineering professionals and other building practitioners appear to access all Standards, regardless of whether they are referenced in a compliance document, through Standards New Zealand. This incurs a cost, as Standards New Zealand charges for such access, in accordance with its funding model.

In conclusion, the Royal Commission considers:

- Standards are a critical part of a performance-based regulatory system.
- Standards relied on for the purposes of building design need to be regularly reviewed and, if required, updated on a prioritised basis. They should be publicly available electronically, and free of charge.
- The review of Standards should be based on agreed priorities and high priority Standards should be reviewed and updated as part of the work programme overseen by the Chief Structural Engineer.
- Standards referenced in the Building Code should be available online free of charge.

3.5.3 Policy and Regulatory Work Programme

The Royal Commission agrees that MBIE should develop, lead and fund a Policy and Regulatory Work Programme in consultation with IPENZ, NZCIC, Standards New Zealand, BRANZ, NZGS, NZSEE and SESOC. The programme would set the objectives for the regulatory framework for the next 3–5 years, identify the initiatives required to achieve the objectives, the specific work priorities, measures and targets where appropriate, and the agreed responsibility for delivery for each piece of work within the programme.

Such a programme would provide clarity for the sector by identifying the priorities for the development, review and update of compliance documents and Standards, and would define the status of all compliance documents and guidance material. This would assist sector organisations to determine where they should develop their own specific guidance and when to provide appropriate advice to others, including the regulator. It would also assist organisations such as BRANZ and universities plan their research programmes so the resulting research is able to assist the development of compliance documents and Standards.

The work programme should be the responsibility of the Chief Structural Engineer. A key driver of the work programme will be the results from collection and analysis of the information on complex building consents provided by building consent authorities.

Work such as the review and update of Standards cited or referenced in the Building Code included in the programme should be funded by MBIE.

To ensure there is no confusion about roles, responsibilities, priorities and timeframes, a communications plan should be developed by MBIE as a key component of the work programme. The communications plan should identify the most appropriate communication method for each group of industry participants to receive information about compliance documents and Standards, and any guidance. The status of any such guidance should also be made clear. The effectiveness of the communications plan should be regularly reviewed.

Recommendations

173. The Ministry of Business, Innovation and Employment should develop, lead and fund a Policy and Regulatory Work Programme in consultation with the Institution of Professional Engineers New Zealand, the New Zealand Construction Industry Council, Standards New Zealand, the Building Research Association of New Zealand, the New Zealand Geotechnical Society, the New Zealand Society for Earthquake Engineering and the Structural Engineering Society New Zealand.
174. The Policy and Regulatory Work Programme should identify the priorities for the development, review and update of compliance documents and Standards, and define the status of compliance documents and guidance material. Work relating to Standards prioritised for update as part of the Policy and Regulatory Work Programme should be funded as part of the work programme.
175. Standards referenced in the Building Code should be available online, free of charge.
176. The Policy and Regulatory Work Programme should be the responsibility of the Chief Structural Engineer.
177. A communications plan should be developed by the Ministry of Business, Innovation and Employment to communicate the Policy and Regulatory Work Programme and ensure information is effective, and targeted for different participants in the sector. There should be clarity about the status of information provided to the sector; for example, whether it is a compliance document, Standard or guidance.

References

1. Department of Building and Housing (2011). *New Zealand Building Code Handbook* (3rd ed.). Wellington, New Zealand: Author.

2. Department of Building and Housing (2009). *Building Act Review.* Retrieved from www.dbh.govt.nz/buildingactreview

3. Non-residential buildings include hostels, boarding houses, hotels and other short-term accommodation, hospitals, nursing homes, educational buildings, social, cultural and religious buildings, shops, restaurants, taverns, offices, administration buildings, storage buildings, factories and industrial buildings, and farm buildings.

4. Information provided to the Royal Commission by the Ministry of Business, Innovation and Employment in November 2012.

5. ISO/IEC 17011:2004. *General Requirements for Accreditation Bodies Accrediting Conformity Assessment Bodies,* International Organization for Standardization.

6. A cluster is a regional group of building consent authorities that work together to develop common processes and forms and to share capability, usually under a shared services agreement, such as arranging for a building consent authority with specialist structural engineering staff to process a consent application of a complex building.

7. The Design Features Report describes the intended structural system at a high level. Dr Barry Davidson notes in his submission that it “would describe the proposed structural form, proposed load paths, expected seismic performance etc. It is not intended to have any details such as member sizes supplied at this stage”.

8. AS/NZS 1170.0:2002. *Structural Design Action Part 0 – General Principles,* Standards Australia/Standards New Zealand.

9. A determination is a binding decision by the chief executive of MBIE and provides a way of solving disputes and questions about the rules that apply to buildings, how buildings are used, building accessibility and health and safety. Most determinations arise from disputes between a building owner and a building consent authority.

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

Section 4: Training and education of civil engineers and organisation of the civil engineering profession

4.1 Introduction and overview

The Royal Commission's Terms of Reference require us to investigate:

> …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.

This includes, among other things:

> …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.

We considered that, under these provisions, we should examine current arrangements for the education and training of structural and geotechnical engineers in New Zealand, the competence standard used by the Institution of Professional Engineers New Zealand (IPENZ) to register engineers, and the occupational regulations that govern the engineering profession. We were also driven to inquire into these matters as a result of evidence that we heard in relation to the failure in the February 2011 earthquake of individual buildings considered as part of the representative sample of buildings, and in particular the CTV building.

To assist with this part of the Inquiry, the Royal Commission sought a report[1] from IPENZ on:

- the framework governing the provision of civil engineering education and training in New Zealand;
- the registration process for Chartered Professional Engineers (in the discussion that follows we have referred to persons so registered by the term "CPEng" as that is the approach adopted by IPENZ and the profession generally);
- requirements and obligations arising from international engineering agreements signed by or on behalf of the New Zealand Government and the rights and requirements for engineers under these agreements;
- regulatory or quasi-regulatory requirements that govern practising engineers (i.e. the Codes of Ethics that engineers are bound by and the IPENZ complaints and disciplinary mechanisms); and
- the roles of IPENZ and other professional and learned societies in the civil engineering profession.

Submissions on these and related matters were made by a range of interested parties including engineering consulting firms, individual engineers, IPENZ, Ministry of Business, Innovation and Employment (MBIE), universities, learned societies, and assessors of competence for CPEng registration.

In addition to considering the various written submissions received, the Royal Commission convened a public hearing on 10 September 2012 that took the form of a panel discussion on the topics and issues set out above. As noted, the discussion that follows is also influenced by the evidence we heard about the failure of the CTV building in the February earthquake.

4.1.1 Education

International agreements underpin the nature and content of engineering education in New Zealand. The Royal Commission has heard nothing that suggests there should be a change in the structure of the Bachelor of Engineering (BE (Hons)) degree. Rather, key matters for further consideration are in post-degree training and continuing education through provision of tailored block courses for those who are working, and mentoring within engineering firms.

4.1.2 Competence

Life safety is and will remain the paramount objective in the design and construction of buildings to resist earthquake motions. This is best achieved by having highly experienced people performing the highest risk activities. In this regard, the Royal Commission has heard proposals and views from interested parties as to the merits, issues and risks of implementing a two-tier certification system that would raise the level of training and experience required of a structural engineer who certifies engineering design plans for complex structures. We consider there is merit in this concept and recommend the creation of "Recognised Structural Engineer" for these purposes.

We have also reviewed the competence requirements against which engineers are assessed for CPEng registration. Having considered the relevant evidence and submissions, we recommend the introduction of an additional competence measure against which every structural engineer must be assessed – "a good knowledge of the fundamental requirements of structural design and of the fundamental behaviour of structural elements subjected to seismic actions".

4.1.3 Codes of ethics

IPENZ members are required to act in accordance with the IPENZ Code of Ethics and CPEngs are bound by a Code of Ethical Conduct. Both codes are identical in the obligations they impose on the registered engineers. The point of difference is that the IPENZ code is accompanied by guidance to help members determine what they must do in order to comply. The CPEng Code does not provide any guidance or advice about how to ensure compliance. CPEngs are expected to self-determine the standards of behaviour in order to meet the terms of the Code.

The key matters of interest to the Royal Commission are the clauses governing the requirement not to misrepresent competence (IPENZ clause 4 and CPEng rule 46) and the obligations to report buildings and structures that place the public's health and safety at risk (IPENZ clause 11 and CPEng rule 53).

For reasons that we discussed in Volume 6 of this Report, we concluded that the structural engineer who designed the CTV building, Mr Harding, was not competent to do so without supervision by a more experienced engineer. Mr Harding was certified as a Registered Engineer (under the previous Engineers Registration Act 1924), but was not in our view sufficiently experienced to design a six-level office building with the seismic load resisting system employed in the CTV building. Under the current CPEng framework, engineers are required to work in their designated area of practice under which they have been assessed for registration as CPEng; any engineering activities undertaken outside that area would be a breach of the CPEng Code of Ethical Conduct, which prohibits the misrepresentation of competence. We also heard in the CTV hearing that the building had been reviewed by structural engineers from Holmes Consulting Group in 1990, who identified a critical structural weakness. In the particular circumstances addressed in Volume 6, we concluded that the reviewing engineers had acted appropriately by informing the building designers and were justified in not raising the issue they had found with the Christchurch City Council (CCC). However, we consider that reviewing structural engineers should have a clearly expressed ethical duty to disclose the existence of a critical structural weakness, in a process that protects them from any liability where they have acted in good faith.

4.1.4 Professional and learned societies

The contribution of a small group of volunteers from the engineering profession's learned societies in guiding and providing a combination of post-degree education and mentoring to structural engineers is both highly valued by the profession and acknowledged by the Royal Commission. We refer to these societies in more detail in section 4.6.

The work undertaken by the societies' members includes both contributing to formal processes for reviewing and updating New Zealand Building Standards, and issuing guidance on best-practice for the profession and industry, some of which is paid work but much of which is not. Society members also contribute technical papers for conference proceedings and provide guidance on best-practice to industry. Processes in which guidance is given are informal, and do not pass through the scrutiny of a regulatory review process: the best-practice advice is not formalised as legal requirements, and therefore may or may not be utilised or taken into account by practitioners.

There are risks in the informal component of this approach. These include whether the necessary expertise will remain available on a voluntary basis to enable the process to continue over time and the absence of an objective process that tests the content and assesses the consequences of the best-practice guidance by formal regulatory review. Assessment of consequences would include examining the costs of the best-practice standards and requirements to determine value in the context of the risks being managed. In addition, without any formal recognition, the adoption of the recommended best-practice standards and requirements is difficult to monitor and cannot be enforced. This makes it unlikely that they will be consistently applied by practitioners.

4.2 Legislative framework

4.2.1 Background

Prior to the enactment of the Chartered Professional Engineers of New Zealand Act 2002 (the CPEng Act) engineers were subject to the Engineers Registration Act 1924. That Act provided for the registration of Registered Engineers who had demonstrated through education and experience that they met the standard for registration. Requirements of a minimum age and for good character and reputation underpinned registration. There was no explicit competence standard; rather, candidates were registered after they had gained an engineering qualification at a specific level and suitable experience over a specified period of time, and presented adequately at an assessment interview. Once registered, there were no specific requirements to maintain registration other than the payment of an annual fee.

4.2.2 Chartered Professional Engineers of New Zealand Act 2002

The CPEng Act repealed the Engineers Registration Act. It:

- states its purpose as being "to establish the title of chartered professional engineer as a mark of quality";
- establishes a registration system for chartered professional engineers, and provides for minimum standards that must be met to achieve and maintain registration;
- requires a code of ethics and a complaints and disciplinary process to apply to CPEngs;
- appoints IPENZ as the Registration Authority, and requires it to make rules as to minimum standards of competence and ethical conduct to be met by CPEngs; and
- establishes the Chartered Professional Engineers Council (CPEC) as the statutory body for overseeing the activities of the Registration Authority. CPEC reviews and approves rules containing the CPEng standards, and hears appeals from the Registration Authority in relation to disciplinary matters.

The Building Act 2004 is the key statute that governs the construction of buildings in New Zealand. It provides for a performance-based building code that is expressed in terms of desired outcomes, rather than prescriptive requirements, as discussed in sections 2.2.3 and 2.2.4 of Volume 4 of this Report. The engineering profession's standards and performance requirements are driven in large part by the requirements of the Building Act and the Building Code. These include, for example, performance standards that buildings are expected to meet and guidance as to how those standards can be met, scrutiny in the building consent and inspection process and protection for homeowners through mandatory warranties.

These provisions flow through to the development of standards and best-practice guidance for engineers and training and education programmes for both continuing professional development and competency assessment for CPEng.

Governance arrangements are provided for by the appointment of IPENZ as the Registration Authority and the establishment of CPEC, a statutory body to which IPENZ is accountable for its performance as Registration Authority.

The parts of the CPEng Act that are relevant to this discussion are:

- Part 2 (sections 6–38): establishing and protecting the title of CPEng; registration procedures; development and maintenance of the register by the Registration Authority: the disciplinary framework for CPEngs and procedures and powers in relation to disciplinary matters; decision-making functions and procedures of the Registration Authority and Council.
- Part 3 (sections 39–61): establishing CPEC and setting out functions, powers and requirements (including reporting requirements) of CPEC and the Registration Authority.

The key powers and functions of the Registration Authority, set out in section 39 of the CPEng Act, are making, and always having, CPEng rules; undertaking activities associated with registration and maintenance of the register; and conducting a complaints and disciplinary process. Section 40 of the CPEng Act requires that the rules contain minimum standards for: a) competence in professional engineering for registration; and b) demonstrating current competence in professional engineering for continued registration. It also provides for rules to be made regarding the frequency at which assessments of current competence must be carried out and for the ethical conduct of CPEngs.

Section 45 of the CPEng Act sets out the key powers and functions of CPEC. These are reporting on the Registration Authority's performance to the Minister, acting as the first appeals body on matters of both registration and discipline, and reviewing and approving proposed rules containing CPEng standards prepared by the Registration Authority.

CPEng rules 8 and 9 set out the CPEng registration process and information requirements to support an application. IPENZ advises that a graduate engineer will take between four and eight years to meet the competency requirements for CPEng registration.

Provisions pertaining to the register of CPEngs are set out in sections 16–19 of the CPEng Act. In accordance with these sections IPENZ, as the Registration Authority, maintains the CPEng register that records the name of the CPEng, and information about the status and history of the engineer's registration, including the date of registration, the period for which the latest registration certificate was issued and any orders made on disciplinary matters in the previous three years. Any suspension from registration must also be noted, together with the reason for it. The engineer's contact details are also provided where this is agreed by the CPEng. In addition (and in accordance with the power to provide other information under section 18 of the CPEng Act), IPENZ has opted to show in the register the date of the next reassessment of current competence.

The register is available electronically, and can be searched for a specific CPEng or all CPEngs in a specified location. The register is also held in hard copy at IPENZ's head office.

The CPEng register does not provide information about the skills and expertise, or practice area, of a CPEng, and the CPEng Act does not require that it do so. At the hearing, IPENZ advised that over the past six years it has been building up practice area information on all registered CPEngs with a view to publishing it in the CPEng register. It is important that consumers of engineering services have access to sufficient information to make a judgement about the suitability of a particular engineer for work required. We note in this respect that section 16 of the CPEng Act states that one of the purposes of the register is to enable members of the public to "select a suitable engineer from a list of chartered professional engineers". Inclusion of information about an engineer's area of practice on the register would be consistent with this purpose. The Royal Commission recommends that IPENZ proceed with this initiative, which it clearly has power to implement under section 18(1)(d) of the CPEng Act. This enables the Registration Authority to include on the register "any other information that [it] considers necessary or desirable for the purpose of the register".

4.2.3 Chartered Professional Engineers Rules of New Zealand (No 2) 2002 (the CPEng rules)

The CPEng rules were made under section 40 of the CPEng Act and compliance with them is a matter of legal obligation. IPENZ advises that the rules that contain competence standards have not been changed since being set in 2002. Other rules have been updated several times since inception. The CPEng rules, relevant to this section, are as follows:

- Part 2 (rules 6–42): Registration of CPEngs, including competence requirements;
- Part 3 (rules 43–53): Code of Ethical Conduct; and
- Part 4 (rules 54–70): Disciplining CPEngs.

Section 41(1) of the CPEng Act states that when preparing a rule containing a CPEng standard, the Registration Authority must: (a) ensure the proposed rule is consistent with the purposes of the CPEng Act; (b) consult with engineers and any persons that it reasonably considers to be representative of other persons or classes of persons affected by the proposed rule; and (c) take into account international best-practice and New Zealand's international obligations.

4.3 The engineering profession

IPENZ is the most prominent professional body for engineers of all disciplines, and has around 13,000 members who have registered into a number of different classes of membership, as set out below. Membership of IPENZ can be held by non-engineers including students and individuals who have made contributions to engineering from outside the profession.

The civil engineering branch of the engineering profession comprises structural, geotechnical, transportation and mining engineers as well as engineering technologists and engineering technicians.

4.3.1 Classes of engineering professionals

The IPENZ register lists all members, the regions where they practise and any other registers they are on (e.g. CPEng register). Candidates for membership of IPENZ in the classes of professional, technical or associate member must demonstrate competence relevant to the class of membership sought. Ongoing membership does not require reassessment of competence – membership lasts for so long as the annual subscription is paid. All members must abide by the IPENZ Code of Ethics. That requires, amongst other things, that members perform engineering activities only in areas in which they are currently competent.

The competence standard against which professional engineers are assessed to become CPEngs is the same as that to become a professional member of IPENZ, although the CPEng requirements to continue to be a CPEng are more onerous because of periodic reassessments of competence. The majority of the almost 3,000 registered CPEngs are also members of IPENZ, although there is no legal requirement that they be members of IPENZ.

The members of IPENZ register into one of the following registration classes:

1. Professional Member (MIPENZ) – a person assessed as competent to practise professional engineering as an independent professional capable of designing innovative solutions to complex engineering problems.
2. Fellow (FIPENZ) or Distinguished Fellow (Dist FIPENZ) – a Member who has made a substantial contribution to the development of the engineering profession, its practices or IPENZ itself.
3. Honorary Fellow (Hon FIPENZ) – those who often have backgrounds outside engineering, but have made worthwhile contributions that impact on professional engineering, or IPENZ itself.
4. Technical Member (TIPENZ) – a person assessed as meeting a standard of engineering practice that is sufficient for them to work independently in a range of engineering situations. They were previously known as Engineering Technologists.
5. Associate Member (AIPENZ) – a person assessed as a competent engineering practitioner, based on strongly developed technical knowledge and practical experience. They are able to perform many standard engineering functions themselves. They were previously known as Engineering Associates.
6. Graduate Members (GIPENZ) – holders of tertiary qualifications in engineering that have been accredited by IPENZ as being of good internationally-benchmarked quality. They have yet to develop the skills necessary to progress through competence assessment to reach one of the above classes of registration.
7. Companions (Comp IPENZ) – persons whose qualifications are not in engineering but have a position of significant responsibility in which they interact with the engineering profession in a significant way.
8. Affiliate and Student Members – these members are those studying towards a tertiary qualification in engineering and who seek involvement in a discussion forum with engineers.

Engineers can apply to be registered as CPEng, the quality mark for the practising members of the engineering profession. This requires demonstration of competence against a standard in their practice area (set out in rule 6(2) of the CPEng rules, which we discuss later in this section).

An engineer can seek registration as an International Professional Engineer (IntPE(NZ)), also known as an APEC Engineer. Registration allows engineers to have their professional standing recognised internationally within the APEC region. This provides for the recognition of ‘substantial equivalence’ of professional competence in engineering. A signatory country to the APEC Engineer agreement may require further assessment of a candidate to be registered on the local professional engineering register, but the extra assessment is to be minimised for those registered under the APEC Engineer agreement.

4.3.2 Civil engineering disciplines

Civil engineering is an engineering discipline that includes the practice fields of structural, geotechnical, transportation and mining engineering. Within each practice field is a smaller, focused area of practice in which the civil engineer specialises, and it is this area of practice that he or she is assessed against for competency by IPENZ. Examples of such areas of practice include design of bridges, dams and building structures, and design using specific materials.

4.4 Education and training of engineers

4.4.1 Washington Accord – international equivalency of engineering degrees

IPENZ, on behalf of the New Zealand Government, is a signatory to the Washington Accord (the Accord), recognising substantial equivalence of engineering qualifications. Other signatories include the United Kingdom, Ireland, USA, Canada, Australia, Hong Kong, South Africa, Japan, Singapore, Taiwan, Korea, Malaysia and Turkey.

The Accord is an independent agreement for mutual recognition of accredited engineering programmes, benchmarking standards for engineering education and benchmarking accreditation policies and processes. The signatories to the Accord agree that they will "identify and encourage the implementation of best-practice for the academic preparation of engineers by mutual monitoring, regular communication and sharing of information and invitations to observe accreditation visits and observe meetings of any boards. Regular monitoring through six-yearly visits is required". Among other things signatories are required to provide evaluators for reviews of other signatories.

Graduates of accredited programmes in any of the signatory countries are considered to have met the educational requirements for entry to the practice of engineering in any other signatory country. However, to become registered or chartered in a signatory country, that country's registration requirements must be met.

4.4.2 Education of engineers in New Zealand

The Royal Commission has not heard any evidence that suggests there is a fundamental problem in the way in which the education of engineers is provided. In addition, we note the international agreements that underpin the prescription of the degrees, which are routinely assessed for compliance. Full participation in this international network is clearly in New Zealand's best interest.

4.4.2.1 Accreditation of engineering programmes for membership of professional societies and the Washington Accord

The Universities of Canterbury and Auckland are the two major providers of professional civil engineering education, both offering four-year honours degrees in engineering, BE(Hons). The engineering programmes offered by both of these universities have been accredited by IPENZ as meeting the requirements of the Accord.

As a result of changes made to the exemplar graduate attributes statement in 2009, signatories to the Accord are assessing their accreditation standards to determine whether changes are needed to accredited engineering programmes. IPENZ advises that there is disagreement within the engineering community in New Zealand as to the need for programme lengthening to maintain New Zealand's international standing in professional engineer education. IPENZ has signalled a probable increase in length of study required for the accredited BE(Hons) degrees by 0.25 years by 2019.

There are also a number of other universities and education providers, such as Unitec Institute of Technology and Auckland University of Technology, that provide education for engineers in a wide range of disciplines, and for technologists and technicians.

4.4.2.2 Civil Engineering programmes at the Universities of Canterbury and Auckland

The Universities of Canterbury and Auckland provide master's degrees in engineering that focus on more specialised engineering knowledge. The majority of those studying for the master's degree are recent graduates with a BE(Hons) degree, as well as a small number of practising engineers. The University of Canterbury advises that initiatives are underway to offer a specialised master's programme in earthquake engineering to be introduced in 2013. As we discuss below, it is clear that over the years the structural and geotechnical engineering content of the BE degree has had to reduce due to the expansion of instruction in other fields of engineering practice. The Royal Commission supports the endeavours of the universities and other academic institutions to provide further scope for those who wish to increase their knowledge and understanding of structural and earthquake engineering, and geotechnical engineering.

The University of Canterbury[2] notes that "the role of universities offering professional level engineering qualifications is to ensure that graduating engineers enter the workforce understanding, and able to apply the principles that underpin core subject areas. Furthermore, universities provide graduating engineers with the potential for transferring new techniques learnt from undergraduate and postgraduate study, into industry". The University of Auckland[3] and the University of Canterbury acknowledge that the formation of a professional engineer is a two-stage process – the engineering degree is the first stage and the second stage is the application of, and building upon, the knowledge gained during the degree through training in industry.

The University of Canterbury provided information to the Royal Commission about the content of its academic programme for structural and geotechnical engineering students wishing to graduate with Civil Engineering degrees. The first year provides a foundation in basic sciences and an introduction to applied engineering subjects, which requires students to achieve an acceptable academic standard in order to progress[4]. The programme of study in the following two years (known as Professional Years 1 and 2) comprises "a sequence of compulsory courses covering the core sub-disciplines in civil engineering. These include environmental engineering, hydraulics and hydrology, structural engineering, transportation engineering, geotechnical engineering, surveying, management, design and support courses in mathematics and computation". In Professional Year 3 (fourth year of study), students can elect to specialise from a menu of elective options with just one compulsory course required, in management.

The University of Canterbury noted that specific education in earthquake engineering does not occur until Professional Year 3 when it comprises up to 50 per cent of the content of structural and geotechnical courses (all of which are elective in that year).

While not identifying the actual courses provided in its bachelor's engineering degree, The University of Auckland submission noted much the same structure for its degree.

4.4.2.3 Structural engineering content in degree

In the hearing on the education and training of engineers, Professor Buchanan of the University of Canterbury noted that "the structural earthquake engineering content of a bachelor's degree in civil engineering at Canterbury and Auckland has slowly shrunk over the last few decades because there are lots of other important things to put in and if you put something else in you have got to take something else out…". An idea proposed was for the creation of a bachelor's degree exclusively dedicated to structural engineering. That is plainly a matter for the universities to consider. However, at the hearing the panellists from engineering consulting firms noted that it is desirable for graduate engineers to have a broad set of skills.

The University of Canterbury advised the Royal Commission that following the Canterbury earthquakes, it undertook a review of the education and training process for engineers involved in the design of large buildings and structures. That review confirmed that "due to the expansion of the body of knowledge in the many sub-disciplines of civil engineering in the last 50 years the proportion of the undergraduate degree that is dedicated to structural engineering has reduced in recent times". The University considers that the "structural and geotechnical engineering knowledge of civil engineers entering the profession should be increased in order to supply the engineering profession with better educated personnel who can design infrastructure appropriate for a seismically active region such as New Zealand". The Royal Commission considers that a sound knowledge of the basic principles of structural and geotechnical engineering is important and agrees with this observation in the University of Canterbury's submission. We recommend that the Universities of Canterbury and Auckland pursue ways in which it can be achieved.

4.4.3 Training

As noted above, the Universities of Auckland and Canterbury have expressed the view that engineering education is the first step in the formation of a professional engineer; the second is applying and building on the knowledge gained during this degree through training in industry. Others, including the Structural Engineering Society New Zealand (SESOC), have said that on-the-job training by employers is critical.

The Royal Commission is of the opinion that post-graduate training for engineers is an essential factor in developing and maintaining competence. We encourage the ongoing provision of continuing education through provision of block courses at the tertiary institutions, the tailoring of courses to those who are working, and mentoring within engineering firms. Engineering consultancies should encourage their engineering staff to take membership in the engineering profession's learned societies and attend seminars. They should provide support for ongoing learning and maintain a structured process for the review and sign-off of work.

SESOC and IPENZ endorse the current methodology that allows engineers to determine their own training needs. SESOC notes further that for structural engineers, those needs are complex and diverse. IPENZ advised the Royal Commission that few CPEngs fail to demonstrate that they have taken reasonable steps in continuing professional development when reassessed for continuing registration. Other submitters expressed support for a prescribed programme of postgraduate training for engineers. The Ministry of Business, Innovation and Employment (MBIE) noted that this would facilitate engineers undertaking adequate training over a period of some years, rather than having a deficit of further training needs at the time of assessment. We note that, under the CPEng Rules, the Registration Authority must assess whether an engineer meets the minimum standard for continued registration every 5–6 years. IPENZ advises that it is unaware of any prescribed programmes of training for engineers in other countries.

In order to retain professional membership of IPENZ, an engineer must undertake at least 50 hours per annum of continuing professional development. This is similar to the requirements for chartered accountants imposed by the New Zealand Institute of Chartered Accountants, who must complete 120 hours over a rolling three-year period with a minimum of 20 hours in each year. Engineers registered with Engineers Australia must complete 150 hours over a three-year period with at least 50 hours relating to the area of practice, 10 hours of risk management and 15 hours of business and management skills.

Engineers seeking to register or re-register as CPEng must demonstrate competency in their area of practice to IPENZ, and are required to assess their own needs for training courses and further education to assist them to meet the competence assessment in the future. The appropriateness of their further training and education will be taken into account in the competence assessment process required for registration and continued registration.

4.4.4 Competence

In order to be registered as CPEng, or registered into an IPENZ competence class, an engineer's competence is assessed by a competence assessment panel against a set of 12 criteria representing the minimum standard for registration.

4.4.4.1 Minimum standard for registration

Under Rule 6(1) of the CPEng Rules, a person must meet "the minimum standard for registration" by demonstrating that he or she "is able to practise competently in his or her practice area to the standard of a reasonable professional engineer". Rule 6(2) lists a number of competencies that must be considered in assessing whether the candidate meets this minimum standard. These require assessment of the extent to which the person is able to:

(a) comprehend, and apply his or her knowledge of, accepted principles underpinning-
  (i) widely applied good practice for professional engineering; and
  (ii) good practice for professional engineering that is specific to New Zealand; and

(b) define, investigate, and analyse complex engineering problems in accordance with good practice for professional engineering; and

(c) design or develop solutions to complex engineering problems in accordance with good practice for professional engineering; and

(d) exercise sound professional engineering judgement; and

(e) be responsible for making decisions on part or all of one or more complex engineering activities; and

(f) manage part or all of one or more complex engineering activities in accordance with good engineering management practice; and

(g) identify, assess, and manage engineering risk; and

(h) conduct his or her professional engineering activities to an ethical standard at least equivalent to the code of ethical conduct; and

(i) recognise the reasonably foreseeable social, cultural, and environmental effects of professional engineering activities generally; and

(j) communicate clearly to other engineers and others that he or she is likely to deal with in the course of his or her professional engineering activities; and

(k) maintain the currency of his or her professional engineering knowledge and skills.

The expressions "complex engineering activities" and "complex engineering problems" are defined in rule 7 of the CPEng rules as follows:

- **complex engineering activities** means engineering activities or projects that have some or all of the following characteristics:
  (a) involve the use of diverse resources (and, for this purpose, resources includes people, money, equipment, materials, and technologies);
  (b) require resolution of significant problems arising from interactions between wide-ranging or conflicting technical, engineering, and other issues;
  (c) have significant consequences in a range of contexts;
  (d) involve the use of new materials, techniques, or processes or the use of existing materials, techniques, or processes in innovative ways;
- **complex engineering problems** means engineering problems that have some or all of the following characteristics:
  (a) involve wide-ranging or conflicting technical, engineering, and other issues;
  (b) have no obvious solution and require originality in analysis;
  (c) involve infrequently encountered issues;
  (d) are outside problems encompassed by standards and codes of practice for professional engineering;

(e) involve diverse groups of stakeholders with widely varying needs;

(f) have significant consequences in a range of contexts;

(g) cannot be resolved without in-depth engineering knowledge.

Demonstration of competence can include providing evidence of academic and other relevant qualifications, current registration on other professional engineering registers, results from other relevant competency assessments, professional development activities undertaken, work history, statement of self-review, other information provided in support of the application (e.g. work samples from recent professional engineering activities) and annotations explaining how the information demonstrates that the minimum standard for registration is met.

4.4.4.2 Competence assessment process

Assessment of competence is outcomes-based, requiring a candidate to demonstrate expertise in his or her chosen field of practice, rather than rely on education and identification of work experiences. In fact, a candidate for CPEng need not have a tertiary qualification although the burden of proof of competence may be onerous in the absence of an engineering degree.

The Royal Commission has been advised by IPENZ that the process of outcomes-based assessment rather than entrance examination is becoming international best-practice. It is the approach followed in Australia, Ireland, South Africa and the United Kingdom, and the assessment process in those countries generally mirrors the IPENZ process. It has overtaken the use of entrance exams, although passing an examination remains the requirement for entry to the profession in the United States and Canada.

In 2005, the International Engineering Alliance adopted an exemplar competence profile against which IPENZ procedures were reviewed in 2006 by the APEC Engineer Framework and the Engineers Mobility Forum. The panel of experts found that the IPENZ procedures corresponded to the agreed benchmark standard and, having compared the standard and procedures to those being used in their own jurisdictions, they were satisfied that substantial equivalence was demonstrated. Another review is imminent (2012/2013).

Evaluation of an application for CPEng registration is made by an assessment panel with a recommendation on the application made to a competency assessment board. Evaluation procedures are set out in CPEng Rules 10–15. CPEng Rule 75 provides that an assessment panel must consist of two or more assessors who are CPEng (or who have CPEng equivalence), at least one of whom has knowledge or experience relevant to the practice area in which the person is being assessed. The panel undertakes an initial assessment of the application for registration as CPEng, and if it meets the criteria, it is referred to a competency assessment board for full review. CPEng rules 20–26 relate to the assessment processes and information requirements for a CPEng to demonstrate current competency for continued registration.

4.4.4.3 Discussion

The Royal Commission is satisfied that the current system for the registration of CPEngs and assessing their ongoing competence is appropriate and represents best-practice in international terms. It provides acceptably for continuing professional development, and the ongoing maintenance of professional competence. We do not see the need for wholesale change.

Based on information advised to the Royal Commission and from its public hearings, we are not convinced that there are systemic issues across the country with engineers working outside their areas of practice. IPENZ, MBIE and SESOC have commented in submissions there is no hard evidence that this occurs. SESOC and IPENZ also noted that it is more likely the case that there are engineers performing incompetently within their areas of practice than practising outside of them.

Nevertheless, there are some issues that we wish to record, as a result of our Inquiry into the performance of buildings in the Canterbury earthquakes. We note from our investigation that the majority of cases of poor performance arose due to either:

- failure to recognise the weakness of the foundation soils; or
- failure to adequately allow for fundamental aspects of structural behaviour.

Below we note just a few of the cases where the designers failed to recognise fundamental aspects of structural behaviour. In some cases, the aspect of fundamental behaviour that caused the problem was not understood by practising designers at the time the design was made, and there was no or little reference to the potential problems in design standards or text books then current.

The most fundamental requirement for structural design is that every load or inertial force must have a valid load path or load paths between the position where the load acts and the foundation soils. Furthermore, every part and detail of this load path must satisfy the requirements of equilibrium and compatibility.

This very basic requirement was violated in the CTV building, where some of the equilibrium requirements for the transfer of inertial forces between the floors and the structural walls were neglected in the design. In addition, the load paths through the beam-column joints were not considered. Analysis of these details shows that the strains were incompatible and consequently the forces required to sustain the imposed actions could not be maintained. This led to rapid degradation of the strength of the details with the formation of wide cracks in the joint zones.

For seismic design, there is a further basic design requirement associated with ductility and capacity design. This requirement is that structural details must not lead to excessive strain concentration in an element, in comparison to the strain capacity of the material. Structural designers have been slow to identify many aspects of this problem, but the performance of buildings in Christchurch has highlighted it.

Examples of excessive strain concentration due to the detailing that was used were apparent in a number of lightly reinforced structural walls. The longitudinal reinforcement content in these walls was too low to transfer sufficient tension force across a primary crack to ensure that secondary flexural cracks would form. The consequence of this was that only a single crack opened up with a very limited length where yielding of reinforcement developed on each side of the crack. In a number of cases this led to failure of the reinforcement (PGC, Gallery Apartments (see sections 2 and 6.5.1 of Volume 2). It should be noted that the reinforcement content did satisfy the then current design standards and some revision of this requirement is necessary. Many other examples occurred where elongation of beams led to wide cracks forming in and around floors containing precast units. In some cases this led to load paths between floors and lateral-force-resisting elements being broken.

The detailing used in the Clarendon Tower building had the design intent of limiting yielding to diagonally reinforced zones in the mid-span region of relatively short beams. This detail amplified plastic hinge rotation in the beams, which led to amplified elongation of the beams. Extensive cracking of the floors, with detachment of the floors from the beams and damage to the support zones of the precast floor units, was the result. The detailing in the diagonally reinforced zones of the beams also caused high strain concentrations in a short length of reinforcement in the region where it was bent down to form the diagonals (see section 6.3.5 of Volume 2).

The Hotel Grand Chancellor was a case where the building had different strengths for seismic displacement to the east and west, which violated one of the basis concepts for the seismic analysis of buildings. The result was that during the February earthquake the building progressively displaced towards the west, greatly increasing the lateral displacement of the structure. The failure occurred in an inadequately confined and proportioned structural wall. How much the progressive increase in lateral displacement contributed to the collapse cannot be determined (see section 3 of Volume 2).

Our conclusion from the evidence we have considered about building performance in the Canterbury earthquakes is that structural designers of buildings where seismic considerations dominate the structural design requirements need to have a good basic understanding of the fundamental requirements for design, and of the assumptions inherent in seismic analysis. In addition, the designer needs to have a good grasp of the strut and tie approach to design, together with the compatibility and load path requirements for concrete and steel structures.

The current arrangements for assessing and ensuring professional competence are very reliant on competence assessment in practice areas that are defined in wide terms. Further, while the building regulatory system has a role to play in rejecting inadequate building designs, there are no formal protections in place other than those that arise under the CPEng and IPENZ codes of ethics to ensure structural engineers do not move outside the proper sphere of their professional competence. It is not in fact necessary to be a CPEng, a member of IPENZ (or the holder of an engineering degree) to design a building.

Our Inquiry into the failure of the CTV building has also given rise to concerns about the ability of the regulatory system to function adequately in processing building consents for complex structures. In respect of some of the identified design defects in the CTV building, we had evidence from experienced structural engineers that it would not have been reasonable to expect the CCC checking engineer to have noted the problem. This is disquieting in the context of a regulatory regime in which councils, as building consent authorities, have the legal duty of ensuring that building designs approved for construction comply with legal requirements. Although the Building Code is performance-based, designers continue to place reliance on New Zealand Standards to comply with the objectives and requirements of the Code. The relevant Standards have become complex documents. At the same time, methods of analysis, during the design phase, of the likely structural performance of buildings in earthquakes have become more sophisticated, a trend that is likely to continue. In the Royal Commission's view, placing sole reliance on the building consent authority to ensure that the designs of complex structures are sound and comply with legal requirements is unwise.

Overall, the evidence that we have heard and considered had led us to the view that there should be greater assurance that complex buildings, whose failure in an earthquake could lead to loss of life, will be adequately designed to minimise that risk. Our proposal for the role of a Recognised Structural Engineer, addressed in section 4.4.5 below, responds to these concerns.

4.4.5 Competency for complex structures

There was unanimous agreement by panel participants and substantial agreement in submissions provided to the Royal Commission that: (a) CPEng provides an acceptable entry level qualification to the structural engineering profession; (b) on-the-job learning is critical to developing the skills and expertise of engineers; and (c) those engineers who engage in the design and analysis of complex structures, or the approval or review of plans of such structures, should be required to achieve a higher level of qualification to do so. Qualification may be educational or experiential, although most likely it will be a combination.

The Royal Commission agrees with this approach. Buildings whose failure in an earthquake poses a significant risk of loss of life should be designed by the most capable of engineers, in the interests of public safety. We therefore are of the view that the law should provide for "Recognised Structural Engineers" who have acknowledged expertise in structural design, with a specified role in respect of complex structures. A partial analogy can be made to the mechanism in place, under section 149 of the Building Act 2004, for engineers providing certificates in relation to dam safety assurance programmes. As a pre-requisite, an engineer providing such a certificate must be a "Recognised Engineer", which is defined as someone having no financial interest in the dam concerned, who is registered under the CPEng Act, and who has "the prescribed qualifications" and "the prescribed competencies". Regulation 5 of the Building (Dam Safety) Regulations 2008 contains the prescribed competencies envisaged by the Act. The Royal Commission recommends extending this approach to provide for a Recognised Structural Engineer, with a specified and mandatory role in the design of some buildings.

Such engineers would either design (or supervise the design) of complex structures of the kind we have identified in section 3 of this Volume. They would have prescribed qualifications and prescribed competencies. In our opinion, a CPEng seeking to become a Recognised Structural Engineer should be able to demonstrate competence through a mixture of higher level education, experience, and training. The prescribed qualifications and competencies for Recognised Structural Engineers should be a more specific prescription of the qualifications and competencies of the role, suitable for inclusion in a specific regulation. This set of qualifications and competencies should be developed by MBIE in consultation with CPEC, IPENZ, SESOC and the New Zealand Society for Earthquake Engineering (NZSEE).

This proposal should, if implemented, address some of the concerns raised in submissions and in the hearing on the education and training of engineers. It would:

- ensure that design plans for higher risk structures are certified by an engineer who is competent in the appropriate practice area;
- require assessment of a candidate to become a Recognised Structural Engineer to focus more strongly on earthquake and structural engineering, thereby requiring a greater depth of education. This could well encourage education providers to offer appropriate block courses that are targeted at working engineers;
- encourage engineers to undertake appropriate continuing professional development courses; and
- ensure that the technical skills and relevant principles that underpin sophisticated modern software programmes for building design are well understood.

In section 3 of this Volume, we describe the kinds of buildings in which we consider Recognised Structural Engineer should be involved. We discuss the process by which designs of these buildings, certified by such engineers, should be submitted for approval to a building consent authority.

Recommendations

We recommend that:

178. The Institution of Professional Engineers New Zealand (as the Registration Authority) should publish on the Chartered Professional Engineer register information about a Chartered Professional Engineer's area of practice and any other information that may further inform consumers of engineering services of the competence of individual engineers, under section 18(1)(d) of the Chartered Professional Engineers of New Zealand Act 2002.
179. There should be ongoing provision of post-graduate continuing education for engineers through the provision of block courses, mentoring within engineering firms and courses suitable for those who are working.
180. The universities of Auckland and Canterbury should pursue ways of increasing the structural and geotechnical knowledge of civil engineers entering the profession.
181. Legislation should provide for Recognised Structural Engineers to be responsible for the certification of the design of complex buildings as described in Recommendations 162–168.
182. The Ministry of Business, Innovation and Employment should develop prescribed qualifications and competencies for "Recognised Structural Engineers" in consultation with the Chartered Professional Engineers Council, the Institution of Professional Engineers New Zealand, the Structural Engineering Society New Zealand and the New Zealand Society for Earthquake Engineering. These prescribed qualifications and competencies should be a more specific prescription of the qualifications and competencies of the role, and require more extensive design experience of the type required for the design of complex structures than that required for a Chartered Professional Engineer. These should be included in an appropriate regulation.

4.5 Current ethical rules

Engineers that are registered as either CPEng or IPENZ members are subject to those bodies' codes of ethics. Engineers that are not registered as either CPEng or IPENZ members are not covered by the code of ethics or by any other regulatory oversight, including complaints and disciplinary mechanisms.

4.5.1 CPEng Code of Ethical Conduct and IPENZ Code of Ethics

Section 40(1)(c) of the CPEng Act requires the Registration Authority to have rules containing a code of minimum standards of ethical conduct for CPEngs. The current ethical rules are set out in Part 3 of the CPEng Rules (rules 43-53). Included are general obligations to society, general professional obligations, obligations to employers and clients, and obligations to other engineers.

In order to be registered as a CPEng, an engineer must agree to be bound by the Rules as amended from time to time (section 8(c) of the CPEng Act). Members of IPENZ are required to observe its Code of Ethics. Both codes provide the same obligations, obliging the engineer to:

(i) take reasonable steps to safeguard health and safety;

(ii) have regard to reasonably foreseeable effects on the environment;

(iii) act with honesty, objectivity, and integrity;

(iv) not misrepresent competence;

(v) not misrepresent membership/CPEng status;

(vi) inform others of consequences of not following advice;

(vii) not promise, give, or accept inducements;

(viii) not disclose confidential information;

(ix) not misuse confidential information for personal benefit;

(x) disclose conflicts of interest;

(xi) not review other engineers' work without taking reasonable steps to inform them and investigate.

The IPENZ Code is accompanied by specific guidance from IPENZ that describes what engineers need to do to meet the particular clause of the Code. The CPEng Code does not contain such guidance.

The Royal Commission has not been persuaded that there is a problem or material weakness in the codes of ethics for CPEngs and for IPENZ members. We are comforted that both codes are identical. It is not clear why guidance is provided for the clauses of the IPENZ Code, but not for the CPEng Code. The Royal Commission acknowledges that a code should not spell out specific actions to be taken, but nevertheless clarification to remove any ambiguity is appropriate. In this regard, arising out of the evidence that it has heard during the Inquiry, the Royal Commission considers it desirable that attention be given to the following matters:

- the test for taking action should be well understood by engineers – i.e. ensuring public health and safety;
- it should be understood that each clause in the codes of ethics stands alone and no one clause can override another. In the case of a perceived conflict between two or more clauses, the question as to which clause should carry most weight in the circumstances presented should be a carefully considered matter of judgement; and
- reporting obligations of engineers when a structure has been identified that presents a risk to health and safety. There should be clarity as to the point at which an obligation of a reviewing engineer to report is extinguished, and where the accountability for addressing the matter and rectifying any weaknesses rests.

4.5.2 Complaints and disciplinary mechanisms

Any person can lay a complaint with IPENZ as the Registration Authority alleging that a CPEng or an IPENZ member has breached either or both codes of ethics. IPENZ can undertake an investigation of a CPEng or IPENZ member on its own motion.

Sections 20–38 of the CPEng Act prescribe the process for complaints and discipline, and the practice for the making of complaints, their investigation and determination by IPENZ as the Registration Authority, and rights of appeal to CPEC. Grounds for making disciplinary orders against CPEngs are set out in section 21 of the CPEng Act. The statutory provisions are supplemented by more detailed provisions in the CPEng rules. Under section 21 of the CPEng Act, a disciplinary order may be made if the Registration Authority is satisfied that a Chartered Professional Engineer:

> (a) has been convicted, whether before or after he or she became registered, by any court in New Zealand or elsewhere of any offence punishable by imprisonment for a term of 6 months or more if, in the Authority's opinion, the commission of the offence reflects adversely on the person's fitness to practise engineering; or
>
> (b) has breached the code of ethics contained in the rules; or
>
> (c) has performed engineering services in a negligent or incompetent manner; or
>
> (d) has, for the purpose of obtaining registration or a registration certificate (either for himself or herself or for any other person),—
>
> (i) either orally or in writing, made any declaration or representation knowing it to be false or misleading in a material particular; or
>
> (ii) produced to the Authority or made use of any document knowing it to contain a declaration or representation referred to in subparagraph (i); or
>
> (iii) produced to the Authority or made use of any document knowing that it was not genuine.

IPENZ rule 11 provides the complaints and disciplinary mechanism for its members. It largely replicates the CPEng mechanism for filing complaints, their hearing and determination. Complaints may be made against an IPENZ member for the following reasons:

- incompetence (a pattern of unsatisfactory work);
- negligence (insufficient care in a particular instance); or
- unethical practice (in breach of the IPENZ Code of Ethics and other codes of ethics administered by IPENZ (e.g. CPEng Code of Ethical Conduct).

Disciplinary penalties (set out in section 22 of the CPEng Act) include: removal of registration, and prohibition of application for re-registration before the expiry of a specified period; suspension of registration for a period of no longer than 12 months or until the person meets specified conditions relating to the registration; censure; and a fine not exceeding $5,000. The disciplinary order made is notified in the register. The Registration Authority must also notify the order and the reasons for it to the Registrar of Licensed Building Practitioners appointed under the Building Act 2004 and may publicly notify the order in any other way that it thinks fit (section 22(5)).

IPENZ has advised that over the past three years there have been 25–30 complaints made against engineers of which 15–20 relate to CPEngs and around 10 are about IPENZ members. This represents a significant increase over a total of around 11 complaints in each of 2004 and 2005. Since 2003 there have been 14 disciplinary committee hearings (of both IPENZ and CPEng cases), of which nine resulted in disciplinary orders.

4.5.3 Codes of ethics – reporting potentially unsafe structures

Rule 43 of the CPEng Code and clause 1 of the IPENZ Code require an engineer to take reasonable steps to safeguard the health and safety of people, in the course of his or her engineering activities. In the course of reviewing an existing building, a CPEng or an IPENZ member would need to consider the obligations imposed by rule 53 of the CPEng Code and clause 11 of the IPENZ Code. These provide an obligation on engineers not to review other engineers' work without taking reasonable steps to inform them and investigate.

In the course of our Inquiry into the failure of the CTV building we have had to consider the question of what should happen after a reviewing engineer has discovered a critical structural weakness in a building. We have discussed in section 2.4 of Volume 6 the circumstances in which Mr Hare of Holmes Consulting Group discovered a critical structural weakness in the CTV building in 1990. This was reported to Alan Reay Consultants Ltd (ARCL), but not to "an authority", because it appeared that ARCL intended to act on the advice received.

Mr Trevor Robertson (CPEng, IntPE, FIPENZ), a Senior Principal of Sinclair Knight Merz, working in the role of Principal Structural Engineer, was called to give expert evidence on issues relevant to the ethical conduct and reporting obligations owed by engineers in such circumstances. Mr Robertson has over 40 years' experience as a structural engineer, and has twice been appointed by IPENZ as a member of ethical complaints investigating committees. We accept that Mr Robertson has expertise in the field of ethical standards for engineers.

He emphasised that the responsibility for the structural integrity of a building, consistent with the codes and engineering knowledge at the time of the building's design, lies with the designer. It was his evidence that if a reviewing engineer determines the design to be non-compliant with the codes under which it was designed, and particularly where this non-compliance may be critical to, or at least compromise, the building's integrity, then the reviewing engineer should report this to his or her client and advise the original designer (if known and still practising) about the discovery and its implications. The reviewing engineer should then satisfy him or herself that the designer accepts responsibility for attending to the matter.

If the designer does not take responsibility, then clause 6 (in Part 3) of the IPENZ Code and rule 48 of the CPEng Code oblige the reviewing engineer to make the person not accepting that advice aware of the possible consequences of that action. The text does not indicate that the reviewing engineer should go any further. However, Mr Robertson said that, in such circumstances, the reviewing engineer may then choose to report the matter to "an authority".

In the Royal Commission's view, further action should be taken if it appears that the original designer will not act on the reviewing engineer's advice. To facilitate this, we recommend that the reviewing engineer be required to advise both the territorial authority and IPENZ of the review findings if the reviewing engineer identifies the building to be a risk to health and safety, regardless of whether the initial design engineer accepts the responsibility for rectifying it. The regulatory authorities and IPENZ could then be expected to pursue appropriate responses and rectification of the matter with the initial designer of the building, or take other action, in the interests of public health and safety.

4.5.6 Review of plans

Building consent authorities are in possession of much potentially useful information about the performance of engineers in preparing building design documentation in support of consent applications.

In section 3 of this Volume, we have recommended that MBIE be able to require consent applications for complex structures to be provided to it by building consent authorities. Review of these plans might indicate whether there is a need for additional guidance or compliance document updates, and assist the identification of training and education needs.

Recommendations

We recommend that:

183. The Institution of Professional Engineers New Zealand should provide clarification of its codes of ethics, in respect of the following matters:

    a the test for taking action should be well understood by engineers – i.e. ensuring public health and safety;

    b each clause in the codes of ethics stands alone and no one clause can override another. In the case of a perceived conflict between two or more clauses, the question as to which clause should carry most weight in the circumstances presented should be a carefully considered matter of judgement; and

    c reporting obligations of engineers when a structure has been identified that presents a risk to health and safety. There should be clarity as to the point at which an obligation of a reviewing engineer to report is extinguished, and where the accountability for addressing the matter and rectifying any weaknesses rests.

184. Part 3, clause 6 of the Institution of Professional Engineers New Zealand Code of Ethics and Rule 48 of the Chartered Professional Engineers Rules of New Zealand (No 2) 2002 should be amended to provide for an obligation to advise the relevant territorial authority and the Institution of Professional Engineers New Zealand in circumstances where a structural weakness has been discovered that gives rise to a risk to health and safety.

4.6 Professional and learned societies in civil engineering

4.6.1 Functions of learned societies

A particular feature of the engineering profession is the existence of learned societies dedicated to particular fields of engineering practice. Membership of the individual societies largely consists of engineers practising within the society's particular field. Many engineers are multi-disciplinary and are therefore members of more than one society.

These learned societies include the Structural Engineering Society New Zealand (SESOC), New Zealand Society for Earthquake Engineering (NZSEE), New Zealand Concrete Society (NZCS), New Zealand Geotechnical Society (NZGS), New Zealand Timber Design Society, Cement and Concrete Association of New Zealand (CCANZ), the Heavy Engineering Research Association (HERA) and others.

The learned societies often play key roles for their particular specialty by facilitating communication of new research through publishing journals, sponsoring academic works and holding regular conferences. The societies are also active in preparing and publishing advice and guidance, often called "practice notes" for their members, but which they make publicly available on their websites.

4.6.2 Functions of professional societies

The engineering profession's professional society is IPENZ, with services targeting the entire engineering profession including civil, mechanical, electrical, and chemical engineering. IPENZ has around 13,000 members, including CPEngs, engineering students, technicians and technologists, and business people who are not engineers but have made worthwhile contributions that impact on the engineering profession.

IPENZ's role includes maintaining a database of members, providing guidance and practice notes on engineering best-practice, and providing career development support, employment brokerage and activities that support the standing of the engineering profession in the community. IPENZ is also the Registration Authority for the CPEng quality mark and undertakes activities in support of that function. IPENZ audits the quality and scope of university degrees and accredits them for the purposes of the Washington Accord, as well as for membership of IPENZ itself.

4.6.3 Contribution to identifying best-practice in engineering

The learned societies make a considerable contribution to the development of standards that define engineering requirements. Throughout the course of its Inquiry, the Royal Commission has been reminded of the significant amount of voluntary time and effort provided by the leaders of the societies on an ongoing basis. This has been valuable to the longer-term integrity of the construction sector in New Zealand, and the country owes them a debt of gratitude.

The learned societies often contribute formally through participation in working groups to inform the development or review of New Zealand Standards. The societies are active in identifying the need for particular Standards to be updated or for new Standards or guidance to be created, and often take it upon themselves to do so through the voluntary efforts of their members. The output from this work may later be submitted to Standards New Zealand or MBIE. However, in many cases it is not progressed in that quarter, and instead becomes informal best-practice guidance (for example, practice notes) to the profession that may be applied at the practitioner's discretion. The informal updating of best-practice guidance is valuable, but not without risk.

4.6.4 Risks

The absence of a regulatory process means there is no review and oversight of the informal best-practice guidance except by the members themselves. Guidance is not mandated for uptake across the industry as a whole, but rather adoption becomes a discretionary matter for each engineer or firm. There is no monitoring of compliance with informal best-practice guidance and so it is not known to what extent it is being followed.

As a result there is likely to be inconsistent application across the industry, especially if the associated incremental costs are sizeable. These costs are borne by the consumer and flow through to the national economy. In the absence of a formal regulatory process, they are neither assessed for reasonableness in the context of the risk being managed, nor are they applied evenly. Indeed, if the additional costs are sizeable, consumers may seek out practitioners who will not implement the new practices or follow the guidelines.

In addition, we note that an informal process of voluntary contributors may not include standard contractual processes such as identifying and managing conflicts of interest that members may hold through their private interests in the construction industry.

It is not clear whether the current model that relies on voluntary contribution from society members is sustainable. In the hearing on the organisation of the engineering profession, the Royal Commission was advised by society executives that it was becoming considerably more difficult to enlist well qualified voluntary contributors to support their initiatives. In the meantime, despite the risks involved, we consider that the societies should continue to advance engineering knowledge and practice as they have done in the past.

As discussed in section 3, the Royal Commission recommends that MBIE develops a policy and regulatory work programme to identify priorities and clarify roles. The Ministry should make contact with and be aware of the views held by the engineering profession's learned societies as to where best-practice guidance is required, and the appropriate process for achieving it, including the need to codify any parts of the advice in the form of regulations or standards and whether the issues should be led by the regulator, or left to the societies.

4.6.5 Coordination between engineers and other construction industry practitioners

The professional and learned societies play an important role in facilitating information sharing, debate, and problem resolution across the various disciplines within the engineering profession. Of particular interest to the Royal Commission is the need for more collaboration between structural and geotechnical engineers. The societies also endeavour at times to bring engineers together with other intersecting professions within the construction industry (for example, constructors, manufacturers and architects).

The Royal Commission notes submissions by MBIE, CCANZ and NZCS that in their view there is a reasonable level of constructive engagement between the different branches of engineering. However, there is scope for more collaboration between architects and engineers. The Royal Commission recommends that MBIE, IPENZ and the New Zealand Registered Architects Board (NZRAB) actively encourage more interaction between engineers and architects.

The Royal Commission has received an interim report provided by a working group to the NZRAB. The working group was commissioned by the NZRAB to report, among other things, on lessons able to be learned from the Canterbury earthquakes. While the NZRAB has, at the time of writing this section, yet to consider the recommendations in the interim report, we consider a number of the recommendations are consistent with evidence heard, or advice provided in submissions during our Inquiry. These include:

- emphasis being placed on structural engineers and architects working together closely at an early stage of design and clients being made aware of the benefits of early engagement of a structural engineer;
- ensuring architects and structural engineers are jointly involved in seismic design features of structures;
- reviewing the structural engineering content of both tertiary degrees in architecture and in competencies required for initial registration as an architect;
- reviewing the provision of "core practice development to ensure the issues identified following the Christchurch earthquakes are addressed for all architects wishing to apply for continuance of their registration".

The importance of early engagement between architects and structural engineers was also noted by Mr David Sheppard, National President of the New Zealand Institute of Architects, at the Royal Commission's hearing on the organisation of the engineering profession.

In section 3 of this Volume, we have recommended the development of a Structural Design Features Report, which is required to be signed by an appropriately qualified engineer prior to the submission of a building consent application. This will help ensure the early engagement of structural engineers in the design of structures. However, we also consider that the professional societies for the respective professions should work to ensure greater collaboration between the two professions. MBIE, as the regulator, clearly has an interest in New Zealand having well-designed buildings and should support this engagement.

Recommendation

We recommend that:

185. The Institution of Professional Engineers New Zealand, the New Zealand Institute of Architects, and the New Zealand Registered Architects Board, supported by the Ministry of Business, Innovation and Employment, should work together to ensure greater collaboration and information sharing between architects and structural engineers.

References

1. Institution of Professional Engineers New Zealand Incorporated. (2011). *Standards and Regulation for Building Construction in New Zealand.* Christchurch, New Zealand: Canterbury Earthquakes Royal Commission.

2. Letter from Dr Shayne Gooch, Dean of Engineering and Forestry, University of Canterbury to Justice Mark Cooper, Commission Chairperson, Canterbury Earthquakes Royal Commission, 2 August 2011.

3. Letter from Professor Michael C R Davies FRSE, Dean, The University of Auckland to Justice Mark Cooper, Commission Chairperson, Canterbury Earthquakes Royal Commission, 1 August 2011.

4. The University of Canterbury advised that of approximately 800 students enrolled in the first year of the BE(Hons) degree, about 450 meet the criteria each year to progress to professional years (letter dated 3 August 2011).

Section 5: Canterbury Regional Council and Christchurch City Council – management of earthquake risk

5.1 Approach under the Terms of Reference

The Terms of Reference for the Inquiry require the Royal Commission to consider the nature of the land associated with the representative sample of buildings in the Christchurch Central Business District (CBD). The Terms of Reference also require consideration of 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. A matter specifically raised, in paragraph (d)(iv), is the role of local government in developing and enforcing legal and best-practice requirements.

We have reported on the results of that aspect of our Inquiry in earlier Volumes of our Report. We note in particular that in section 4 of Volume 1, we concluded that liquefaction and the loss of strength of surface soils as a consequence of the February earthquake had adverse effects on the foundations of buildings in the Christchurch CBD (see section 4.9 of Volume 1). Further, in Volume 2, we identified liquefaction as having contributed to the damage sustained by particular buildings, namely the Christchurch Town Hall (discussed in section 6.1.3 of Volume 2); Craigs Investment House at 90 Armagh Street (section 6.3.1); the Victoria Square apartment building at 100 Armagh Street (section 6.4.1); and the IRD building at 224 Cashel Street (section 6.5.3).

In Volume 1, we made a number of recommendations designed to ensure a greater understanding and knowledge about ground conditions, so as to ensure better foundation performance not only in the Christchurch CBD, but in CBDs in other New Zealand cities (Recommendations 3–9 in Volume 1, section 1). We also made recommendations in relation to foundation design where there is a risk of liquefaction or significant soil softening in an earthquake (Recommendations 10–13), foundation design generally (Recommendations 14–20 and 25–31) and ground improvement (Recommendations 21–24). These recommendations all reflect the existence of, and assume, urban land zonings that permit development of substantial buildings in New Zealand's cities.

Existing urban zones are the consequence of the processes and procedures followed under the Resource Management Act 1991 (RMA) and, before its enactment, the various Town and Country Planning Acts. The Royal Commission's Terms of Reference generally have a focus on building performance and consequently, we have not thought it appropriate to inquire in great detail about the decision-making process that has led to the existing zoning patterns in Christchurch, which set the scene for the widespread damage experienced as a consequence of liquefaction and lateral spreading in the eastern suburbs of Christchurch. Nor have we done anything other than note the fact that land that might be subject to liquefaction was developed in the Christchurch CBD in exercise of development rights conferred many years previously.

As already noted, the Terms of Reference have a focus on building performance. We observe however that by paragraph (e), the Royal Commission is empowered to inquire into "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". We considered it would be inappropriate to ignore entirely the fact there has been unnecessary damage and costs sustained as a result of the development of land subject to a risk of liquefaction without duly considering that risk. Apart from anything else, an understanding of how that has been possible under the existing regulatory system might enable better outcomes in the future. We are required by the Terms of Reference to make recommendations on any measures necessary or desirable to prevent or minimise the failure of buildings in New Zealand due to earthquakes likely to occur during their lifetime. These aspects of the Terms of Reference are not restricted to the consequences of the Canterbury earthquakes, and they require us to consider buildings in central business districts throughout the country.

As a result of our Inquiry into these matters we conclude that there should be better provision for the acknowledgment of earthquake and liquefaction risk in the various planning instruments that are made under the RMA. One way of minimising failure of buildings in the future is to ensure that the land on which they are developed is suitable for the purpose. Having said that, we need to emphasise that it is not possible to predict with any certainty when an earthquake will occur and, in reality, the public and private investment in the country's cities is such that it is not realistic to redirect development away from the existing central business districts. However, when zoning for new development areas is contemplated, we consider that it would be appropriate for the risks of liquefaction and lateral spreading to be taken into account.

5.2 Introduction

As part of our Inquiry into the Canterbury earthquakes, the Royal Commission has examined whether the Canterbury Regional Council (CRC) and the Christchurch City Council (CCC) took appropriate actions to meet their responsibilities and obligations under the RMA to manage earthquake risk. Two issues were of particular interest to the Royal Commission. The first was whether the CRC and the CCC sufficiently considered earthquake risk (including the risks of liquefaction and lateral spreading) by using available information when they made decisions about the zoning of land. The second was whether information about earthquake risk was provided to the public in a meaningful way.

In late 2011, the Royal Commission asked resource management policy consultant, Mr Gerard Willis to advise us about the manner in which earthquake risk had been dealt with in the relevant planning documents of the CRC and CCC. He was the author of a report[1] (by Enfocus Ltd) "Management of Earthquake Risk by Canterbury Regional Council and Christchurch City Council – Obligations and Responses under the RMA" that was provided to the Royal Commission in November 2011. It was published on the Royal Commission's website and submissions from the public were invited. Submissions were received from the CCC and CRC, as well as the Ministry of Business, Innovation and Employment (MBIE) and from one individual. The content of this section is based on Mr Willis' advice, our consideration of the submissions received and the knowledge we have gained over the course of our investigation.

We set out the following key observations:

- Mr Willis considers that there was a lack of clarity about the division of responsibility between the CRC and CCC for managing earthquake risk and about their policies for earthquake risk mitigation. However, this did not have a material impact on the quality of hazard planning for the Canterbury region over the past decade.
- In its planning documents, the CRC considered its role to be that of information provider and it was active in commissioning research and disseminating information. Controlling land use for the mitigation of earthquake hazard, among other things, was a function that was devolved to the CCC. The CRC did however retain a role in the control of land use where the impact of the activity or land use had an effect on water quality.
- Technical information received over time by the local authorities relevant to the assessment of earthquake and liquefaction risks was often not consistent, but had since 2005 indicated a low risk of material damage resulting from an earthquake.
- The CRC and CCC did not have a good understanding of the consequences of an earthquake, but sought to inform themselves by commissioning reports and advice, on the risk and the management of it. However, they seldom used information held in making decisions on land zoning, land development and/or subdivision and building consent applications.
- Most urban zonings were confirmed well before information was available on earthquake risk in the Canterbury region (i.e. prior to 1977), although development of many parts did not occur until after that time. It is problematic to revisit zoning decisions when development rights have subsequently been acquired.
- It is difficult to decline applications for subdivision consent when they are in accordance with the use for which the land was zoned. At the time of subdivision consent, earthquake risks should be addressed through consents being conditional upon either land remediation or the adoption of specific construction techniques.
- Geotechnical reports should be required where earthquake risk is identified. This requires local authorities to better understand earthquake risks and consequences affecting both the region and specific development proposals.

In its submission to the Royal Commission, the CCC advised it had made a number of changes to its practices to better manage earthquake-related risks in the future. These are intended to place a greater emphasis on understanding risk in various parts of Christchurch, and on seeking and understanding geotechnical information associated with proposed plan changes and land use and subdivision consent applications. The CRC's submission to the Royal Commission confirmed its intention to continue to adopt a collaborative and partnership-focused approach in which information relating to natural hazards and environmental issues is obtained and made available for territorial authorities and other relevant organisations.

In mid-2011, the Ministry for the Environment published the "Canterbury Fact Finding Project" report, jointly prepared by Hill Young Cooper and the Resource Management Group Ltd[2]. The project looked at the extent to which information on liquefaction and lateral spreading hazards was known, available and factored into planning and development processes in the period from 1977 to the present. We have considered it in the course of our investigation of these matters.

5.3 The Resource Management Act 1991

The requirements and obligations for regional and territorial authorities in the management of natural hazards are set out in the RMA. Section 2 of the RMA defines natural hazard as meaning "any atmospheric or earth or water related occurrence (including earthquake…) the action of which adversely affects or may adversely affect human life, property, or other aspects of the environment". We consider that the reference to earthquake would include liquefaction, but the latter is covered in any event as an "earth or water related occurrence that adversely affects property". The key obligations for regional councils and territorial authorities are:

- regional councils have the functions of: establishing, implementing and reviewing objectives, policies and methods to achieve integrated management of the natural and physical resources of the region (section 30(1)(a)); preparing objectives and policies in relation to any actual or potential effects of the use, development and protection of land which are of regional significance (section 30(1)(b)); and the control of the use of land for the purpose of the avoidance or mitigation of natural hazards (section 30(1)(c)(iv));
- territorial authorities have the function of the control of any actual or potential effects of the use, development or protection of land, including for the purpose of the avoidance or mitigation of natural hazards (section 31(1)(b));
- the Regional Policy Statement (RPS) must state, among other things, the local authority (which could be the regional council, or a territorial authority) responsible for specifying the objectives, policies and methods for the control of the use of land to avoid or mitigate natural hazards (section 62(1)(i));
- both regional councils and territorial authorities must keep records of natural hazards to the extent that they consider appropriate for the effective discharge of their functions (section 35(5)(j));
- a territorial authority may refuse to grant a subdivision consent, or may grant a consent subject to conditions, if it considers that the land in question is likely to be subject to material damage by certain natural hazards (section 106).

The RMA obligations of the CRC, including the demarcation of responsibilities between itself and the CCC, are recorded in its RPS for Canterbury. Regional councils across New Zealand published their first Regional Policy Statements in 1998, with the next generation of Statements publicly notified in 2011, and in the case of Canterbury, not yet fully operative. The functions of territorial authorities are recorded in their district plans. For Christchurch, the district plan relevant to our Inquiry is the 2005 Christchurch City Plan (the City Plan).

The Enfocus Ltd report characterises and comments on the initial RPS (1998) documents publicly notified around the country as reflecting "the early stages of RMA implementation and the bedding in of regional council and territorial authority relationships". With respect to the Canterbury RPS (1998) and the City Plan (2005), Mr Willis observed that:

- the Canterbury RPS focused on hazards generally, with no discussion of managing or mitigating earthquake risk as a specific natural hazard. However, the shortcomings of the Canterbury RPS (1998) do seem to have been acknowledged by the Proposed RPS for Canterbury, which was publicly notified in June 2011. The latter includes a broader suite of policies that provide guidance and direction to those exercising control over land use and explicitly addresses earthquake risk (policy 11.3.3 – Earthquake faults, chapter 11 of the proposed RPS, entitled "Natural Hazards");

- the absence of clear specification of policies relating to earthquake risk mitigation and division of responsibility between the CRC and CCC did not of themselves have a material effect on the quality of hazard planning in the region over the past decade, or lead to any failure in the mitigation of earthquake risk; and
- the CRC and CCC recognised earthquake risk, understood their functions and were broadly carrying out those functions.

Sections 6 and 7 of the RMA relate to managing the use, development, and protection of natural and physical resources, and identify matters of national importance and other matters that should be recognised when exercising RMA functions and powers. The Minister for the Environment has appointed an independent technical advisory group to review these sections including whether they can be improved to give greater attention to managing natural hazards, noting the RMA issues arising from the Canterbury earthquakes.

So far as we are aware, the report[3] from the technical advisory group has not, at the time of writing, been formally considered by the Government. However, we consider that there is a clear case for ensuring that regional and district plans are framed having appropriate regard to the potential effects of earthquakes and liquefaction (and other natural hazards), and the function of processing resource and subdivision consents should also be performed in a way that recognises that risk. The Royal Commission recommends that changes should be made to the principles in sections 6 and 7 of the RMA to bring the management of natural hazards into the list of things that should be considered when councils are exercising functions under the RMA.

5.4 Regional and district planning

5.4.1 CRC: Canterbury Regional Policy Statement (1998)[4]

An RPS sets out objectives, policies and methods to address a region's resource management issues. One of its goals is to achieve integrated management of the region's resources. As noted earlier, one of its key requirements is to identify the division of RMA functions between the regional council and the territorial authorities. In the absence of specification, the regional council is responsible.

Under the RPS (1998), the CRC saw its regulatory role as limited to:

- control of land use in circumstances where the impact of the activity or land use results in effects such as on water quality; and
- processing resource consent applications within its regional council functions (i.e. to control the taking, use, damming or diversion of water, the discharge of contaminants, etc.).

It was also noted in the Enfocus Ltd report that according to the RPS (1998) and a letter to the Royal Commission dated 31 August 2011[5], the CRC saw its role in earthquake risk mitigation as mainly that of an information provider. In accordance with this role, the CRC was active in commissioning research for the identification and assessment of natural hazards in Canterbury and information dissemination.

All remaining earthquake risk mitigation obligations (e.g. control of any actual or potential effects of the use, development or protection of land, including for the purpose of the avoidance or mitigation of natural hazards) were expected to be met by the CCC although this demarcation of responsibility was not clearly articulated in either the RPS (1998) or the 2005 City Plan.

A key question is whether it was prudent for the CRC to remove itself from taking any role in the control of the use of land, even when the primary responsibility is held by the CCC and notwithstanding the RMA provides for it to do so legitimately (see section 30(1)(c) of the RMA). This is a matter for the CRC, and not one on which the Royal Commission has formed any view. It should be noted that a regional council is not prevented from acting, irrespective of whether it has passed primary responsibility to the territorial authority. Mr Willis notes that best-practice hazards planning guidance ("Planning for the Development of Land on or Close to Active Faults", 2003, issued by the Ministry for the Environment[6]) is for a regional council to continue to have a role in terms of providing policy guidance as to where and how risk ought to be avoided or mitigated, and in advocating that policy in district plan preparation and individual resource consent applications. We observe that it is plain from our consideration of the seismicity of Canterbury that the risk is one that should be considered and understood at the regional level, and we consider that regional councils should take a lead role in this respect. In Auckland, the Auckland Council should ensure that it has the appropriate understanding of the seismicity of the area it administers.

5.4.2 Christchurch City Plan[7]

The 2005 City Plan recognised the CCC's obligations to control land use for the purpose of avoiding or mitigating natural hazards and to consider declining land subdivision applications where it considered land is likely to be subject to a natural hazard. It recognises earthquake risk but does so at a high level and does little to provide for ways and means of managing it. The focus of the City Plan is information provision and an expectation that earthquake risk issues will be addressed by controlling building construction through the requirements of the Building Act 2004.

The City Plan does not identify liquefaction zones, nor does it include a requirement for a risk assessment or set out risk standards, although there is a policy that refers to limiting development in areas of "moderate to high risk". Mr Willis was not aware of any other district plans that contain such information although he comments that this does not mean that the risk assessment has not been undertaken. One reason for its omission in Christchurch may be to do with the high variability of soils so that precise and definitive information on liquefaction risk may require geotechnical investigation on each individual property in a zone.

5.5 Technical information

5.5.1 Advice sought

The CRC and CCC have sought advice and have been provided with information relating to earthquake risk on numerous occasions since 1995. In its submission to the Royal Commission, the CRC identifies some 26 reports that it commissioned relating to earthquake hazard and risk investigations in the Canterbury region. We note the following key reports:

- Geology of the Christchurch Urban Area, GNS Science 1992. (It is unclear what led to the provision of this report).
- Earthquake Hazard and Risk Assessment: Probabilistic Seismic Hazard Assessment, GNS Science 1999 (revised 2007), commissioned by the CRC.
- A report commissioned by the CRC in 2004 from Beca Carter Hollings and Ferner Ltd, which provided specific advice on the liquefaction risk in Christchurch. A peer review of the Beca report was commissioned by the CCC from URS New Zealand to determine whether it could be used as a basis for information to be placed on Land Information Memoranda (LIMs) for the purposes of notifying the public of earthquake risk. However, the peer review highlighted the many caveats and qualifications noted in the Beca report and the limited information on which the liquefaction maps in the report had been prepared. This led to an approach to the provision of data on LIMs that referred to the indicative nature of the liquefaction zones. This would signal the need for a detailed geotechnical site investigation at the time of significant new development.
- In 2005 the CRC commissioned Opus International Consultants Ltd (Opus) to develop an earthquake risk assessment methodology in order to assist the quantification of the risk of an event or range of possible events. The model was not fully developed and was overtaken by a government-funded GNS Science and NIWA project to develop a national risk assessment model (Riskscape) that covered much of what was intended for the Opus model. Christchurch was chosen as a pilot for the project. We understand from Mr Willis that Riskscape is still under development although an early version is available.
- Estimated Damage and Casualties from Earthquakes affecting Christchurch, GNS Science 2005, commissioned by CCC.

5.5.2 Earthquake and liquefaction risk assessments

Meaningful advice on earthquake risk was not available until the early to mid-1990s. Mr Willis comments that much of the advice received over time by the CRC and CCC was not entirely consistent but would have created a picture of relatively low liquefaction risk. A letter from GNS Science to the CCC in 2003[8] advised that, among other things, the majority of houses in Christchurch would not be affected by liquefaction, even during the strongest shaking (MM8)[9] likely to be experienced.

At the public hearing on territorial authorities' earthquake-prone policies on 14 November 2011, the Royal Commission heard from Mr Peter Mitchell, General Manager of Regulation and Democracy Services at the CCC. Mr Mitchell has been employed by the CCC for 28 years. Counsel assisting the Royal Commission explored with Mr Mitchell the extent to which information about earthquake risk had been conveyed to the Council. In particular, reference was made to a report prepared by members of the Group managed by Mr Mitchell on the subject of "Earthquake-prone Buildings Policy, Dangerous Buildings and Insanitary Buildings Policies", that was on the agenda for the Council's meeting of 15 December 2005. That report had a section headed "Earthquake Risk For Christchurch City" in which reference was made to a GNS Science report of 2003[10]. Counsel explored a number of statements in the GNS Report with Mr Mitchell, as follows (the statements in this report are in quotation marks).

- "Early studies of the seismic hazards affecting Christchurch indicated a relatively high seismic hazard level, only marginally lower than that of Wellington". Counsel asked Mr Mitchell if that had been the view within the Council about the earthquake risk in Christchurch at that time. Mr Mitchell said he did not think that Councillors had been advised of that observation of GNS Science. His evidence was that the clearly acknowledged risk to the City was from the Alpine fault" although he noted that the smaller fault lines on the Canterbury side of the Southern Alps could be triggered. But he did not consider the CCC viewed the risk as "marginally lower than Wellington", despite the reference in the report.
- "More recent studies, however, indicate a lower level of hazard that is more in keeping with the location and activity of all earthquake sources (i.e. both close-in distributed seismicity sources and known fault sources). The recent results are also more consistent with the historical record than the earlier ones, and have been used as the basis of our study. During its 160-year recorded history Christchurch has not experienced MM8 shaking, and only occasionally have spot intensities of MM7 been observed". Mr Mitchell expressed the view, which he thought would have been shared by other members of staff, that the seismic risk in Christchurch was "at the lower end of the scale" but that earthquakes could happen based on the past history of earthquakes in the region.

In addition, counsel referred Mr Mitchell to a subsequent GNS Science report[11], dated May 2005, in which the following was said:

> This indicates that Christchurch lies in an intermediate seismicity zone, some distance from a zone of high activity. However, known earthquake sources, in particular the Ashley, Springbank and Pegasus fault zones, are present within the region and are large enough and close enough to cause significant damage throughout the city.

Counsel assisting asked Mr Mitchell if that was a view that the CCC would have held and been aware of for some time. He answered "no, not before receipt of that advice at that time". He noted this advice underpinned the CCC's earthquake-prone buildings policy adopted in 2006 (we discuss the CCC's earthquake-prone buildings policies in section 4.2 of Volume 4).

Notwithstanding the advice received, the CCC appeared to have taken a view that the risk of material damage resulting from an earthquake was low. The passive earthquake-prone buildings policy that was adopted in 2006 did not contain timeframes for the upgrading of the City's earthquake-prone buildings.

Mr Mitchell's evidence contributes to the view formed by the Royal Commission that while some local authorities were active in commissioning advice on seismic risk, they were less attentive to applying it in a meaningful way in decision making. It is not clear why the CCC would adopt earthquake-prone buildings policies that were passive in nature given the level of risk in Christchurch as described by GNS Science advice, referred to above. One reason may have been the ambiguity in terms such as "intermediate seismicity" and lack of understanding of the consequences of an earthquake less than the reportedly occasional magnitude 7 events. However, it was, in the Royal Commission's view, incumbent upon the CCC to take measures to understand the information to inform its policies.

Mr Willis notes in the Enfocus Ltd report that planning and decision making was based on the more recent GNS Science advice, and one consequence was that the risk to domestic buildings was not considered sufficient to warrant geotechnical reports being required as a rule.

5.6 Earthquake risk management

We discuss in this section the means by which the CRC and CCC undertook earthquake risk management in planning and decision making, with respect to:

- land zoning;
- land development and/or subdivision (i.e. when actions are taken relying upon on earlier zoning decisions); and
- building consent applications and in particular the inclusion of geotechnical information and the imposition of construction and/or soil remediation conditions on applicants as a condition of consent.

Mr Willis reviewed the nature and extent of information sought, received and disseminated to the public on earthquake risk by the CRC and CCC and the degree to which the information was used to advocate for earthquake risk mitigation.

As noted earlier, the CRC had largely placed responsibility for the control of the use of land for the purpose of the avoidance or mitigation of natural hazards with the CCC. Mr Willis expresses the view in the Enfocus Ltd report that the CRC has performed well in the collection of information relating to earthquake risk, identification and assessment of earthquake risk and the dissemination of information on earthquake risk to the public. His report notes that the councils had endeavoured to inform themselves through the commissioning of risk assessment models in the mid-2000s (e.g. the Opus model and Beca report). He comments that "Canterbury's experience with risk assessment appears at least as well advanced as other major centres in New Zealand…".

However, it appears that the CRC has seldom used the information in its possession on earthquake risk to either inform decision making or to advocate for earthquake risk management in planning processes. It has considered liquefaction and lateral spread risks to be issues for territorial authorities to address at the time of subdivision and development. For example, for the then Proposed Change 28 to the City Plan (this was a private plan change publicly notified on 22 November 2008 relating to land at Ferrymead[12] that was subsequently approved in October 2009), the CRC's submission did not raise concerns about liquefaction risk, which has proved to have been an important issue.

Proposed Change 1[13] to the RPS was for the extension of the urban limits to make available additional land for greenfields urban development. It was notified in July 2007, revoked in 2011 and instead incorporated as Chapter 12A of the RPS authorised by the Canterbury Earthquake Recovery Act 2011. It was based on Proposed Change 1 but updated as a result of the Canterbury earthquakes. Section 12A took effect from 17 October 2011. The CRC did not raise the issue of earthquake risk in the planning process, on the basis that this was a matter for territorial authorities to manage when processing subdivision and development consents. In its appeal to the Environment Court[14] against the Pegasus Bay development (Waimakariri District), liquefaction risk was raised, but as a matter secondary to the main issues of transportation and growth management.

Neither has the CCC been active in using information it has sought to inform decision making, by triggering the need for applicants to provide earthquake risk information as part of their plans, and if necessary to take remedial action on the land, or otherwise mitigate the risk.

As noted earlier, the CCC sought a peer review of the Beca report (that had been commissioned by the CRC) on liquefaction risk as it was considering placing notice of the risk on LIM reports for individual properties. As a result of the limitations of the Beca report, the information on LIM reports communicated only the indicative nature of liquefaction zones, rather than a more detailed articulation of the risk.

5.7 Zoning

The "Canterbury Fact Finding Project" report recorded that most urban zonings (at least within that report's study area)[15] were confirmed well before (i.e. pre-1977) information of substance became available on earthquake hazard risk in the region (in the 1990s). However, notwithstanding zoning decisions taken before 1977, development of many parts did not occur until after that time, often not until the mid-1980s and in some cases in the 2000s. Therefore intervention to ensure earthquake risk was managed might have occurred at the time development and/or subdivision plans were submitted for consent.

The following key issues associated with zoning decisions taken by the local authorities were raised in the Enfocus Ltd report:

- the CRC does not prohibit areas being developed due to risk of liquefaction and lateral spreading; rather, it takes the view that land can be remediated, and construction methods can be used in many cases that will enable land development to occur. The Enfocus Ltd report questions that approach, suggesting it may be more appropriate to prohibit development of such areas if other areas not susceptible to the risk can be substituted. The CRC however notes that "liquefaction is but one factor amongst several that must inform strategic planning for urban growth…". The CRC further notes that development of a site subject to liquefaction risk requires that risk to be mitigated in order for subdivision land development to proceed, which is a matter for a territorial authority to address;
- where zoning decisions were made prior to substantial information about earthquake risk being available in Canterbury (before the early to mid-1990s), it was very difficult for local authorities to use zoning to manage natural hazards. To do so, they would need to revisit zoning decisions, which could adversely affect those holding development rights; and
- in more recent times, but prior to the Canterbury earthquakes, the risk of earthquakes and their consequences have seldom been taken into account by CCC in zoning decisions either by requiring the risk to be addressed as a matter of course or by imposing conditions for managing the risk prior to development. Proposed Change 1 to the RPS (1998) for the expansion of the urban limits to make additional land available for greenfields urban development took into account the natural hazards of flooding and sea level rise, but not liquefaction risk. However, there have been exceptions, notably for Plan Change 28 relating to zoning at Ferrymead. In that case, the risk of liquefaction and lateral spreading was assessed at the CCC's request, with the result that all business-zone development is to be set 50 metres back from the bank of the Heathcote River.

5.8 Subdivision consents

The "Canterbury Fact Finding Project" report states that there was no evidence of the use of section 106 of the RMA (refusing subdivision if the land is likely to be subject to material damage) or its predecessor, section 274 of the Local Government Act 1974, to deny subdivision consent. Neither was there any evidence of active consideration of liquefaction and lateral spreading risk in this context. Mr Willis endorsed the reviewers' comment that "the planning reality is that once land is zoned for a specific use it is very difficult for a council to refuse a subdivision that enables that use to establish".

The CRC has advised the Royal Commission of its view that natural hazard risk is a matter for territorial authorities to consider at the point of subdivision and development. This was supported by MBIE in its submission to the Royal Commission. However, the City Plan, at least in the case of the eastern suburbs, indicated reliance on building construction standards under the Building Act 2004 to manage earthquake risk, rather than on the RMA consenting processes. MBIE considers that "the Building Act should only be relied on for the building related aspects of managing earthquake risk and to ensure that building work does not cause the land to become a natural hazard (as defined in the Building Act)".

Regardless of the lack of flexibility resulting from earlier zoning or subdivision and development decisions, it remained incumbent on the CCC to ensure that any earthquake risk associated with the land subject to development and/or subdivision plans was considered, and where necessary managed and/or mitigated. Where appropriate, applicants should have been required to undertake geotechnical investigations or other hazard assessment and if, as a result of those inquiries, risk was found to be present, mitigation actions should have been identified and monitored.

5.9 Geotechnical investigations and consenting requirements

Since the 2005 GNS advice to the CCC indicated low risk of liquefaction and lateral spreading to domestic buildings, the CCC decided that residential dwellings would not require changes in foundation engineering requirements and consequently there was no need to have a geotechnical survey. Evidence suggests that the CCC has seldom imposed conditions requiring site remediation or stabilisation prior to consents for developments or subdivisions being approved.

Advice from Mr Ian McCahon, geotechnical engineer, during the Royal Commission's hearing on soils and foundations was that the CCC would normally seek a geotechnical report for the consenting of a major structure in central Christchurch.

Mr Willis advised that it is not clear within CCC processes as to what triggers CCC consent officers to require geotechnical and/or hazard assessments and information although he notes that a different approach has been taken since 22 February 2011. The CCC advised in its submission to the Royal Commission that it is giving increased attention to the need for geotechnical investigations to accompany consent applications and is requiring them for subdivision consent applications. In addition, it is imposing conditions, such as requiring specific foundation design, where appropriate. We also note that, as discussed in Volume 1, the CCC commissioned Tonkin & Taylor Ltd to carry out a substantial study of the subsurface conditions in the Christchurch CBD[16].

5.10 Future measures

In its submission to the Royal Commission, the CCC advised that:

- the City Plan is being reviewed to ensure that it gives effect to the RPS, as well as reviewing its objectives, policies and rules regarding earthquake risks;
- it is using the detailed information regarding possible risk areas that has been made available since the Canterbury earthquakes to commission, or require, geotechnical assessment for plan change requests and land use consent applications when this is considered necessary;
- the Canterbury Earthquake Recovery Authority's liquefaction maps are being used to identify risk levels across various zones of Christchurch to determine whether a hazard is likely (for the purposes of the CCC being in a position to decline a subdivision application under section 106 of the RMA where that is considered the appropriate response). The CCC advises that all applications for subdivision consents will now be required to be accompanied by a geotechnical report and that the content of reports must be consistent with MBIE guidelines for geotechnical investigation and assessment of subdivisions; and
- internal guidance to CCC officers has been developed regarding the assessment of section 106 matters, which should result in a consistency of approach taken on resource consent applications.

We record our view that these are appropriate procedures for the CCC to adopt.

The CRC also provided a submission in which it noted its intent to continue to work collaboratively with the territorial authorities and other key partner organisations with respect to the development and sourcing of information relating to natural hazards and environmental information. The CRC notes that it has "carried out a whole range of investigative work to assist in the mitigation of the risks of earthquakes across the Canterbury region" and that "most of these investigations were undertaken in collaboration with the relevant territorial authorities to ensure that the information collected would be useful to them in carrying out their legislative responsibilities".

The CRC considers that there would be merit in creating "a far stronger and clearer legislative definition and framework" for the roles of regional and territorial authorities in land use control issues.

5.11 Conclusions

The Royal Commission draws the following conclusions:

- the process by which land was initially zoned for urban development by the CRC, followed by subdivision and/or development that was granted consent by the CCC, was sufficient to meet legislative requirements historically applicable. However, the weaknesses in the process were the lack of compelling earthquake risk advice prior to the early to mid-1990s when land was zoned by the CRC, and the lack of action from the CCC to require developers to investigate the geotechnical risks associated with their development plans;
- the importance of information gathering on natural hazards affecting a region is not limited to its collection and use to assess risk, but also to understanding the consequences of the risk materialising and identifying risk mitigation and management strategies for implementation where appropriate;
- where information on natural hazards and their consequences is unclear, local authorities should seek further clarification to satisfy themselves that they are sufficiently aware of the hazards to enable effective planning;
- The RMA should be amended, and processes under it adopted, to ensure that the risks posed by earthquakes are appropriately considered in decisions about zoning and land use; and
- Regional councils and territorial authorities should ensure that they are adequately informed about the seismicity of their regions and districts. Since seismicity should be considered and understood at a regional level, regional councils should take a lead role in this respect, and provide policy guidance as to where and how liquefaction risk ought to be avoided and mitigated. In Auckland, the Auckland Council should perform these functions, as it has regional responsibilities following the abolition of the Auckland Regional Council.

Recommendations

We recommend that:

186. Sections 6 and 7 of the Resource Management Act 1991 should be amended to ensure that regional and district plans (including the zoning of new areas for urban development) are prepared on a basis that acknowledges the potential effects of earthquakes and liquefaction, and to ensure that those risks are considered in the processing of resource and subdivision consents under the Act.

187. Regional councils and territorial authorities should ensure that they are adequately informed about the seismicity of their regions and districts. Since seismicity should be considered and understood at a regional level, regional councils should take a lead role in this respect, and provide policy guidance as to where and how liquefaction risk ought to be avoided or mitigated. In Auckland, the Auckland Council should perform these functions.

188. Applicants for resource and subdivision consents should be required to undertake such geotechnical investigations as may be appropriate to identify the potential for liquefaction risk, lateral spreading or other soil conditions that may contribute to building failure in a significant earthquake. Where appropriate, resource and subdivision consents should be subject to conditions requiring land improvement to mitigate these risks.

189. The Ministry for the Environment should give consideration to the development of guidance for regional councils and territorial authorities in relation to the matters referred to in Recommendations 186–188.

References

1. Enfocus Ltd (November 2011). *Management of Earthquake Risk by Canterbury Regional Council and Christchurch City Council.* Christchurch, New Zealand: Canterbury Earthquakes Royal Commission.

2. Hill Young Cooper and Resource Management Group Ltd. (August 2011). *Canterbury Fact Finding Project*. Retrieved from http://www.mfe.govt.nz/issues/Canterbury-earthquakes/fact-finding-full-report.pdf

3. Technical Advisory Group. (February 2012). *Report of the Minister for the Environment's Resource Management Act 1991 Principles Technical Advisory Group*. Retrieved from http://www.mfe.govt.nz/publications/rma/tag-rma-section6-7/tag-rma-section6-7.pdf

4. Canterbury Regional Policy Statements. The 1998 RPS and the notified 2011 RPS can be found at Environment Canterbury's website http://ecan.govt.nz/our-responsibilities/regional-plans/rps/Pages/Default.aspx

5. Letter from Environment Canterbury to the Canterbury Earthquakes Royal Commission, 31 August 2011.

6. Ministry for the Environment (2003). *Planning for the Development of Land on or Close to Active Faults.* Retrieved from http://www.mfe.govt.nz/publications/rma/planning-development-active-faults-dec04/html/

7. The Christchurch City Plan can be found at http://www.cityplan.ccc.govt.nz/NXT/gateway.dll?f=templates&fn=default.htm

8. Letter from GNS Science to Building Control Manager, Christchurch City Council, 14 July 2003.

9. MM refers to Modified Mercalli Intensity scale which is a measure of how ground shaking from an earthquake is perceived by people and how it affects the built environment at a particular location. In any given earthquake, the Mercalli Intensity will depend on the location of the observer and will usually be greatest nearer to the earthquake's hypocentre. This information is complementary to "static" magnitude estimations (M_L, M_W, M_e) that describe the energy released at the earthquake source rather than the ground shaking experienced in surrounding areas. These terms are explained in Volume 1, of our report at section 2.6.1.

10. Cousins, J. (2003). *Earthquake, volcano and tsunami risks to property of Christchurch City Council*. Lower Hutt, New Zealand: Institute of Geological and Nuclear Sciences.

11. Cousins, J. (2005). *Estimated damage and casualties from earthquakes affecting Christchurch*. (Client Report 2005/2007). Report prepared for the Christchurch City Council. Lower Hutt, New Zealand: Institute of Geological and Nuclear Sciences.

12. City Plan Change 28 was a private plan change relating to around 29.9 hectares of land known as 'Kennaway Park' at Ferrymead. Information can be found at http://resources.ccc.govt.nz/files/CityPlan-OperativePlanChange28.pdf

13. Information about Proposed Change 1 to the RPS for the development of greater Christchurch can be found at http://ecan.govt.nz/our-responsibilities/regional-plans/rps/Pages/proposed-change-no-1.aspx.

14. As advised verbally by the CRC to Mr Willis in the course of the review.

15. The study area consisted of the residential component of the eastern suburbs of Christchurch and Brooklands, Kaiapoi, and Kairaki/The Pines.

16. Tonkin & Taylor Limited (2011). *Christchurch Central Geological Interpretative Report*. Christchurch, New Zealand: Christchurch City Council.

Appendix 1: New Zealand Society for Earthquake Engineering Guidelines

Guidelines for carrying out structural assessments of the seismic resistance of existing building stock can be broadly defined in two categories, involving increasing levels of thoroughness and accuracy.

Building assessments in preparing for future earthquakes	Building assessments post-earthquake
Initial Evaluation Procedure	Overall Damage Survey or Initial assessment
Desktop study	Rapid Assessments (Levels 1 and 2)
Detailed Assessment	Detailed Engineering Evaluation

Confusion can arise in the types of structural assessments being used. There are many similarities and some overlap in these types of assessments.

1. Building assessments in preparing for future earthquakes

It is important to have agreed procedures for evaluating the seismic resistance of existing building stock. Their purpose is to determine the susceptibility of buildings to damage from earthquakes and to devise and implement structural improvements that will bring all buildings up to or above a predetermined minimum level. Evaluation of an existing structure requires not only knowledge of the current design standards but also additional experience of the potential limitations that older buildings have. These include material properties, methods of construction, potential weakness in form, and judgement on the significance of observed damage. The result of this evaluation is often expressed as a percentage of the standard required for a new building.

In 2006, the New Zealand Society for Earthquake Engineering released guidelines for assessing whether a building is potentially earthquake-prone to assist local authorities to prepare for future earthquakes. These guidelines are *Assessment and improvement of the structural performance of buildings in earthquakes: including Corregendum No 1.*

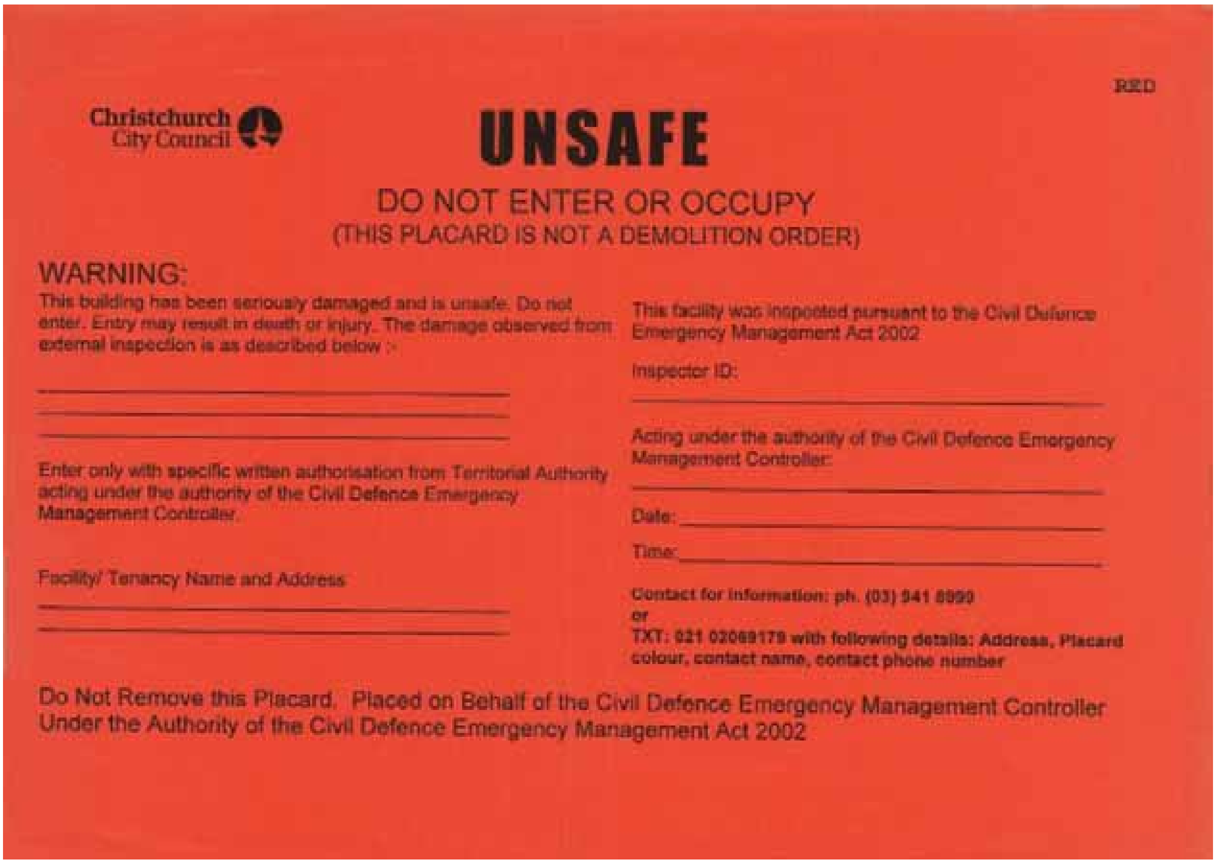
2. Building assessments post-earthquake

In the immediate aftermath of a major earthquake, the Overall Damage Survey and rapid assessments are used as a basic sifting method for identifying the worst of the immediate hazards. For rapid assessments, evaluators do a quick visual assessment of the type and extent of a building's structural damage, and on that basis can post a green (inspected), yellow (restricted use), or red (unsafe) placard. The percentage new building standard is **not** calculated in this process.

The Detailed Engineering Evaluation is a similar assessment to a Detailed Assessment, with the difference being that there is an assessment on the effects of the damage caused by the recent earthquakes. A percentage new building standard may be calculated in this process.

In 2009, the New Zealand Society for Earthquake Engineering released the latest version of its guidelines for building safety evaluations. These guidelines are *Building Safety Evaluation During a State of Emergency: Guidelines for Territorial Authorities.*

Appendix 2:
The Christchurch City Council placards



RED

Christchurch City Council

UNSAFE

DO NOT ENTER OR OCCUPY

(THIS PLACARD IS NOT A DEMOLITION ORDER)

WARNING:

This building has been seriously damaged and is unsafe. Do not enter. Entry may result in death or injury. The damage observed from external inspection is as described below :-

Enter only with specific written authorisation from Territorial Authority acting under the authority of the Civil Defence Emergency Management Controller.

Facility/ Tenancy Name and Address

This facility was inspected pursuant to the Civil Defence Emergency Management Act 2002

Inspector ID:

Acting under the authority of the Civil Defence Emergency Management Controller:

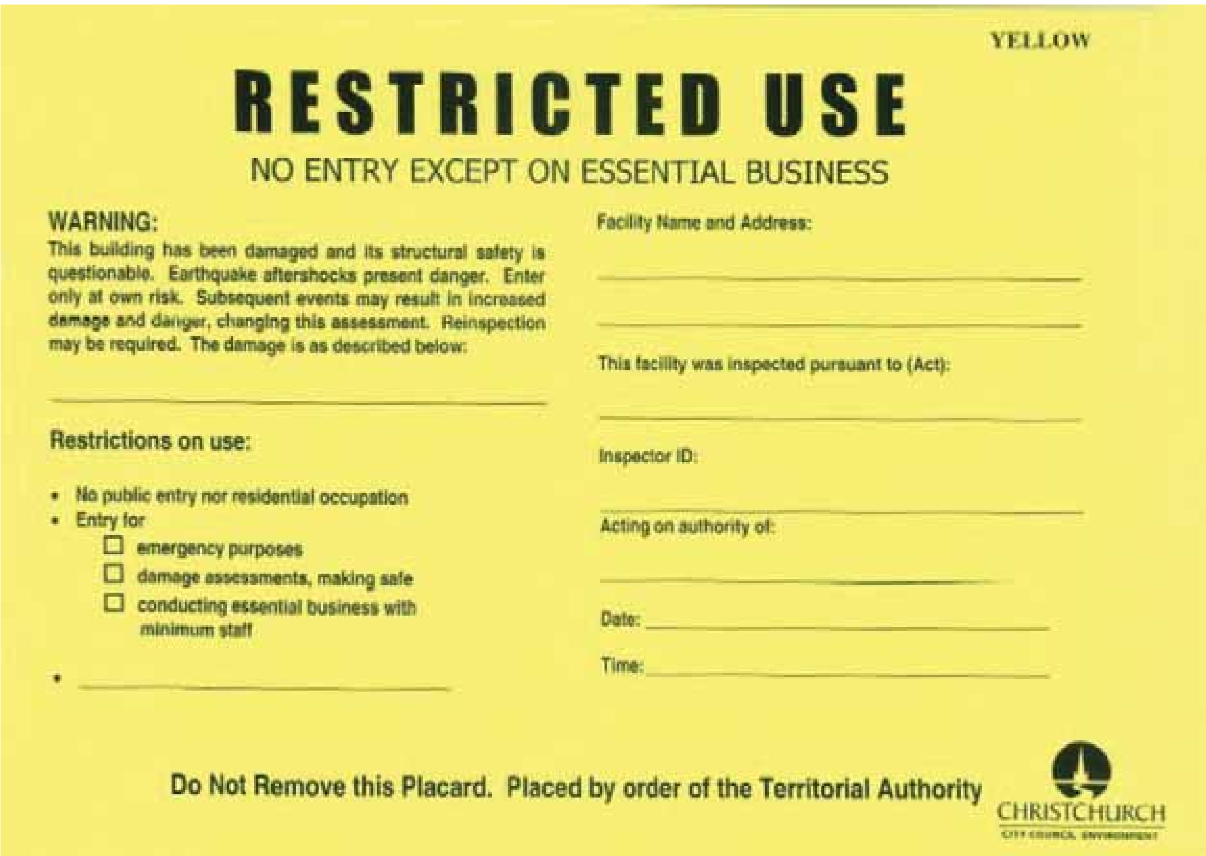
Date:

Time:

Contact for information: ph. (03) 941 8999
or
TXT: 021 02069179 with following details: Address, Placard colour, contact name, contact phone number

Do Not Remove this Placard. Placed on Behalf of the Civil Defence Emergency Management Controller Under the Authority of the Civil Defence Emergency Management Act 2002

Figure 17: The red placard used in Christchurch after the Canterbury earthquakes (source: Christchurch City Council)



YELLOW

RESTRICTED USE

NO ENTRY EXCEPT ON ESSENTIAL BUSINESS

WARNING:
This building has been damaged and its structural safety is questionable. Earthquake aftershocks present danger. Enter only at own risk. Subsequent events may result in increased damage and danger, changing this assessment. Reinspection may be required. The damage is as described below:

Restrictions on use:

- No public entry nor residential occupation
- Entry for
  - ☐ emergency purposes
  - ☐ damage assessments, making safe
  - ☐ conducting essential business with minimum staff
- ______

Facility Name and Address:

This facility was inspected pursuant to (Act):

Inspector ID:

Acting on authority of:

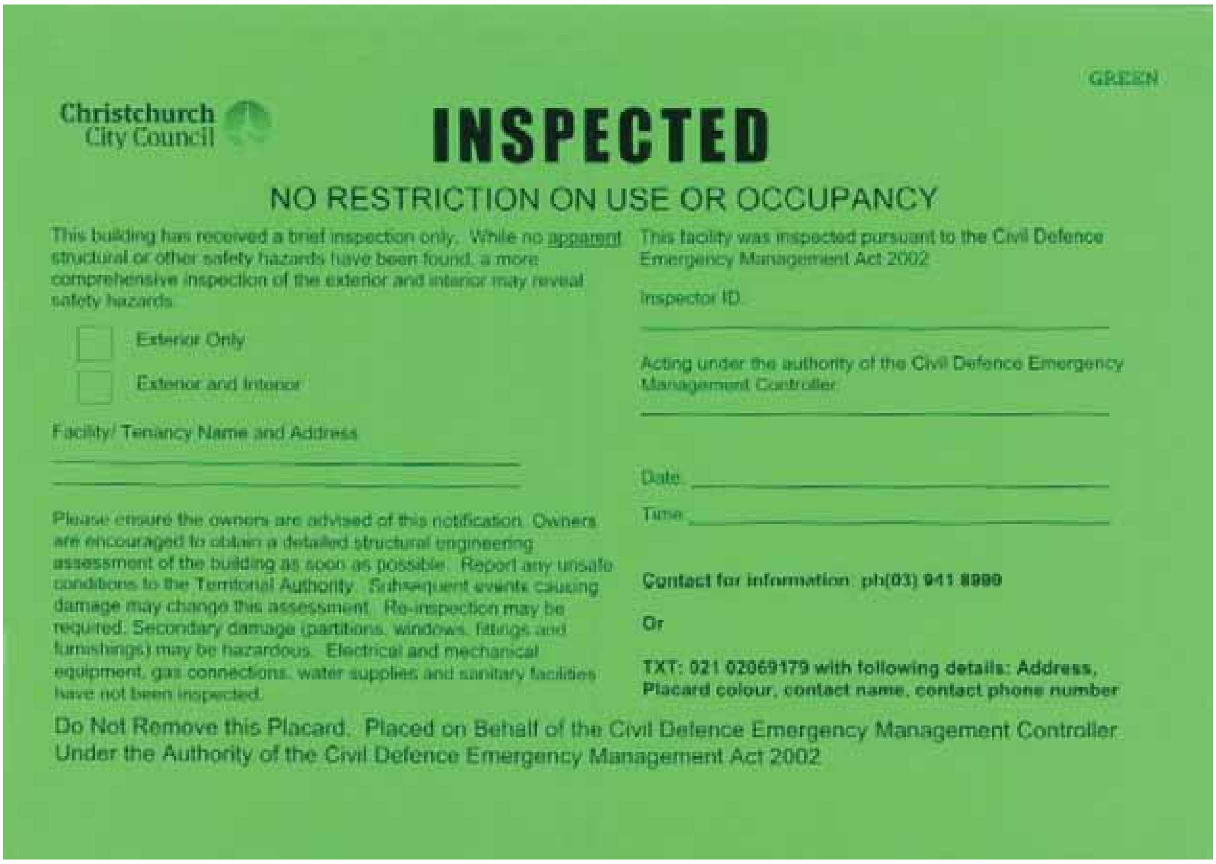
Date:

Time:

Do Not Remove this Placard. Placed by order of the Territorial Authority

CHRISTCHURCH

Figure 18: The yellow placard used in Christchurch after the Canterbury earthquakes (source: Christchurch City Council)



GREEN

Christchurch City Council

INSPECTED

NO RESTRICTION ON USE OR OCCUPANCY

This building has received a brief inspection only. While no apparent structural or other safety hazards have been found, a more comprehensive inspection of the exterior and interior may reveal safety hazards.

☐ Exterior Only

☐ Exterior and Interior

Facility/ Tenancy Name and Address

Please ensure the owners are advised of this notification. Owners are encouraged to obtain a detailed structural engineering assessment of the building as soon as possible. Report any unsafe conditions to the Territorial Authority. Subsequent events causing damage may change this assessment. Re-inspection may be required. Secondary damage (partitions, windows, fittings and furnishings) may be hazardous. Electrical and mechanical equipment, gas connections, water supplies and sanitary facilities have not been inspected.

This facility was inspected pursuant to the Civil Defence Emergency Management Act 2002

Inspector ID

Acting under the authority of the Civil Defence Emergency Management Controller

Date

Time

Contact for information: ph(03) 941 8999

Or

TXT: 021 02069179 with following details: Address, Placard colour, contact name, contact phone number

Do Not Remove this Placard. Placed on Behalf of the Civil Defence Emergency Management Controller Under the Authority of the Civil Defence Emergency Management Act 2002

Figure 19: The green placard used in Christchurch after the Canterbury earthquakes (source: Christchurch City Council)

Appendix 3:
The CPEng Certification Form

Statement by Chartered Professional Engineer in respect of the building at:

(Building Address)...

(Business Name *if applicable*) ....

I, ... (*name*), am a Chartered Professional Engineer (No............,) with relevant experience in the structural design of buildings for earthquake actions.

I have been engaged to provide advice to the owner on the interim securing / strengthening of the above building following the earthquake of 4 September 2010.

I am aware of all the measures taken to secure or strengthen the building (the work) which were carried out by (*Name and contact address of contractor).* ....

....

I have inspected the work on completion and am satisfied on reasonable grounds that:

a. *Structural integrity and performance.* Where the structural integrity and/or structural performance of the building (or part of the building) was materially affected by the Darfield earthquake or any aftershocks to date, interim securing measures have been taken to restore the structural integrity and performance of the building to at least the condition that existed prior to the earthquake of 4 September 2010.

b. *Potentially dangerous features.* Potentially dangerous features on the building such as unreinforced masonry chimneys, parapets and walls have been removed or secured so that their integrity and level of structural performance is consistent with that generally achieved in other parts of the building, and so reduces the danger to people's safety and of damage to other property.

c. *Threat from nearby buildings.* (Delete one if not applicable)

- Protective measures installed on the subject building are sufficient in nature and extent to protect its occupants in the event of collapse of potentially dangerous features on *adjacent or nearby buildings.*
- I have identified *all* potentially dangerous features such as unreinforced masonry chimneys, parapets and walls *on all adjacent or nearby buildings* that have potentially dangerous features which threaten the subject building or its occupants.

  Buildings which I have identified in the above category are:

  i. ....

  ii. ....

  iii. ....
- I have advised the owner of the subject building that approval for resumption of occupancy and use will be subject to Council approval to remove the red or yellow safety notices from the buildings listed above.

Signed .... Chartered Professional Engineer

Date ....

Christchurch City Council Building Evaluation Team - Certification Commercial.doc - Version 1 dated 18 October 2010

Figure 20: The CPEng Certification Form (source: Christchurch City Council, 2011)

Appendix 4: Section 124 notice

Notice under s124(1)(b) of the Building Act 2004 (as inserted by the Canterbury Earthquake (Building Act) Order 2010) for hoarding to restrict entry to a commercial building

DO NOT APPROACH OR ENTER THIS BUILDING

THIS BUILDING IS A DANGEROUS BUILDING UNDER SECTIONS 121 AND 124 OF THE BUILDING ACT 2004

No Entry Is Permitted Without Supervision By A Qualified Engineer

USING OR OCCUPYING THIS BUILDING IS AN OFFENCE PURSUANT TO S128 OF THE BUILDING ACT 2004

Contact the Christchurch City Council Building Recovery Office for approval of any proposed action to remedy the danger: 941-8999 or buildingrecoveryoffice@ccc.govt.nz, Ground Floor Civic Offices, 53 Hereford Street

DO NOT REMOVE THIS NOTICE

Placed by the Christchurch City Council pursuant to s124(1)(b) of the Building Act 2004

ISSUED ON / / (VALID FOR 60 DAYS UNLESS RENEWED BY THE CHRISTCHURCH CITY COUNCIL)

Figure 21: The section 124 notice used in Christchurch after the September earthquake (source: Christchurch City Council)

Appendix 5:
Design features report example

Design Features Report - ***Primary Structure***					
Project:	Aardvark Apartments and Office Complex - Quaketown	Page:	1	of	n
By:	SESOC Structural Design Limited - William Brown CP Eng 1234	Date:	dd	mm	yy
	PO Box 5678 Quaketown : Ph +64 3 456 7890 : williambrown@ssdl.co.nz : www.ssdl.co.nz				

Primary Structure	Design Life	50	Site	Level, on reclamation / steeply sloping etc		
Level / Area:	*Use*	*Structure*	*FRR*	*DL*	*LL*	*SDL*
Roof	No access	RC column / Steel truss / ply diaphragm	0.5	0.5	1.5	0.5
Levels N to 3	Office	RC column / RC beam / PCC floor	2	1.0	2.5	0
Level 2	Retail	RC column / RC beam / PCC floor	2	1.0	2.5	0
Level 1	Retail	RC column / RC beam / PCC floor	2	1.0	2.5	0
Ground	Retail	RC column / RC beam / PCC floor	2	1.0	2.5	0
Basement 1	Car park	RC wall / RC beam / PCC floor	2	1.0	3.0	0
Basement 2	Car park	RC wall / RC beam / PCC floor	2	1.0	3.0	0
Foundations	RC bored piles. 750 and 900mm					

Significant Design Features: 1. Base isolated above Basement 1; 2. Curtain-wall glazing; 3. Etc

Design Standards: 1. AS/NZS 1170 2. NZS 3101 3. NZS3404 4. Etc

Soils and foundations	Founded on:	Fractured greywacke				Ground Floor RL	100.00	
Soil properties	qu = 10	Ø =	0.5	Øeq =	0.8	Water table (max/min)	RL 98.500	RL 95.000
Retaining values	ρs = 100	Ka =	0.5	Ko =	0.8	Kp = 0.8	Seismic design req'd	Yes

Earthquake	1170 / SS	Z =	0.13	Nr Fault	>100km	Soil Cat	C	Analysis	Time History			
Lateral load system:	X-direction (N-S)		RC Frame			Y-direction (E-W)		RC Wall				
Key parameters	Tx =	0.9	μx =	4	Δmax	2.50%	Ty =	0.3	μy =	4	Δmax	1.20%

Wind	Region	A6	Terrain	2	Elev'n	3,456m	Ht, z	18m	VR (m/s)	50	Δmax	100mm				
Md values:	N	0.8	NE	0.8	E	0.8	SE	0.7	S	0.6	SW	0.5	W	0.4	NW	0.3
Any	1.0															
Multipliers:	Terrain, Mzcat	0.6	Shielding, Ms	0.6	Topographic, Mt	0.6										
Directional Site Wind Speeds	Dir 1		Dir 2		Dir 3		Dir 4		Table C1 D limit							
SLS / ULS (m/s)	45	91	46	92	47	93	48	96	L /250							
Wind Pressure Coefficients:	Cpi max	0.6	Cpi min	-0.3	Canopies	1.2										
Cpe wall	Wind	0.9	Lee	0.8	Side	0.7	Cpe roof	Up	0.9	Down	0.8	Cross	0.7			

Snow and Ice	Region	N1	Elevation (m)	1234	Sg =	0.9	S(design) 0.6
Other data							

Creep and Shrinkage	Kp = (2-1.2*As'/As)	Walls	1.2	Floors	1.4	Columns	1
Other data							

Durability	Design Life:	Found'n	50	Structure	50	Roof	15	Cladding	15
Other data									

Serviceability	Floor Prim	L/200	Floor Sec	L/300	Roof Prim	L/100	Roof Clad	L/300	Other	L/300
Transient Vibration:	BRANZ SR14 / Murray method / Allen method within acceptable limits									

Notes:

Design Features Report Jun2010A.xls 1 DFR design by David Hopkins June 2010

Figure 22: Example of a Design Features Report (source: Dr David C Hopkins, submission to the Canterbury Earthquakes Royal Commission, August 2012)

Design Features Report - ***Secondary Structure***

Project:	Aardvark Apartments and Office Complex - Quaketown		Page:	1	of	n
By:	SESOC Structural Design Limited - William Brown CP Eng 1234		Date:	dd	mm	yy
	PO Box 5678 Quaketown : Ph +64 3 456 7890 : williambrown@ssdl.co.nz : www.ssdl.co.nz					

Earthquake - Parts and Portions				*Cp values for parts (g)*			
Level / Area:	*Floor acc'n*	*Part*	*Cp*	*Part*	*Cp*	*Part*	*Cp*
Roof	1.2	Aerial	2.5	Chimney	2.5	PC Panel	2.5
	Insert or delete rows as necessary to cover all relevant levels						
Level 5	1.1	PC Panel	2.5	Equipment	2.5	Lift	2.5
Level 4	1.1	PC Panel	2.5	Equipment	2.5	Lift	2.5
Level 3	1.1	PC Panel	2.5	Equipment	2.5	Lift	2.5
Level 2	0.4	PC Panel	2.5	Equipment	2.5	Ceilings	2.5
Level 1	0.3	PC Panel	2.5	Equipment	2.5	PC Panel	2.5
Ground	0.3	PC Panel	2.5	Equipment	2.5	PC Panel	2.5
Basement 1	0.3	PC Panel	2.5	Equipment	2.5	PC Panel	2.5
Basement 2	0.3	PC Panel	2.5	Equipment	2.5	PC Panel	2.5

Wind Coefficients for Parts					*Cp values for parts*	*(Insert as appropriate)*						
Level / Area:	*$V_{R (h)}$*	*Ht, z*	*Vdes*	*Part*	*Cpn*	*Cpl*	*Cfig*	*Cw*	*C_L*	*Cdyn*	*Cxx*	*Cyy*
Roof	54	20	45	Aerial	0.8	0.4	0.7	0.6	0.5	na	na	na
			Insert or delete rows as necessary to cover all relevant levels									
Level 5	48	18.0	48	Glazing	0.8	0.4	0.7	0.6	0.5	na	na	na
Level 4	44	14.5	44	Glazing	0.8	0.4	0.7	0.6	0.5	na	na	na
Level 3	40	11.0	40	Glazing	0.8	0.4	0.7	0.6	0.5	na	na	na
Level 2	40	7.5	40	Glazing	0.8	0.4	0.7	0.6	0.5	na	na	na
Level 1	40	4.0	40	Glazing, sign	0.8	0.4	0.7	0.6	0.5	na	na	na
Ground	50	0.0	50	Glazing	0.8	0.4	0.7	0.6	0.5	na	na	na

Barriers and handrails				*Top edge (TE)/ Rail (R) / Intermediate(Int)*						*Infill*			
Area	*Part*	*Ht*	Rail Ht	Horz (kN/m)		*Vert (kN/m)*		*Point (kN)*		*Horz (kPa)*		*Point (kN)*	
				Load	*At*	*Load*	*At*	*Load*	*At*	*Load*	*At*	*Load*	*At*
Roof	Barrier	1.6	1.2	1.0	R	1.0	R	0.6	R	0.8	R	0.8	R
				0.5	TE	0.5	TE	0.3	TE	0.5	TE	0.5	TE
Offices	Barrier	1.6	na	1.0	1.2m	0.8	TE	0.8	TE	0.8	TE	0.8	TE
					na		na		na		na		na
Apartments	Barrier	1.2	1.2	1.0	R	0.8	R	0.8	R	0.8	R	0.8	R
				0.5	TE	0.5	TE	0.5	TE	0.5	TE	0.5	TE
Car Parks	Barrier	0.3	0.3	3.0	R	0.0	R	4.0	R	na	na	na	na
				0.5	TE	0.5	TE	0.5	TE	0.5	TE	0.5	TE
Other	Barrier	1.6	1.2	1.0	R	0.8	R	0.8	R	0.8	R	0.8	R
				0.5	TE	0.5	TE	0.5	TE	0.5	TE	0.5	TE

Notes: 1. For further detail refer Drawings S101 to 108 inclusive.

Figure 22 continued: Example of a Design Features Report

Canterbury Earthquakes
Royal Commission
Te Komihana Rūwhenua o Waitaha

Canterbury Earthquakes
Royal Commission

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