ENG.ATC.0002.1

DRAFT 13 August 2012

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# BUILDING SAFETY EVALUATION AFTER THE FEBRUARY 22, 2011 CHRISTCHURCH, NEW ZEALAND EARTHQUAKE: OBSERVATIONS BY THE ATC RECONNAISSANCE TEAM


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## BUILDING SAFETY EVALUATION AFTER THE FEBRUARY 22, 2011 CHRISTCHURCH, NEW ZEALAND EARTHQUAKE: OBSERVATIONS BY THE ATC RECONNAISSANCE TEAM

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**August 2012**

**Acknowledgements**

A number of organizations and individuals assisted the ATC reconnaissance team and provided much useful information. ATC wishes to acknowledge their valuable assistance and generous help.

Organizations:

Canterbury Earthquake Recovery Authority (CERA)
Christchurch City Council, Environmental Policy and Approval Unit (CCC EP&A)
New Zealand Department of Building and Housing (DBH)
Institution of Professional Engineers of New Zealand (IPENZ)
New Zealand Ministry of Civil Defense & Emergency Management (MCDEM)
New Zealand Society for Earthquake Engineering (NZSEE)
Structural Engineers Association of California (SEAOC)
Structural Engineers Association of Washington (SEAW)

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| Helen Ferner | BECA |
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| John Hare | Holmes Group |
| Jason Ingham | University of Auckland |
| Janiele Maffei | California Earthquake Authority |
| Laurence Kornfield | City and County of San Francisco |
| Anne Mackenzie | Build Green |
| Steve McCarthy | CCC EP&A |
| Lisa Moon | University of Adelaide |
| Kelvin Newman | CCC EP&A |
| Patrick Scofield | CCC EP&A |
| Richard Sharpe | BECA |
| Marko Schotanus | Rutherford & Chekene/SEAOC |
| John Snook | CERA |
| Mike Stannard | DBH |
| Dave Swanson | Reid Middleton/SEAW |
| Fred Turner | California Seismic Safety Commission |
| Peter Wood | MCDEM and NZSEE |

Note on Images:

Photographs in the report were taken by the reconnaissance team unless otherwise noted. Sources for other illustrations are indicated where shown.

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# 1. Introduction

The Applied Technology Council (ATC) sent a small reconnaissance team to Christchurch, New Zealand to observe the building safety evaluation process following the magnitude 6.2 February 22, 2011 earthquake. This report summarizes the reconnaissance team's observations, findings, and recommendations regarding postearthquake building safety evaluations.

## 1.1 Background and Purpose of ATC Team Visit

The defacto national standard in the U.S. for the safety evaluation of buildings after an earthquake is the ATC-20 document *Procedures for the Postearthquake Safety Evaluation of Buildings* (ATC, 1989a). This was first published by ATC in 1989. It has been used after a number of U.S. earthquakes, including the 1989 Loma Prieta and 1994 Northridge earthquakes in California, and the 2001 Nisqually, Washington earthquake.

ATC is planning to update the ATC-20 document, and sent the reconnaissance team to Christchurch to observe the safety evaluation process and meet with individuals involved in the safety assessments after the February 2011 earthquake. ATC believed that the earthquake presented an important opportunity for study, particularly for regions considered to have moderate seismicity. The earthquake was very damaging. New Zealand conducted postearthquake safety evaluations using methodologies similar to those in ATC-20. Building stock in Christchurch is similar to that of California and other parts of the United States. 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.

The team was in Christchurch from June 26, 2011 to July 1, 2011. The primary purpose of the visit was to observe the damage, to examine the safety evaluation process used, and to learn from the New Zealand experience. In particular, the team sought to identify implications for U.S. practice, to identify needed research and development for the future, and to gain ideas for the future improvement of ATC-20.

The breadth of the team's review included: (1) the preparations for building safety evaluation, including training of evaluators; (2) the preparations to manage the safety evaluations, including making provisions for needed supplies and useable postearthquake working places; (3) the conduct of the safety assessments, including office tracking of the results sent from the field; (4) the immediate emergency measures taken, such as cordoning, barricading, falling hazard abatement, shoring and building stabilization; and (5) the transfer of the responsibility for repairs to engineers hired by owners, including written criteria for the repairs.

## 1.2 Reconnaissance Team

The ATC reconnaissance team consisted of Bret Lizundia, Ronald Gallagher, and Jim Barnes. Mr. Lizundia was the ATC Board President at the time of the trip, and he is a practicing structural engineer and a principal at Rutherford & Chekene in San Francisco. Mr. Gallagher, a structural engineer with R. P. Gallagher Associates in Oakland, California, was in charge of preparation of the original ATC-20 documents (ATC, 1989a and 1989b). He was formerly Senior Vice President with URS/John A. Blume & Associates, San Francisco. At the time of the reconnaissance trip, Mr. Barnes was a civil engineer with the California Emergency Management Agency (Cal EMA) in Sacramento, California and where he was responsible for coordinating and overseeing the earthquake safety assessment program in California. He is now with the California Department of Transportation where he serves as a coordinator of disaster damage repair to major roads and highways in Northern California. All were experienced in the postearthquake safety evaluation procedures used in the U.S. and had observed safety evaluations after a number of damaging earthquakes.

Opinions expressed in this report are those of the authors and do not necessarily represent those of their employers.

### 1.3 Brief Overview of the Canterbury Earthquakes

Christchurch is New Zealand's second largest city, and as of June, 2010 it had a population of 377,000 (CCC, 2010). It is located on the east coast of the South Island (Figure 1-1) in the Canterbury region. The city and surrounding areas were shaken by a series of tremors called the Canterbury earthquakes. The first and largest was the magnitude 7.1 Darfield event on September 4, 2010. Extensive aftershocks followed. The most damaging of these by far was the magnitude 6.2 Christchurch event that occurred on February 22, 2011.

Given below is an overview of the most significant of the Canterbury earthquakes. The information summarized is based on two New Zealand reports (GNS Science, 2011a and Royal Commission, 2011). Magnitudes indicated are moment magnitudes ($M_w$).

The September 4, 2010 M7.1 earthquake damaged some older masonry buildings in the Central Business District (CBD) of Christchurch and caused liquefaction in the eastern suburbs of the city. The epicenter was near the town of Darfield, about 40 km west of the CBD. Modified Mercalli Intensities (MMI) of VIII and IX were reported, with the highest intensities in the epicentral area and moving eastward to Christchurch. Peak ground accelerations (PGAs) reached 0.8g horizontal and 1.26g vertical near the epicenter and 0.3g horizontal and 0.2g vertical in the CBD. There were no deaths. There were extensive aftershocks. The three most significant occurred on December 26, 2010; February 22, 2011; and June 13, 2011. Figure 1-2 shows locations of the September and February events.

The M4.7 December 26, 2010 (Boxing Day) aftershock was of small magnitude but had an epicenter only 1.8 km northwest of the Christchurch Cathedral in the center of the CBD. It was followed by M4.4 and M4.6 events a few hours later that were in the same area. These events produced localized effects that caused further damage to buildings in the CBD. The maximum horizontal PGA was 0.4g, and the maximum vertical PGA was 0.5g, with most records in Christchurch around 0.2g. MMIs reached VII and VIII.

The very damaging M6.2 February 22, 2011 Christchurch earthquake, considered an aftershock, had an epicenter only 6 km southeast of the CBD and caused extensive damage and liquefaction in Christchurch. PGAs of 1.7g horizontal and 2.2g vertical were recorded near the epicenter with values of 0.7g horizontal and 0.8g vertical in the CBD. Building collapses included nonductile concrete buildings and unreinforced masonry buildings. Deaths caused by this event totaled 182, with 42 related to unreinforced masonry buildings (Royal Commission, 2011).

The M6.0 June 13, 2011 aftershock had an epicenter near Sumner southeast of the CBD. It was preceded by a M5.7 event. It caused further damage to buildings in Christchurch as well as Lyttleton, widespread liquefaction and more rockfalls in the Port Hills suburbs. One fatality occurred. PGAs of 2.0g horizontal and 1.1g vertical were recorded near the epicenter in Sumner, with 0.4g horizontal and 0.2g values recorded in the CBD.

### 1.4 Devastating Effects on Christchurch

Prior to the February 2011 earthquake, officials believed that the Christchurch area had a moderate seismic exposure. The seismic hazard factor, *Z*, used in the New Zealand building code to determine base shear for building design was 0.22 for Christchurch as compared to the much higher 0.40 used for the capital, Wellington. Wellington had experienced a very large, estimated magnitude 8.2 earthquake in 1855. (The *Z* factors used in the New Zealand code are somewhat similar to the *Z* factors used in the 1997 and earlier editions of the Uniform Building Code.)

The damage from the initial M7.1 September 2010 event appeared to fulfill these expectations of moderate exposure, and Christchurch experienced relatively moderate damage with no loss of life.

When the M6.2 February 2011 event occurred, the severity of shaking and scale of building damage came as a surprise. Response spectra for a number of recorded sites exceeded 500-year design levels, in some cases by a substantial margin. For some periods, spectral values corresponded to a 2,500-year or higher hazard level. Parts of the city were devastated (Figure 1-3). Direct property losses from this event were on the order of $15-20 billion (CATDAT, 2012).

Catastrophic damage was experienced in the Central Business District. Most older brick buildings there were severely damaged. Two concrete buildings, one five-story and one six-story, collapsed with significant loss of life. More than 40 major buildings were so badly damaged as to require demolition, including many high-rises. Large areas of the city experienced liquefaction, and over 5,000 homes in the liquefaction areas have been permanently abandoned, with the possibility of this number growing substantially. Additional information on the effects of this earthquake can be found in the reports prepared for the Royal Commission (Royal Commission, 2011).

### 1.5 Brief Overview of Building Safety Evaluation in Christchurch

In a massive effort by local officials, with considerable outside assistance, over 72,000 buildings in Christchurch were inspected in the 10 days immediately after the February earthquake. Figure 1-4 shows the number of inspections per day and the cumulative total of inspections for the 10 day period. This was done with virtually no preparations for the scale of damage that occurred. There was little time after the earthquake to train safety evaluators (see

Figures 1-5 and 1-6). Consequently, there was a considerable need to improvise on an urgent basis, and in this regard officials did an outstanding job. Over 130,000 buildings were inspected in the first 21 days (NZSEE, 2011).

The procedures used to evaluate building safety in Christchurch were based upon a document developed by the New Zealand Society for Earthquake Engineering (NZSEE, 2009). The original ATC-20 procedures (ATC, 1989a) were used as a basis for this document, but significant changes were made. These are briefly discussed below.

ATC-20 uses a hierarchy of three levels of safety evaluation (Rapid, Detailed and Engineering Evaluations). The NSZEE approach also uses three levels (Level 1 and Level 2 Rapid Assessments and a Detailed Engineering Evaluation). Briefly, the ATC-20 Rapid Evaluation is similar to the Level 1 Rapid Assessment and is done by similar personnel, but the NZSEE Level 1 is typically an exterior inspection. The ATC-20 Rapid Evaluation may be used for only the exterior, or both the exterior and interior. The Level 2 Rapid Assessment is similar to the ATC-20 Detailed Evaluation procedure and is done with similar personnel, but NZSEE written procedures do not offer the degree of guidance found in the ATC-20 document. It appeared to the ATC team that Level 2 Rapid Assessment may be more cursory.

The placarding (i.e., posting) systems of the ATC and NZSEE procedures are the same, but placarding procedure is done somewhat differently. Generally, the Christchurch City Council (CCC) used UNSAFE, RESTRICTED USE, and INSPECTED placards only on commercial buildings. However, some single family residences within the cordon area were reported to be posted (Schotanus, 2012). For most residential buildings, if a building was not posted UNSAFE, the occupant was given a small flyer (see Appendix A) that advised them that part of the building might be unsafe and that they should contact an engineer. While this served to speed up the inspection process, it was not immediately very helpful to the occupant. If the occupants chose not to seek the opinion of an engineer, they could remain in some danger.

There were also some procedural problems. For example, if a building was posted RESTRICTED USE and then later posted UNSAFE, the earlier placard was often not removed. This could lead to some confusion. Fortunately, placards were dated and CCC could be consulted for an explanation as the placards had phone numbers to call for additional information. Additionally, the ink used to mark up the placards often faded, making placards occasionally difficult to read. Placard color also often faded. The public was sometimes presented with multiple postings on a building, sometimes with faded writing on them.

Chapters 4 and 5 of this report provide more detailed discussion on these issues.

## 1.6 Background on the Development of the ATC-20 Procedures

The original ATC-20 document *Procedures for Postearthquake Safety Evaluation of Buildings* (ATC, 1989a), and its companion ATC-20-1 Field Manual (ATC, 1989b), were developed over the period 1987 to 1989 and published in September 1989. These documents found immediate use when the damaging October 17, 1989 M7.1 Loma Prieta earthquake occurred in California just a few weeks after their release.

Following the Loma Prieta earthquake, ATC updated ATC-20 with the ATC-20-2 Addendum document published in 1995 (ATC, 1995). This document added the knowledge gained in the aftermath of the Loma Prieta event and introduced the RESTRICTED USE placard (in place of the old LIMITED ENTRY placard).

In 1996, the ATC-20-3 Rapid Evaluation case studies document was published (ATC, 1996). This document added to the ATC-20 Rapid Evaluation methodology and illustrated over 50 examples of building safety evaluation using the Rapid Evaluation procedure. Rapid Evaluation is the first of the three ATC-20 safety evaluation procedures.

More recently, in 2005, ATC updated the ATC-20-1 Field Manual (ATC, 2005). This document summarizes the latest ATC-20 methodology and includes topics and discussion not covered in the other ATC-20 series documents. Unfortunately, it is often not understood, both in the U.S. and elsewhere, that this document with its improvements better summarized the ATC-20 methodology than the original document (ATC, 1989a)

### 1.7 Level of Effort of this Report

The time spent in Christchurch observing damage and meeting local officials and engineers was limited to a one week visit that occurred four months after the February 2011 event, although there were follow-up emails and correspondence. Additionally, research was done through internet searches and reading the reports of others.

The team also received comments from New Zealand engineers and several U.S. and Canadian structural engineers who participated in the building safety evaluations in Christchurch immediately following the February 2011 event. Their observations and insights were very helpful in developing a picture of the immediate postearthquake situation and its subsequent evolution.

To help investigate the damage in the Canterbury earthquakes, the New Zealand government formed the Canterbury Earthquakes Royal Commission. It commissioned a series of reports, a number of which were quite useful in preparing this report.

### 1.8 Outline of the Remainder of the Report

The remainder of the report is organized as follows. Chapter 2 describes the unique challenges Christchurch officials faced, including the combination of strong ground shaking, extensive liquefaction, and widespread damage in the CBD. Chapter 3 describes ideas and practices that the reconnaissance team found to be useful and may have application in the U.S. and elsewhere. Chapter 4 documents observations on the process of postearthquake safety evaluations and the posting of buildings. Chapter 5 focuses on management issues in the implementation of a postearthquake safety evaluation program. Finally, Chapter 6 describes research and development needs and recommends some of the next steps for ATC in both updating ATC-20 and developing additional guidelines and training programs.


Figure 1-1 Location of Christchurch, New Zealand. (Source: U.S. Central Intelligence Agency website, 2011)

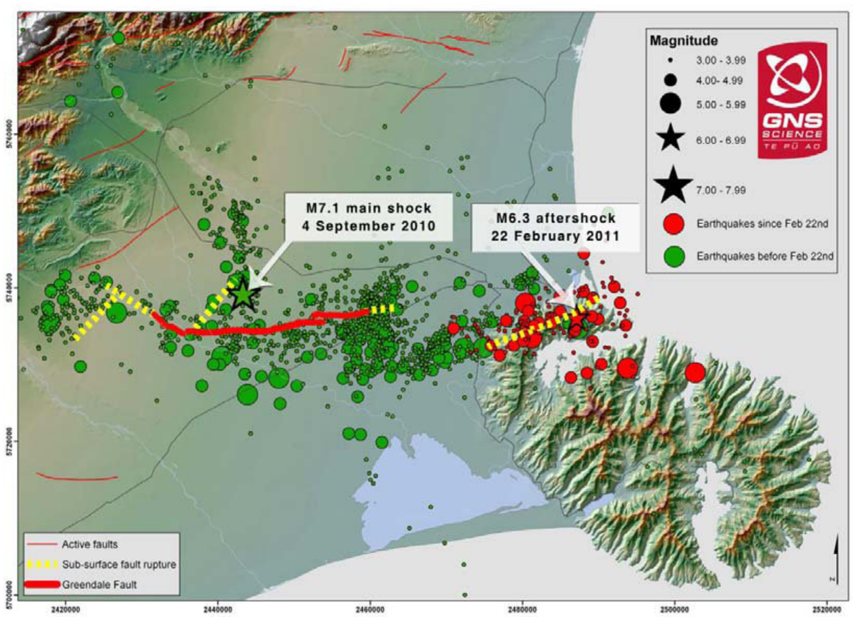


Figure 1-2 Map showing epicenters of the Canterbury earthquake sequence. (Source: DBH, 2011a)

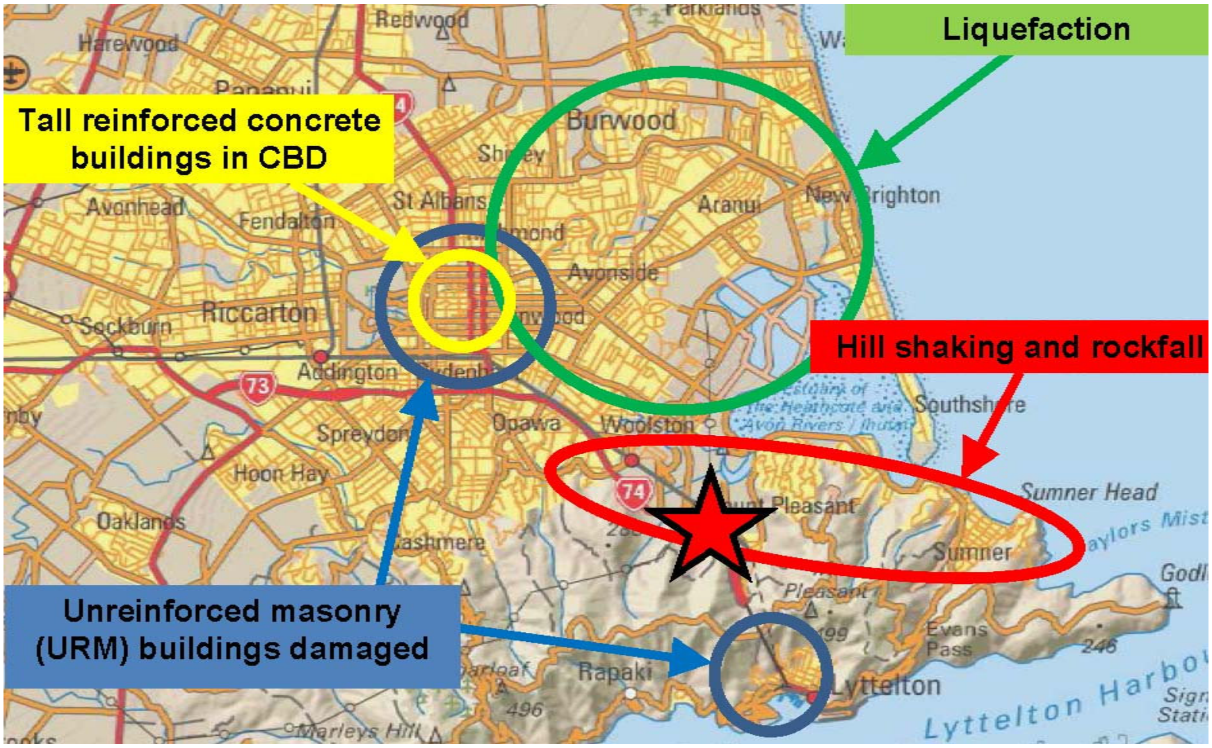


Figure 1-3 Overview of damaged areas from February 22, 2011 Christchurch earthquake. (Source: DBH, 2011a)

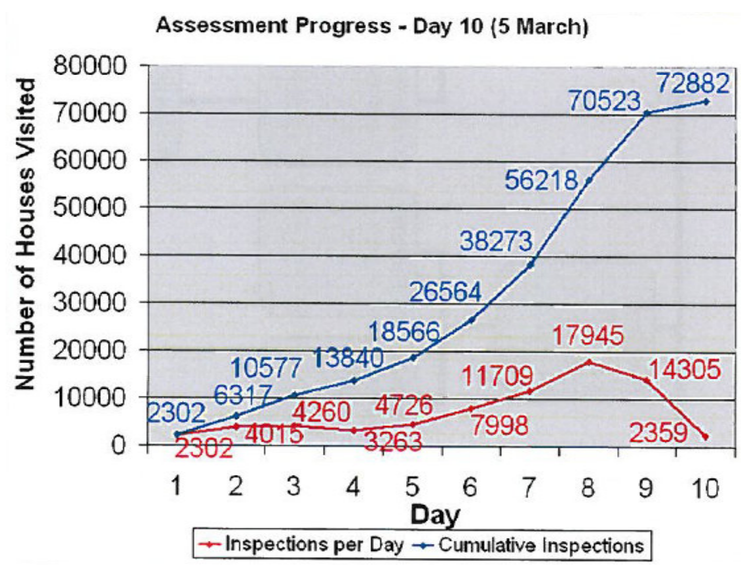


Figure 1-4 Inspections per day and cumulative inspections in the 10 days following February 22, 2011 Christchurch earthquake. (Source: Christchurch City Council)

Figure 1-5 Building safety inspectors at a briefing in the days immediately following the February 22, 2011 earthquake. (Source: Ken Elwood)


Figure 1-6 Safety assessment personnel in the Central Business District. Note the broken windows and canopy glazing. (Source: Ken Elwood)

# 2. Challenges Encountered after the Earthquake

The February 2011 Christchurch event created a number of unusual difficulties and challenges generally not encountered after magnitude 6.2 earthquakes. It is not that these difficulties have not occurred elsewhere in the world, but it is their combined effect and the severity of the earthquake damage that made the Christchurch situation unique. These are discussed below.

## 2.1 Scale and Extent of Liquefaction

The soil liquefaction that took place in the city of Christchurch during the February event was on a scale that is considered unprecedented. Liquefaction first occurred in the September 4, 2010 earthquake; however, the February 22, 2011 event caused the most damaging liquefaction and lateral spreading (Cubrinoushi and McCahon, 2011). Approximately 20 to 30 percent of the city experienced some degree of liquefaction and soil consolidation. The resulting differential settlements and lateral spreading caused structural damage to homes, buildings and bridges (see Figures 2-1 and 2-2 for examples).

Liquefaction occurred over very large areas, particularly along both sides of the Avon River and near the city's wetlands. Residential areas were particularly hard hit with at least 5,000 homes having to be permanently abandoned, with the possibility of many more. In the hard hit areas, sand boils, and sand ejecta seemed to be everywhere.

Immediately after the earthquake, most yards and streets in the harder hit areas became flooded due to the sheer volume of water and fine sand ejected and water flowing from broken water mains. A few vehicles were even swallowed into holes and became partially buried.

Some areas of the city will have to be permanently abandoned because it is impractical to replace underground utilities, and it is considered too risky to let homes remain. The reconnaissance team considered this to be a bold and pragmatic move on the part of the local authorities, especially in view of the continuing threat of future earthquakes.

Sand boils and pavement separations from lateral spreading were also observed in the CBD. Liquefaction contributed to the CBD structural damage, but the extent of this was difficult to distinguish from shaking effects. In general, liquefaction was less severe in the CBD than in the hardest hit residential areas in the eastern suburbs.

## 2.2 Combination of Strong Shaking and Liquefaction

In addition to assessing the safety of dwellings and buildings shaken by very strong ground motions, the safety evaluation task was made more difficult by additional damage attributable to the differential settlements and lateral spreading caused by liquefaction.

One example is the six-story concrete frame building shown in Figure 2-3. This building suffered some shaking damage, but much more damage was due to liquefaction-induced settlement of a row of columns (Figure 2-4).

A number of high-rise buildings were left leaning after the earthquake. While many had severe structural damage that caused them to lean, the residual drift in others was due, in large part, by ground settlements caused by liquefaction and subsidence.

## 2.3 Large Scale Ground Settlement

The Avon River flows through the northeast part of Christchurch. Many areas along the river experienced significant ground settlement due to subsidence caused by soil consolidation and liquefaction. After the February earthquake, authorities added about 30 cm to one meter to the height of the berms on both sides of the river to prevent future flooding of nearby homes. Figure 2-5 shows an example.

## 2.4 Number of High-rise Buildings Seriously Damaged

A great many mid-rise and high-rise buildings in the Central Business District were severely damaged. Two of these, the six-story CTV building (Figure 2-6) and the five-story Pyne Gould building (Figure 2-7) collapsed with loss of life. Others such as the Grand Chancellor Hotel (Figures 2-8 and 2-9) were left in a precarious state. Relative to the size of the city, the ATC team felt that there was an unusually high number of severely damaged mid-rise and high-rise buildings in a developed city.

A number of relatively new buildings such as the Grand Chancellor Hotel (Figure 2-8) were so severely damaged that they will be demolished. To give a sense of the scale of the damage to mid-rise and high-rise buildings, a partial list of those to be demolished is given below.

| Building to be Demolished | No. of Stories |
|---|---|
| AMI House | 8 |
| Avonmore House | 11 |
| Clarendon Tower | 17 |
| Copthorne Hotel, Durham Street | 11 |
| Crowne Plaza | 12 |
| DTZ Building | 8 |
| Gallery Apartments | 14 |
| Grand Chancellor Hotel | 22 |
| The Establishment | 10 |

Investigations have been made on many failed buildings, including CTV (BECA, 2011b), Pyne Gould Coporation (Hyland and Smith, 2011) and the Grand Chancellor Hotel (Dunnning Thornton, 2011).

The Grand Chancellor Hotel and the 19-story Forsyth Barr building both had precast concrete stairs collapse in their upper stories (see Figures 6-1 and 6-2). With no usable stairs and with elevators inoperable, people trapped in the upper floors could not leave the building without outside assistance.

Buildings that were seriously damaged were generally older, nonductile concrete structures, often with irregularities. Surprisingly, a number had shear wall lateral force-resisting systems.

Not all seriously damaged buildings were old. Several relatively new buildings were left permanently leaning, apparently due to foundation problems, making repairs difficult if not economically unfeasible.

A significant contributing factor in the demolition of so many damaged buildings was the widely available and relatively inexpensive earthquake insurance. This led owners to pursue demolition instead of exploring retention and strengthening options.

The issues surrounding demolition of damaged buildings are complex; they include not just the extent of damage, but also financial and insurance considerations and the requirements for repair and upgrade. In New Zealand, a widely used metric in the evaluation of existing buildings is the Percentage of New Building Standard, or %NBS. In the aftermath of the earthquake, the Christchurch City Council passed an ordinance requiring a damaged building with less than 33% NBS to be strengthened. The minimum strengthening level is 67% NBS. Insurers are often arguing to pay only for work needed to achieve 33% NBS. In these situations, some owners take the payout for the 33% NBS level, and then demolish the building. They are making a financial assessment that it is not worth the capital outlay for the remaining effort needed to get to 67%NBS, and either will let the property lay vacant or will rebuild a new building on the site in the future. (Snook, 2012)

### 2.5 Concentration of Damage in Central Business District

Damage in the Central Business District (CBD) was particularly severe. The team was told that, of the approximately 4,000 buildings there, some 1,000 may be demolished. The Canterbury Earthquake Recovery Authority (CERA) is responsible for overseeing demolitions in the CBD; and nonresidential, selected historic buildings, and residential buildings over four stories outside the CBD. As of June 30, 2012, the CERA demolition list had 823 buildings slated for demolition and 167 slated for partial demolition (CERA, 2012). The reasons for the concentration of damage in the CBD include a very large number of unreinforced masonry buildings (URM) and the poor performance of a number of relatively new mid-rise and high-rise buildings of mostly nonductile and semi-ductile concrete construction. A significant contributing factor was ground motions stronger than anticipated by the building code. Liquefaction also played a part in some mid-rise and high-rise building damage.

Damage was so severe and so pervasive (Figure 2-10) that officials cordoned off the entire 50 plus blocks of the CBD to control entry and keep the general public out of dangerous areas. Figure 2-11 shows typical CBD damage immediately after the earthquake with streets blocked by debris.

## 2.6 Large, Damaging Aftershocks

There were at least nine M5.0 or larger aftershocks after the February event, which itself was considered an aftershock to the September 2010 earthquake. Particularly damaging was the M6.0 aftershock of June 13, 2011. This produced considerable additional damage, including further destruction of the famous Christchurch Anglican Cathedral in the CBD when temporary steel shoring put in place to complete urban search and rescue (USAR) operations and to allow removal of the Rose Window failed (Figure 2-12). Many URM buildings were further damaged, particularly those in the CBD. Additional liquefaction also occurred following strong aftershocks.

## 2.7 Slides and Rockfalls

There were numerous slides and rockfalls in the Redcliffs, Sumner, and Lyttelton areas along the coast. In some areas, the cliffs are 150 to 200 meters high. Many homes at the bottom of the cliffs were damaged or destroyed by the landslide and rock fall debris, and a number of homes at the top of cliffs suffered damage from foundation failures and differential settlements. Some homes were torn in two, with parts pulled down the cliff (Figure 2-13). Large cracks also appeared in many of the cliffside streets at the top of the cliffs, necessitating the posting of homes between the cracks and the cliffs UNSAFE.

## 2.8 Safety Evaluations Conducted with Limited Preparedness

The majority of the individuals the ATC team interviewed felt that there was not adequate preparation for the scale of the disaster. Updated postearthquake safety evaluation procedures were in a draft state (NZSEE, 2010). Relatively few people had been trained in their use.

Even with limited preparations and training, officials were able to complete over 72,000 safety assessments in the 10 days after the event (Figure 1-4). This was highly useful because buildings were at least given a quick examination, and the worst hazards could be identified fairly quickly.

To accomplish 72,000 inspections in ten days and 130,000 in twenty-one days, officials had to improvise. Manpower was obtained from a number of sources, including Christchurch building department staff, volunteer engineers from New Zealand and other countries, private engineers, and building inspectors (e.g, building control officers), engineers and others from other New Zealand cities.

One U.S. observer noted that the response was remarkably well organized, methodical and systematic considering the scale of the disaster. Also, that the multi-level approach used (e.g., triage, critical building program, search and rescue, initial and follow-up inspections) was impressive (Court, 2012).

## 2.9 Fractured Rebar in Shear Walls

An unusual phenomenon was observed in some concrete shear wall buildings. Vertical reinforcement in shear walls was found to be fractured. It was reported for the first building where this was observed that when structural engineers initially inspected a wall, only a relatively small horizontal crack was found. However, when concrete covering the bar was removed, complete tensile fracture of the bar was found. Upon further exploration along the crack in the wall, other vertical bars were also found to be similarly fractured.

This phenomenon has the potential to be an extremely important finding, and the New Zealand structural engineering community is looking into it further. At the time of the reconnaissance trip, at least five buildings were reported to have experienced this type of damage. Some engineers have reported this number has increased as more investigation has been done (Bull, 2012). One theory is that this occurs in lightly reinforced walls with much higher than expected concrete strength, where the capacity of the reinforcing is less than the tensile capacity of the wall, preventing distributed concrete cracking and yielding of reinforcing. Instead, with the light reinforcing, tensile strains are concentrated at the initial crack and early fracture occurs. Figure 2-14 shows a fractured bar, and Figure 2-15 show exploratory work underway to search for damaged rebar.

A concern for future postearthquake inspections is that these cracks may close or leave only small crack widths that may be superficially repaired without consideration of the fractured, or possibly fractured, vertical reinforcing steel.

Figure 2-1 Home damaged by liquefaction. Note sand boil under window at right.

Figure 2-2 Pedestrian bridge damaged by liquefaction and subsequent lateral spreading. The bridge was initially damaged in the September 2010 Darfield earthquake, but experienced much more damage in the February 2011 event.

Figure 2-3 The Trade Union building was damaged by both ground shaking and differential settlement caused by liquefaction. This building was later demolished.


Figure 2-4 Trade Union building columns on right in the picture settled over 30 cm due to liquefaction induced settlement.

Figure 2-5 New built-up berm on the banks of the Avon River.

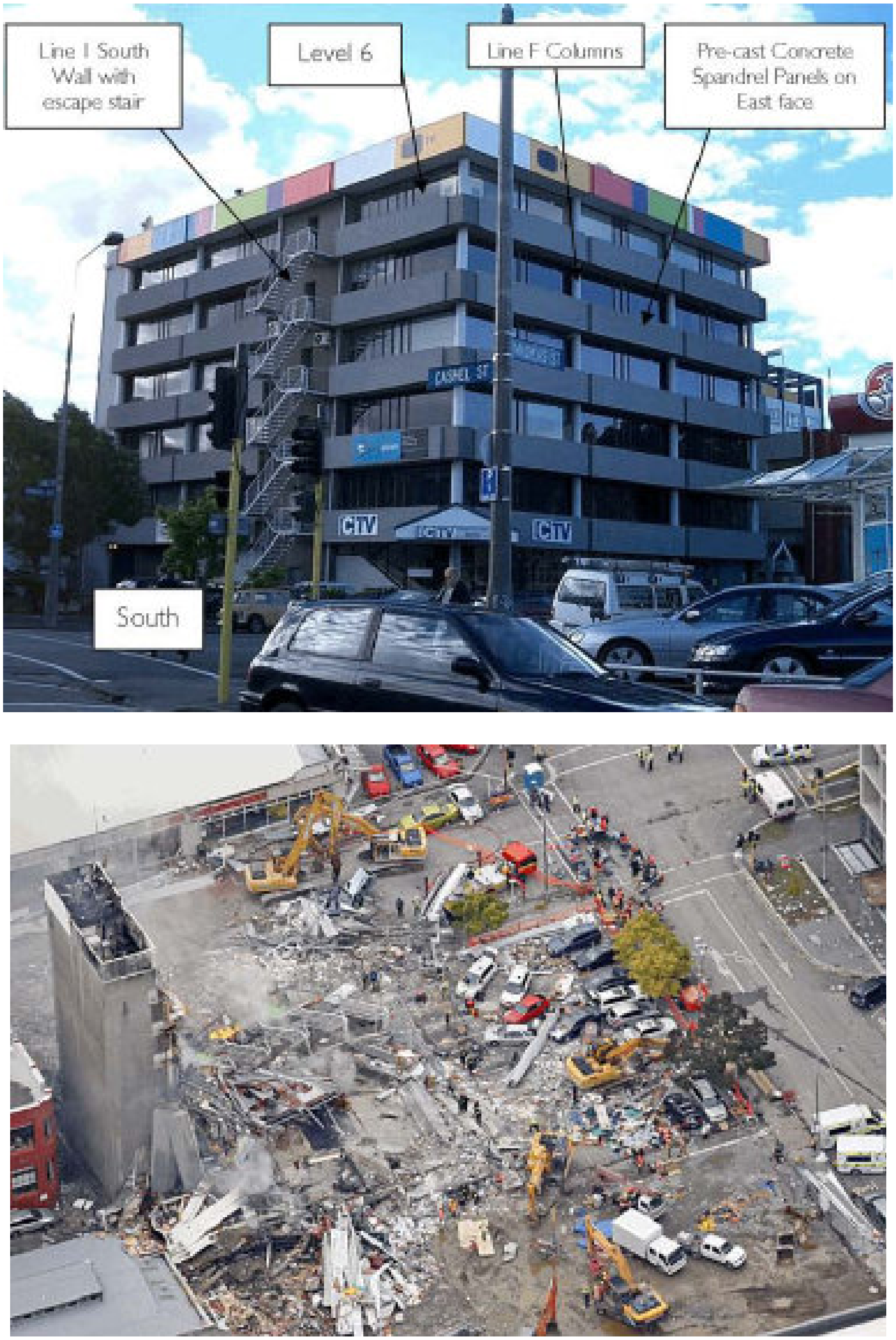


Figure 2-6 CTV building before and after collapse. One hundred and fifteen people were killed in this building. (Source: Hyland and Smith, 2011)


Figure 2-7 Pyne Gould Corporation building before and after collapse. (Source: BECA, 2011b)

Figure 2-8 The severely damaged Grand Chancellor Hotel in the CBD. This 22-story building was one of a number of high-rise buildings to be demolished.

Figure 2-9 Shear wall failure in the Grand Chancellor. Failure of this wall caused the entire building to lean. (Source: Dunning Thornton, 2011)

Figure 2-10 An example of the concentration of damaged URM buildings in the CBD.


Figure 2-11 Damage in the Christchurch CBD immediately after the February 2011 earthquake. (Source: Christchurch City Council)

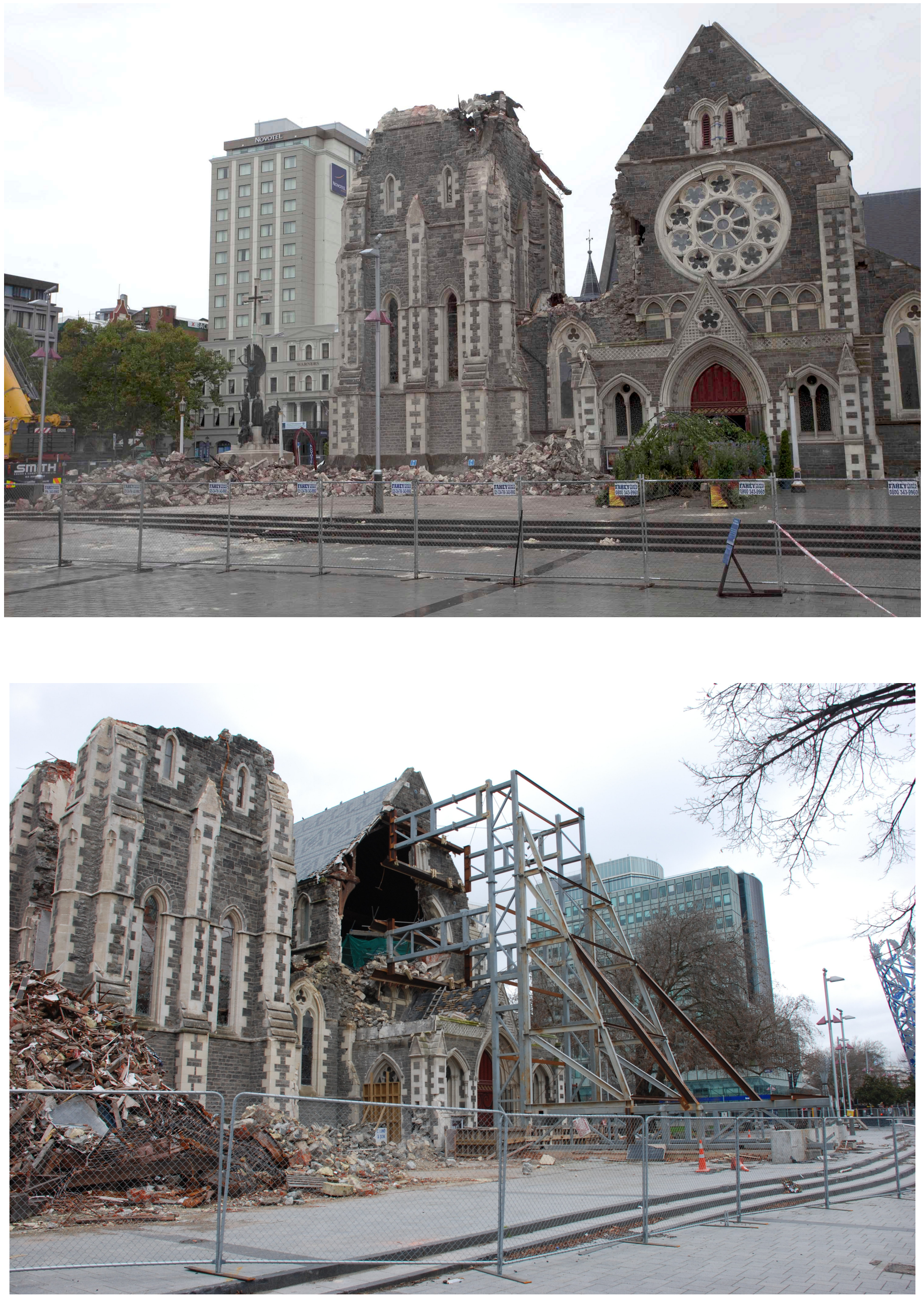

Figure 2-12 Failure of temporary wall shoring at the famous Christchurch Anglican Cathedral intended to allow removal of the Rose Window. The picture at top shows the wall and Rose Window after the February 22, 2011 earthquake, and the picture at the bottom shows the wall, and loss of the Rose Window, after the June 13, 2011 aftershock. (Source: Top picture, Christchurch City Council)


Figure 2-13 A home destroyed by slope failure in the Sumner area. Part of the home is at the top of the cliff and the other part at the bottom (just above the shipping containers on the right).

Figure 2-14 An example of a fractured vertical reinforcing bar in a concrete shear wall. (Source: Des Bull)


Figure 2-15 Exploration work in concrete shear wall for possible fractured bars. (Source: Des Bull)

# 3. Useful Ideas and Practices Observed

Faced with an unexpected disaster, local officials exhibited considerable innovation and resourcefulness. The ATC team observed and through discussions learned of a number of ideas and practices that can be used in the U.S. and elsewhere. These are summarized below.

## 3.1 Use of Triage

On the first day after the earthquake, before the formal building safety evaluations were begun, teams were sent into the field to “triage” all city blocks in the CBD. The intent of the triage was to identify immediately collapse-vulnerable buildings and ensure people were not trapped in any of the buildings. A list of potentially dangerous buildings was provided back to the Emergency Operation Center (EOC). This quick walk-through the heavily damaged area was highly useful to get an overview of the damage and was used to inform urban search and rescue teams (USAR) efforts. (Elwood, 2012)

## 3.2 Use of Indicator Buildings

Following a large earthquake, many buildings become damaged and are susceptible to additional damage from aftershocks. This presents a problem for those managing the safety assessments. Some aftershocks may be strong enough to damage previously undamaged buildings (e.g., buildings posted INSPECTED), or further damage already damaged buildings, thus requiring a change in posting (e.g., from RESTRICTED USE to UNSAFE). An important decision officials must make is when to require the reinspection of previously inspected buildings.

An example of this occurred after the 1987 Whittier, California earthquake. Following this M5.9 event, the local jurisdiction had inspected approximately 3,000 buildings when a M5.3 aftershock occurred three days later. The 3,000 buildings had to be re-inspected. Eventually, over 7,000 buildings were inspected, with 3,000 inspected twice.

One innovation in Christchurch was the use of “indicator buildings.” Indicator buildings represented the unreinforced masonry, reinforced masonry, reinforced concrete, and precast concrete structures typical of Christchurch. One such building is shown in Figures 3-1 and 3-2. If an indicator building showed new damage after an aftershock, similar buildings nearby that likely experienced the shaking could then be re-examined for safety. This is better than the rather intuitive methods that have been used in the U.S.

In California, the California Geological Survey maintains a strong-motion instrumentation program and develops Internet Quick Reports (IQR) following earthquakes of M4.0 or larger. An IQR normally includes a ShakeMap indicating estimated ground shaking intensities. The estimated intensity information can be used by those in charge of safety assessments to locate areas of probable damage.

Use of indicator buildings, and the IQRs if these are available, will improve the information available to safety assessment decision makers.

## 3.3 Emergency Stabilization of Mid-Rise and High-Rise Buildings

The team estimated that at least 30 percent, and probably more, of the mid-rise and high-rise buildings in the CBD were seriously damaged. Two buildings collapsed outright during the February event. These were the five-story Pyne Gould building and the six-story CTV building.

A number of mid-rise and high-rise buildings were noticeably leaning or had such severe damage that emergency stabilization was required. The Christchurch City Council quickly initiated a project called Operation Critical Buildings to identify buildings in the CBD that posed a threat of collapse or a hazard to adjacent buildings and roads. Some 42 "critical buildings" were identified and quickly evaluated. The city was advised on actions that should be taken to reduce the risk posed by the critical buildings. Recommendations ranged from "stabilization before demolition" to "no immediate action". Team members included structural engineers, urban search and rescue (USAR) teams, and contractors familiar with the construction of the critical buildings. The Critical Buildings Project was reported to be a very well run operation (Elwood, 2012). Highlights of this concept include the following:

- "Critically damaged" buildings over six stories were extracted from the vast inventory of buildings being evaluated by the building assessment teams, allowing teams to focus on numerous "simpler" buildings.
- A single team, led by a senior engineer and supported by Christchurch City Council staff, managed the incoming data on the critical buildings efficiently.
- Engineers familiar with the buildings reported directly to the Critical Buildings team.
- Surveys of the worst critical buildings were regularly reported to the Critical Building team to understand the extent of damage and track any possible movement during aftershocks.
- Available domestic and international experts were requested to provide input on critical buildings, sometimes in the form of short reports.
- Availability of drawings for building was critical for the rapid assessment of extent of damage and stability of buildings. This is an important lesson for other municipalities – building drawings must be immediately available after a major earthquake.

Examples of the emergency stabilization measures taken to keep "critical" structures from collapsing, especially collapsing on their neighbors, are shown in Figures 3-3 and 3-4.

## 3.4 Central Business District Cordon

The Central Business District (CBD) which comprised over 50 blocks in the center of the city was cordoned off the day after the February earthquake (see Figure 3-5). Only officials, emergency workers, and safety evaluation teams were allowed entry.

One unintended consequence of cordoning the CBD was that a great many cars and trucks were left on streets and alleyways. These vehicles initially impeded access for emergency response and recovery efforts, but they were later removed.

In the weeks following the earthquake, the cordoning "evolved" and boundaries of the CBD cordon were gradually reduced, though at the time this report was written portions of the CBD remained cordoned. Because of the aftershock hazard and the unstable state of many damaged buildings, entry to the CBD was controlled. At the time the ATC team was there, late June and early July 2012, the New Zealand Army controlled entry, and only people with passes were allowed in.

Control included monitoring both individual entry and exit. This was done to keep track of the number and names of individuals in the CBD at any one time. Should a very strong aftershock occur, the authorities would know exactly who was in the CBD.

### 3.5 Use of Laser Scanner for Slope Stability Monitoring

Landslides and rockfalls occurred near the sea coast area cliffs (Figure 3-6). In the Sumner and Redcliffs areas of Christchurch, where cliffs were 150 meters or more in height, a three-dimensional laser scanner was used to monitor the cliffs. Scans were taken days or weeks apart to identify areas with movement in the cliff face and also to monitor landslides. This work was performed by GNS Science of New Zealand.

It was reported that laser scanning was also used to assess deformation of a number of buildings, both exteriors and interiors (Brunsdon, et al., 2012).

This technology seems to be an excellent way to monitor and anticipate future earth movements that can threaten buildings, roads and other important structures. It should also prove useful in monitoring damaged buildings. At least one group of researchers recommends this technology for use in postearthquake safety evaluations (Chang, et al., 2008).

### 3.6 Shelter-in-Place Strategies

In the liquefaction areas, residents were sometimes permitted to remain in their homes even though utilities had been damaged and were not usable. A "shelter-in-place" strategy was developed where if a home was not damaged sufficiently to trigger an UNSAFE posting, the occupants were permitted to remain. Above ground water lines and portable and/or chemical toilets were put in place to serve the remaining residents. Also made available were portable communal showers (see Figure 3-7).

For example, undamaged or slightly damaged homes in the severe liquefaction areas generally had no water or sewer service. Underground utility lines were destroyed, but residents could remain sheltered-in-place because temporary water, toilet and shower facilities were made available, and the homes could be inhabited until the final disposition of the home, either by repair or demolition.

The "shelter-in-place" approach has certain advantages over the standard public shelter practices used in the U.S. and elsewhere. Rather than being huddled in a mass care facility that requires additional (and possibly scarce) resources to be used for food, water, medical, and security needs, the shelter-in-place approach allows survivors to remain in familiar surroundings with their own food, clothes, medicine, and other possessions. Generally, this is less stressful than the mass care shelter situation. Shelter-in-place allows for animals and pets to be taken care of humanely, which also helps alleviate stress on the survivors and reduces the need for post-disaster animal care by the local government. Finally, the shelter-in-place approach allows persons to get ready for work, if their workplace is operational, and therefore is of greater help with the overall economic recovery of the community compared to the mass care approach, which may not allow ready access to clean clothes, showers, etc.

The desire to shelter-in-place has received growing attention by U.S. policy makers, and the strong emphasis in Christchurch provides a valuable case study in its implementation. An important lesson is the difference between structural safety and habitability. ATC-20 focuses on damage to the structure and life safety risks. Whether power, water, sewer, and communication services remain operational is not explicitly addressed, nor is whether the building can still be locked or otherwise secured against intruders. For residential placards, New Zealand's Earthquake Commission adopted a "3S" approach, meaning if a building was "Safe" per the structural evaluation, sanitary, and secure (lockable), then the residence was considered usable for shelter-in-place. Check boxes were added to the inspection forms to identify the sanitary and secure categories. (Brunsdon and Wood, 2012).

### 3.7 High Priority Evaluation of Shopping Centers and Drug Stores

ATC-20 offers the advice to conduct safety evaluations of essential facilities first. Hospitals, police and fire stations, and emergency headquarters must be among the first buildings inspected. Officials in Christchurch added shopping centers and drug stores to the list of high priority inspections.

It was felt that the public need for items such as food, diapers and medicines was important and that the best way to ensure supply was to inspect the buildings of these businesses and identify those that could be left open.

### 3.8 Use of Shipping Containers as Barricades

There was extensive use of shipping containers as barricades where falling hazards were severe (Figure 3-8 shows an example). These were placed against, or close to, buildings to keep parapets, walls and store fronts from falling into the street. This permitted street traffic to be relatively close to very damaged buildings.

It was reported that in some cases shipping containers were also used as areas of safe refuge. Ends and doors were left open to allow unimpeded access to the inside of the container for avoidance of falling debris in aftershocks (Swanson, 2012).

Shipping containers were also used as effective barricades and retaining walls in the Sumner and Redcliffs areas to impede the flow of slide and rock fall debris from damaging dwellings or blocking roads (Figure 3-9).

Informally, engineers reported that some of the shipping containers used as barricades were empty; other containers were filled with weight at the base to make them more resistant to lateral loading and overturning.

### 3.9 Targeted Safety and Evaluation Teams

Another innovation was the creation of specialized task forces to address sections of the city or issues of the community. The task forces targeted shopping malls (to make food and necessities available to the public), the suburbs, critical buildings (six or more stories), the Central Business District, cordoning and access, and demolition. The teams were named after the community element that they targeted for safety assessment and clearance, as follows.

- Operation Shop
- Operation Suburb
- Operation Critical Buildings
- Operation Cordon and Access
- Operation Demolition

By initially focusing selected resources to pursue the building safety evaluation of these targeted community elements, the Christchurch authorities were able to move more rapidly to open up, or deem unsafe, entire segments of the community. This approach has certain advantages over the block-by-block method that has been used in California, the western U.S., and other places.

Under Operation Shop, for example, the focus was on the opening of stores, pharmacies, and hardware stores. This helped establish which stores can be opened to the public, which helps both the survivors and the economy.

Operation Suburb was the largest task force effort, and focused on the rapid safety assessment of homes in the suburbs. About 1,000 people were briefed and deployed each day from a sports stadium, with military precision (Brunsdon, et al., 2012). Approximately 72,000 homes were eventually evaluated for safety, mostly in the eastern suburbs and Port Hill areas.

Operation Critical Buildings focused on damaged buildings six or more stories in height that affected street and road traffic, adjacent buildings, or that were considered critical infrastructure. Some 42 multi-story buildings were identified as having critical structural damage.

Operation Cordon and Access focused on the extent of cordoning needed to keep the public safe from dangerous buildings. As a result, 22 km (13.2 miles) of fencing was installed to barricade the public from dangerous areas. An inner city cordon was established around the Central Business District (CBD), while an outer cordon was initially installed about four avenues away and gradually reduced in size as they areas were cleared for safety.

Finally, Operation Demolition focused on identifying and disposing of those buildings that presented a hazard to the public and adjacent structures and streets. As of July 1, 2011, the NZ

National Controller gave approval for the demolition of 129 buildings. As of June, 2012 some 1,000 buildings within the CBD are to be demolished or partially demolished (CERA, 2012), and early estimates indicated around 10,000 homes may be demolished or relocated as well (Brunsdon and Wood, 2012). Clean debris is being disposed of by dumping as reclamation in the Port of Lyttleton, and other debris is disposed of and sorted in landfills. Operation Demolition focuses also on sustainable debris management, including the re-use of crushed debris for road base.

### 3.10 Use of Private Engineers for Safety Evaluations

Private engineers were permitted to inspect and post buildings under the authority of the Christchurch City Council. This was done in two ways. In the early stages of the emergency phase, engineers were signed up using the Memorandum of Understanding document reproduced in Appendix B, and then they were deployed as part of an assessment team. Those volunteering to perform assessments were protected from liability. At later stages, especially following some of the more significant aftershocks, private engineering consultants were requested to submit Rapid Evaluation Level 2 forms and to advise if changes in status of the placards were required. This recognized that the private engineers were often much more familiar with individual buildings, and therefore able to immediately identify issues. In addition, as owners had already contracted with engineers in many cases, this made the assessments more efficient and allowed engineers from public agencies (CCC or CERA) to focus on buildings that might not otherwise be inspected (Brunsdon, et al., 2012)

One firm prepared for having its employees “volunteer” to perform safety evaluations by having the Memorandum of Understanding approved well in advance of the earthquake by its legal team. This permitted the firm’s engineers, who were paid by the firm, to assist as “volunteers” in Christchurch without delay (Sharpe, 2011).

### 3.11 Damage Reconnaissance by Remote Means

Two innovative methods were used to assess damage in places deemed too risky for human entry.

The first involved a video camera mounted on a small unmanned aerial vehicle (UAV). This was used to inspect the inside of the large, heavily damaged Roman Catholic Cathedral of the Blessed Sacrament (Hampton, 2011). The UAV was flown through a window to obtain information for structural assessments of the interior this badly damaged masonry structure.

The second involved use of a tracked robot. A remote-controlled New Zealand Army robot with a video camera was used to assess the same Catholic Cathedral. The robot entered the structure through a hole cut in a door. Operators watched on a laptop in a reinforced shipping container nearby (Gates, 2011).

### 3.12 Land Management Issues and Recovery

ATC-20 primarily focuses on the safety evaluation and posting of an individual building. Metaphorically, it is the tree in the larger urban forest. The widespread damage to buildings and infrastructure from strong ground shaking, liquefaction, landslides, and rockfalls and the potential for further damage in future earthquake events led the government to create zonation maps of the Canterbury region which effectively tagged the entire "forest" of buildings. The zonation maps and associated land management and recovery process are managed by the Canterbury Earthquake Recovery Authority (CERA). Figure 3-10 shows an example of one of the zonation maps for the eastern areas of Christchurch. CERA made the determination not to repair or reconstruct or reoccupy certain areas which are subject to high degrees of liquefaction, have a high risk of further damage due to aftershocks, and have buildings and infrastructure which are mostly uneconomical to repair or where repairs would be prolonged and disruptive. These areas have been mapped out by CERA in what is known as the "Red Zone." CERA is presenting government buy-out offers to homeowners in the Red Zone. By January 10, 2012 "owners of 5078 of the 6500 red-zone properties in Canterbury had accepted an offer, agreeing to sell to the Government and leave their homes before April" of 2013 (Heather, 2012). These areas will be abandoned by the City unless it becomes feasible to address the liquefaction problem.

As stated before, the ATC team considered this to be a bold and pragmatic move on the part of New Zealand authorities. By preventing repairs and rebuilding in areas subject to repeated severe damage, the authorities hold back from spending repair funds in areas where little of lasting good would be accomplished, while keeping more funds for repairs in areas where longer term viability exists. This is an efficient use of limited funds, which will lead to the most good accomplished over time.

Figure 3-10 also shows a land zonation map taken from the CERA website of the eastern suburbs of Christchurch as of June, 2011, showing Green, White, and Orange Zones. The homes and infrastructure in the Green Zone were considered suitable for repair and rebuilding. Land classified as Orange meant further engineering investigation was underway. Damage may have also resulted from the June 13, 2011 earthquakes and may not have been fully accounted for in this version of the map. Orange Zones were to be progressively reclassified as Red (not suitable) or Green (usable) following the engineering investigations. The White Zone primarily covered the southeastern hill areas where geotechnical investigation was underway and primary concern was for landslides and rockfalls, rather than liquefaction. On September 5, 2011 and October 14, 2011, large portions of this area were reclassified as Green.

### 3.13 Use of USAR Personnel as Safety Escorts

Swanson (2012) notes that the Christchurch City Council made extensive use of Urban Search and Rescue (USAR) personnel as safety escorts for the building safety evaluation teams within the CBD. These USAR personnel were from other regions of New Zealand and were on two-week rotating deployments to the Canterbury region. Their roles on the safety assessment teams were to ensure that the safety evaluation teams were conducting their field work in a safe manner. They had two-way radios, first aid kits, and were in radio communication with the Emergency Operations Center (EOC).

### 3.14 Use of On-Call Locksmiths for Building Access

A unique aspect of the Christchurch earthquake was the cordoned CBD that only allowed access by official personnel. Consequently, there were many instances where locked private commercial buildings were being accessed by professional on-call locksmiths to allow the building safety evaluation teams access for building evaluations. These on-call locksmiths were contracted by and deployed by the Christchurch City Council EOC, and they were deployed when needed to open locked doors so the safety evaluation teams could access damaged buildings. Response times were typically only 30 minutes or so as the locksmiths were radio dispatched. This system of utilizing professional locksmiths was an efficient way to provide needed access by the safety assessment teams without damaging private property by breaching locked doors and entries (Swanson, 2012).

### 3.15 Use of Internet and Social Media for Information Updates

Another unique aspect of the Christchurch City Council postearthquake response the relatively extensive use of the internet and social media to provide near real-time updates to the public on the response and recovery process of the region. One aspect of these new communication tools was the issuance of CBD cordon maps showing the specific zones within the CBD cordoned areas and planned dates for these area cordons to be lifted. Another unique tool was the development and distribution of maps of the CBD that showed areas of higher risk from buildings that could potentially collapse in a strong aftershock. These communication tools were a valuable resource to communicate essential earthquake response and recovery information to the public that had internet and social medial access (Swanson, 2012).

### 3.16 Introduction of Usability Categories

A category to indicate the postearthquake “usability” of a building was added to the updated NZSEE guidelines (NZSEE, 2010). This provided additional information beyond the basic posting category. The updated Level 2 Rapid Assessment form incorporates Usability Categories to “enable an additional level of status information” to be made available to building occupants, managers and owners. This concept was an enhancement introduced after the New Zealand team visit to the 2009 Padang, Indonesia earthquake and was reported to also have been used after the 2009 L’Aquila earthquake in Italy (NZSEE, 2010).

The usability categories in the updated NZSEE guidelines are as follows:

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

For example, when Usability Categories were used, officials had the safety evaluators write "G1" on the placard if the building had no apparent damage, and "G2" if the building could be used, but suffered minor damage. This information then was entered into a database.

The ATC team did see placards with the Usability Category indicated. The Level 2 Rapid Assessment form shown in Appendix A has a place for these at the end. An individual who performed safety evaluations in the CBD reported that his team did assign Usability Categories to all buildings (Swanson, 2012). Another individual reported that by March 14, 2011 all Level 2 Rapid Evaluations were using Usability Categories as a matter of policy (Turner, 2012).

The ATC team felt that Usability Categories can be useful in providing local jurisdictions with building status information in a very concise format. If the Usability Categories are understood by building owners and occupants and the public, their usefulness will be even greater. Adding such categories to the placard may be worth considering.


Figure 3-1 This building was used as an "indicator building" by Christchurch officials. Note the shipping containers used as barricades at the front of the building.


Figure 3-2 Close-up of the indicator building of Figure 3-1.


Figure 3-3 Examples of emergency stabilization measures. (Source: Prof. Sri Sritharan, Iowa State University)

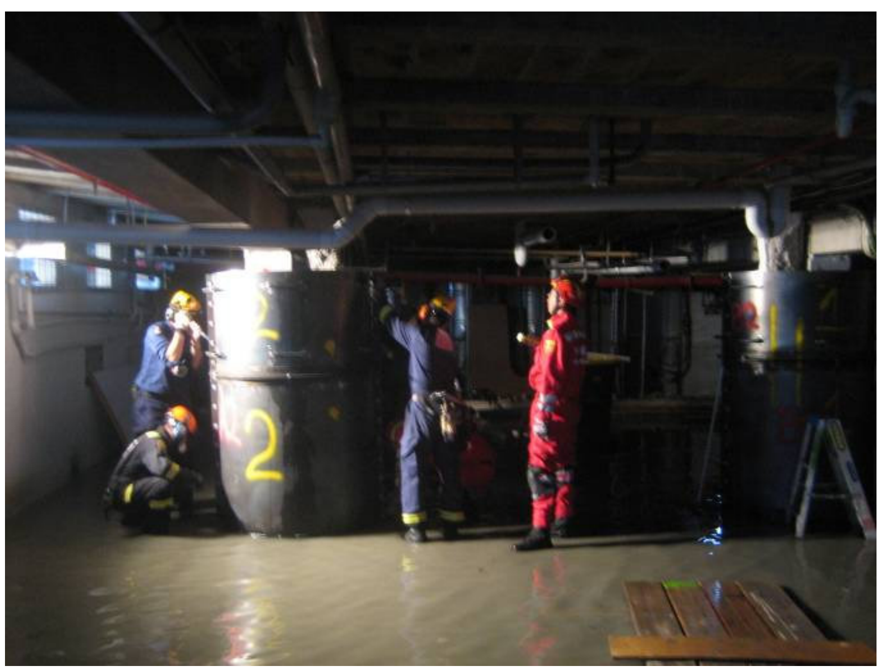

Figure 3-4 Emergency stabilization of columns. (Source: Holmes Consulting Group)

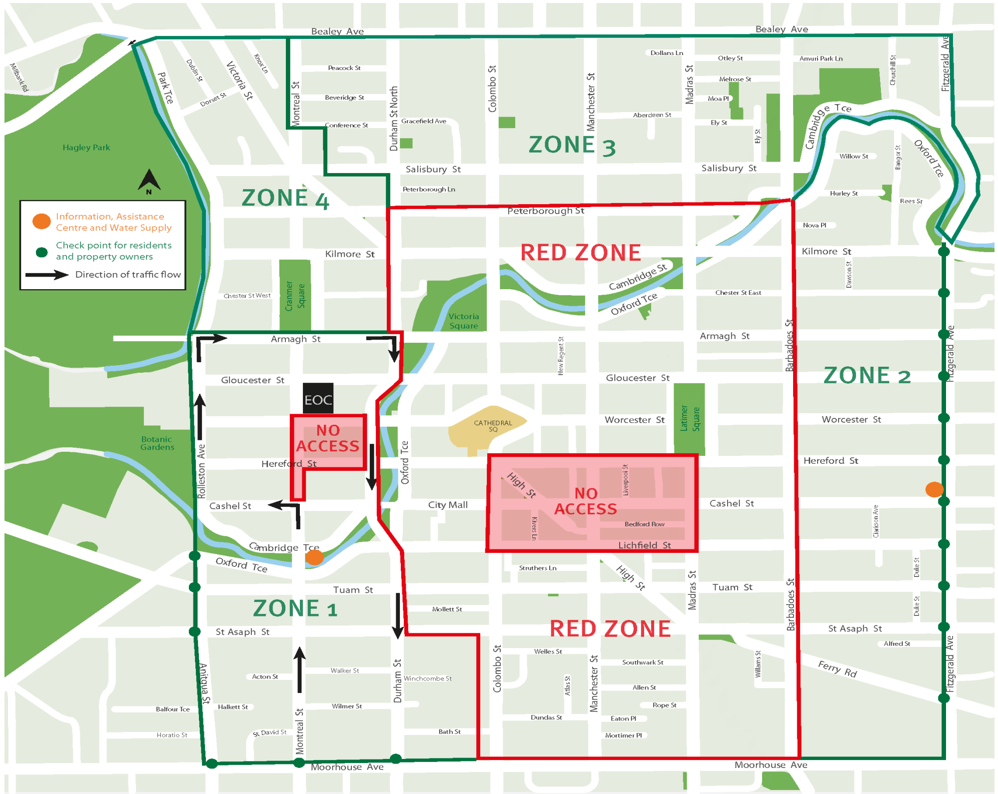


Figure 3-5 Central Business District Cordon. (Source: Christchurch City Council)

Figure 3-6 One of the cliffs in the Sumner District that experienced slides and rock falls. Note debris at bottom of cliff. (Source: GNS Science, 2011a)


Figure 3-7 Community shower in the heavily damaged neighborhood of Bexley. These were provided for residents of the liquefaction areas who remained in their homes.

Figure 3-8 Shipping containers were used to keep possible falling debris from damaged buildings from blocking streets. The red containers protect the building to the left and the portion of the street adjacent to it from the URM building on the right.


Figure 3-9 Shipping containers were frequently used to barricade roads from slides and rock falls.

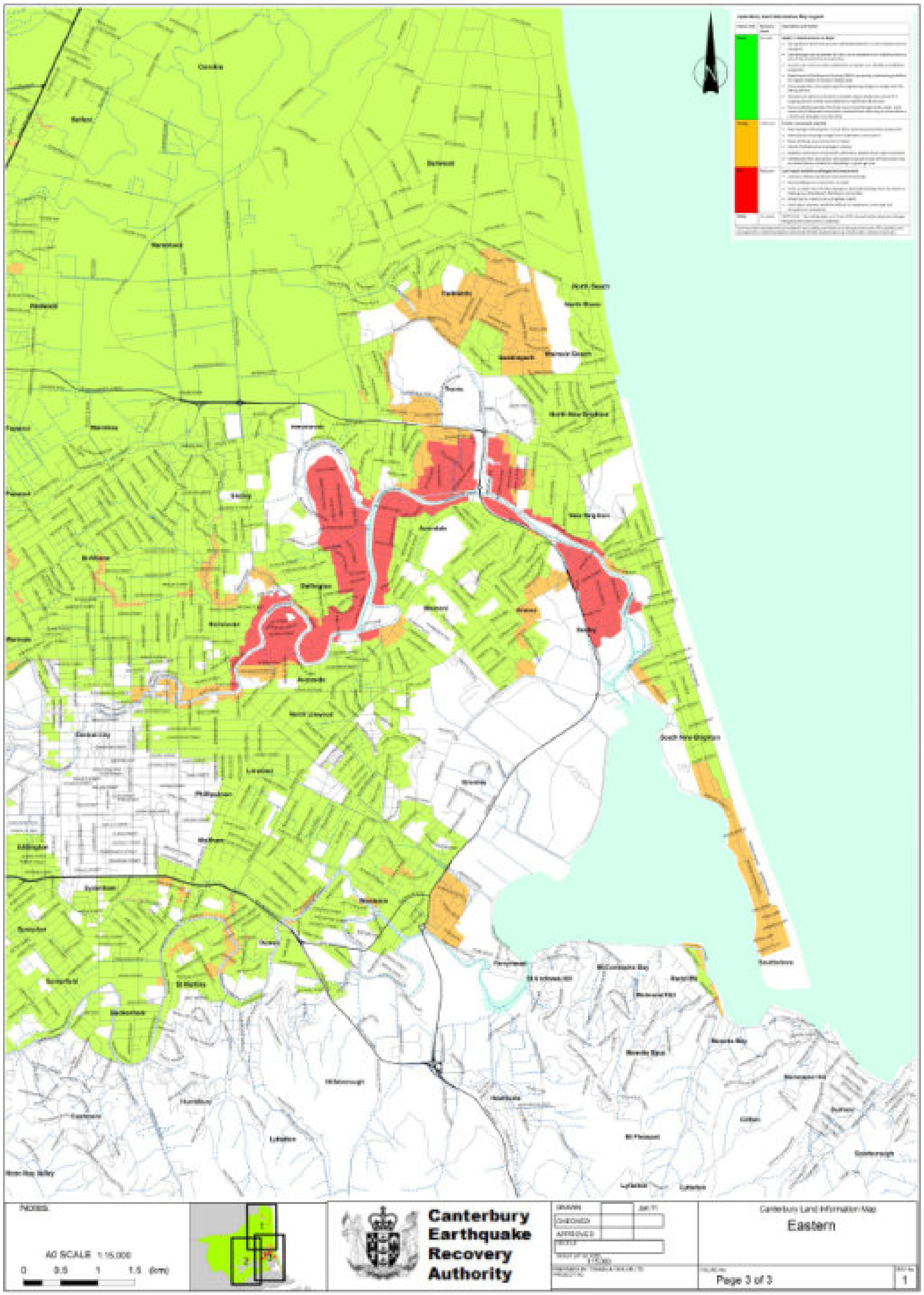


Figure 3-10 Land Zonation Map by Canterbury Earthquake Recovery Authority for the eastern suburbs as of June 2011 (CERA, 2011).

# 4. Safety Evaluation Issues in Christchurch

Christchurch and New Zealand officials were faced with an unprecedented disaster. Government was not prepared for the sheer number of building safety evaluations that needed to be made. While initially caught off guard, authorities responded well and developed a program that led to the inspection of 72,000 buildings in the first 10 days after the February earthquake.

This section presents the ATC team's observations on the safety evaluations that were conducted following the February event. Additional information is contained in CCC (2011a, 2011b), MCDEM (2011), (Galloway and Hare, 2012), and Royal Commission (2012). The team's observations on the preparation and management of safety evaluations are presented in Section 5.

The ATC team's assessment of safety evaluations was done by: (1) meeting and de-briefing officials and other individuals involved in the safety evaluations; (2) touring the damaged areas and observing the placarding, barricading, and other postearthquake measures taken; and (3) participating in a meeting with government officials, structural engineers and others dissecting the safety evaluation process. The team also met with national government representatives in Wellington at the end of its visit to discuss preliminary findings.

## 4.1 New Zealand Safety Evaluation Guidelines Were Under Development

A document prepared by the New Zealand Society for Earthquake Engineering was used for building safety evaluations (NZSEE, 2009). This was based somewhat on the original ATC-20 document (ATC, 1989a) with changes to fit the New Zealand experiences and preferences. This was the "official" version at the time of the February earthquake. An updated version of the document was developed and made available on 14 July 2010 as a "draft" (NZSEE, 2010), but this was not used.

The NZSEE document covered primarily Rapid Evaluations and, because it was under on-going development, provided somewhat limited safety evaluation guidance. It did not contain instructions on how to inspect a building, examples of posting and barricading, guidance on how to inspect various types of buildings, guidance on filling out safety assessment forms and placards, and advice for dealing with occupants and owners of damaged buildings.

The current ATC-20 methodology is summarized in the second edition of the ATC-20-1 Field Manual (ATC, 2005). This document was published in 2005. It contains discussions and new topics not covered in the original, 1989 ATC-20 documents (ATC, 1989a and 1989b) and the 1995 ATC-20-2 Addendum (ATC, 1995). Unfortunately, both in the U.S. and elsewhere this was not widely known among users and potential users of the ATC-20 documents.

During interviews and meetings, the team discovered that many of the key personnel involved in the Christchurch safety evaluations were not familiar with the 2005 version of the Field Manual. Consequently, this potentially useful resource was not utilized.

While there are a number of similarities between the two documents, there were some terminology differences. For example, the NZSEE document has a second level of Rapid Evaluation, designated Level 2. This corresponds to the ATC-20 Detailed Evaluation and uses a similar safety assessment form. Both the ATC-20 Detailed Evaluation and the Level 2 Rapid Evaluation are to be conducted under the direction of the local jurisdiction, primarily by government employees, volunteer engineers, and engineers contracted by the government. The ATC-20 Detailed Evaluation is not intended to be "rapid". Instead, it is intended to be as thorough and comprehensive as necessary, using visual examination techniques, to evaluate safety. Hence, the name "Detailed", as in detailed visual examination, is used instead of "Rapid", as in rapid visual examination.

### 4.2 Safety Evaluations were Performed by Personnel with Limited Training

It was reported by a number of individuals interviewed that safety evaluation personnel received little or no training before the earthquake and only a relatively modest amount of training immediately after the earthquake and before going into the field.

Training of safety evaluators is essential to achieve uniform evaluations. Without training, or with limited training, different evaluators can arrive at different conclusions about the status of the same building. Also, recommendations for follow-up actions (e.g., barricading) can be different. One evaluator might close a sidewalk while another might close the entire street. Training is also important to avoid unnecessarily conservative postings. For example, a RESTRICTED USE posting may be more appropriate than the more restrictive UNSAFE posting.

### 4.3 Safety Evaluations Slowed by Lack of a Pool of Prequalified Personnel

There was no prior prequalification and certification of the Christchurch safety evaluation personnel. Not having a pre-qualified cadre of personnel to draw from put New Zealand officials in the difficult situation of trying to organize and qualify personnel on the spot. Understandably, there was little choice in the matter at the time.

Lack of a pre-qualified pool of inspectors slowed the process and caused problems. The reconnaissance team was told that due to concerns with the quality and variability of the initial posting of buildings (i.e., tagging) by less experienced engineers, many buildings had to be reevaluated and retagged. While New Zealand authorities had few choices given the timing of these earthquakes, a prequalified cadre that was already trained and that could be swiftly mobilized would better serve the public in the future.

### 4.4 Fading Ink on Placards

At the time of the ATC team's reconnaissance, many of the placards in Christchurch had been in place for up to four months. The color of some placards was faded, and the writing on many was difficult to read because the ink had faded.

A solution is to write on placards with water-proof, fade-resistant ink or pen and to have placards printed on durable, water-resistant paper.

### 4.5 Old Placards were Often Not Removed

It was observed that a number of buildings had two placards. One placard was typically from the first inspection, and the second from a subsequent follow-up inspection. Both were often left in place. Often they had different postings (see Figure 4-1 for an example). This became confusing when the ink faded, and it was sometimes difficult to determine which was the latest placard. Some buildings had a different kind of placard (Figure 4-2).

The preferred procedure is to have only one placard at a time. The practice of not removing the older placard can be confusing to both owners and occupants, especially if the placard becomes difficult to read from rain or fading ink, or the posting and restrictions on occupancy change from the initial evaluation.

Not removing the initial placard when posting a newer one was reported to be a procedural error (Brunsdon, et al., 2012 and Schotanus, 2012).

### 4.6 Full Advantage of the RESTRICTED USE Placard was not Taken

The RESTRICTED USE placard is designed to provide local jurisdictions with flexibility in posting. Occupants can continue to use a damaged building, provided use is in accordance with the restrictions that have been placed on the building. For example, if an otherwise undamaged house has a broken chimney, the occupants can continue to live there, but the fireplace and area within falling distance cannot be used.

One problem the ATC team observed was that many placards used in Christchurch had the phrase “No Entry Except on Essential Business” under the RESTRICTED USE title (see Figure 4-3 and Appendix A for examples). This statement appears to be inconsistent with the general intent of the RESTRICTED USE posting which is to permit safe use of damaged buildings. In contrast, ATC-20 expressly allows for evaluators to select a variety of options for restricting the use of a building.

The RESTRICTED USE placards used in Christchurch, several variations of which were observed, required that the evaluator mark the restrictions placed on a structure on the placard by checking a circle in front of a specific restriction. The placards had from two to five pre-written restrictions. Some versions had an optional blank line to be filled-in by the safety evaluator. For many buildings with RESTRICTED USE placards, it appeared that the placard was being used only to permit limited entry and not continual use.

Complicating matters was the fact that the meaning and use of the RESTRICTED USE placard may not have been well understood by all of those doing the safety evaluations. The initial 1989 version of ATC-20 was used as the guidance document for the NZSEE safety assessment guidelines. As result, the RESTRICTED USE placard was much more like the earlier ATC-20 LIMITED ENTRY placard used after the Loma Prieta, California earthquake.

In summary, the system used in Christchurch did not take full advantage of the flexibility of the RESTRICTED USE placard. Examples of typical restrictions and restrictions to cover unusual situations may be found in the 2005 ATC-20-1 Field Manual (ATC, 2005).


Figure 4-1 A building with two different placards. Often the older placard was not removed.


Figure 4-2 Another kind of "Red Tag" observed in Christchurch.


Figure 4-3 A RESTRICTED USE placard with the “Y2” Usability Category indicated in the upper right hand corner. The “L1” in the upper left hand corner probably refers to the fact that the building received a Level 1 Rapid Evaluation at the time of the posting.

## 5. Preparation and Management of Safety Evaluations

The ATC team spent time meeting with the officials who managed the safety evaluations. From these discussions, and conversations with others, a number of issues were identified that made the management of the safety evaluations after the February 2011 event difficult. These are discussed below.

### 5.1 Lack of a Prior Program to Train Safety Evaluators and Coordinators

NZSEE (2011) notes that:

> *"At the time of the September 2010 Darfield earthquake, only a limited number of NZ engineers had undertaken training in building safety evaluation. Pilot training courses based on the NZSEE Guideline were prepared in 2009 with funding provided by the Dunedin and Christchurch city councils. Two training modules…were delivered to Dunedin, Christchurch, and Wellington city council building control officials and engineers in 2009, and Hastings District Council and Waitakere City Council building control officials in 2010. In addition, all 24 NZ Urban Search and Rescue (USAR) engineers were trained in June, 2010. A wider rollout of training session through NZSEE and IPENZ was planned for late 2010."*

The scale of the September 2010 and February 2011 earthquakes was such that a large number of evaluators were needed, well beyond the number of those who had been trained. The ATC team was told by many officials that there was not a program in place to train sufficient numbers of safety evaluators (i.e., those doing the actual inspections) and coordinators (i.e., those overseeing and managing the work of the safety evaluators). Training was effectively done by the safety evaluators gaining experience in the field, after an introductory review of the subject before being sent out.

Pre-qualifying and credentialing of safety evaluators will create a pool of trained individuals that can be quickly mobilized to conduct inspections. Also, provisions for immunity from liability and worker's compensation for "volunteers" can be established in advance. In Christchurch, immunity from liability for volunteer engineers was granted by means of a contract (see Appendix B) between the individual and the emergency operations center manager (termed the "Controller"). However, no mention of worker's compensation insurance in the event of injury was mentioned in the contract.

One training and certification program is that of the California Emergency Management Agency (Cal EMA). They have trained and certified over 7,000 individuals. Cal EMA requires all students to provide their credentials at the time of the class. Credentials include a professional architect or civil engineering license (structural and geotechnical engineers in California are also civil engineers), or one of a number of building inspector certifications that require understanding of structural load path. These are checked against licensing board websites, and only those with current credentials are allowed into the active database for deployment. Those without these credentials are placed into an archive database, in the event they obtain their credentials later. Other jurisdictions in the U.S. outside of California also have training and certification programs.

### 5.2 No Prior Large Cache of Placards, Assessment Forms and Supplies

The team was told by some that the city of Christchurch had no prior large cache of safety evaluation placards and safety assessment forms and the supplies necessary for safety evaluations (e.g., caution tape, clear package tape for attaching placards, Rapid Evaluation forms, waterproof pens and placards). A cache of supplies kept in an appropriate accessible location would have made the initial start of safety assessment operations easier**.**

The fact that 72,000 inspections were performed in 10 days indicates that this issue was fairly easily overcome. Indeed, one engineer involved in the emergency assessments reported that when he arrived at the Emergency Operations Center the day after the February earthquake "all safety supplies including hard hat, steel toed shoes, high visibility vest, spray paint for danger markings, were available for all helping on triage teams" (Elwood, 2012).

### 5.3 Welfare Personnel Added to Safety Evaluation Teams

In discussions with Christchurch officials, it was learned that a typical safety evaluation "team" for houses and residential buildings might consist of four people: one safety evaluator, two "welfare" staff (e.g., members of a non-governmental organization such as the Red Cross), and a driver.

The consensus of those individuals interviewed was that the addition of the two welfare staff, while of aid to the occupants, significantly slowed the building safety evaluation process and is generally not desirable.

### 5.4 Placard Meanings Were Not Well Understood by the Public

Royal Commission (2012) notes that authorities used flyers, posters, and public meetings—mostly for residential owners—to try to explain the building safety evaluation process and the placarding categories. Nonetheless, the ATC team was told by a number of individuals that the public was confused by the INSPECTED placard. Under both NZSEE and ATC-20 procedures, the INSPECTED placard signifies that a building has been given a safety evaluation and found to have little or no damage. In other words, the seismic resistance of the building has not been significantly changed by the earthquake, and no other hazards are present.

After the Christchurch earthquake, many members of the public believed that the INSPECTED placard meant that the building was "safe". The assumption was that a building posted INSPECTED was "safe" in future earthquakes rather than continued use of the building is permitted because no change had resulted from the earthquake that resulted in the posting.

Under both NZSEE and ATC-20 procedures, a building that is undamaged and posted INSPECTED after a small earthquake may suffer significant damage or even collapse in a subsequent event that subjects the building to additional and/or stronger ground motions. In some cases, that is exactly what occurred in Christchurch, with downtown buildings being posted as INSPECTED after the distant September event, only to be damaged and posted UNSAFE following the much stronger shaking February event. The Pyne Gould and CTV buildings had been posted as INSPECTED following the September event. Both collapsed in February, killing many occupants. The scenario was highlighted by lawyers representing the victims in the Royal Commission hearings on the earthquakes.

A possible solution to this common misconception is to leave the owner or occupants of the building with a written explanation of the safety evaluation, what the placard on their building means, and where additional assistance can be obtained from the local jurisdiction. One engineering firm working for owners advised its engineers to indicate to the owner that the structure had “no diminished capacity” (Sharpe, 2011).

Building safety, whether structural or nonstructural, is always the primary responsibility of the building owner. The INSPECTED placard merely means that the building is as viable and safe as it was before the event, with no guarantee of future performance. Building owners who are concerned about the overall structural safety of their buildings, particularly older buildings, must pursue as investigation and possible structural upgrade to mitigate against future events.

### 5.5 Number and Location of URM Buildings was Unknown

The greatest number of damaged commercial buildings by far were constructed with unreinforced masonry (URM) bearing walls. URM buildings were also the cause of 42 deaths in the February 22, 2011 earthquake (Royal Commission, 2011). Many URM buildings were two- and three-story structures with cavity wall construction used on the exterior walls. The damage to many of these buildings was severe, and a great many businesses were forced to close.

University researchers (Dizhur, 2011) reported that, prior to the September event, the Christchurch City Council had inventory lists with approximately 2,300 URM bearing wall buildings. After field review by researchers studying the earthquake damage, it was found that a very large portion of these buildings were actually wood frame with brick veneer. Ingham and Griffith (2011a) estimate there were 958 URM bearing wall buildings at the time of the September 2010 earthquake. As part of a research project, they inspected 595. By July 25, 2010, they reported 224 URM buildings had been demolished in the Canterbury region.

Some communities in New Zealand have mandatory strengthening requirements for URM buildings. Christchurch had taken what is sometimes termed a “passive” approach to seismic retrofitting of URM buildings, meaning strengthening was triggered only when certain modifications to the building were made such as a change in occupancy type. Nonetheless, Ingham and Griffith (2011b) report that of the 368 URM bearing wall buildings surveyed in the CBD following the February event, 231 buildings had some level of earthquake strengthening, with 31 known to have no retrofit, and 106 buildings where it was not clear if they had been retrofit. 97% of the unstrengthened buildings suffered damage categorized as heavy, severe, or destroyed. This dropped to 58% for the buildings with strengthening. Strengthening levels varied widely, and those buildings with lower levels of strengthening did much worse than those with higher levels of strengthening.

Had there been an effective, mandated URM retrofit program with high levels of strengthening in Christchurch, the damage, loss of life, and business disruption that occurred would have been substantially less.

### 5.6 Placards were Used as Basis for Rendering Aid

It was reported that the posting of UNSAFE on a residence was used as the basis for rendering financial assistance to the occupants, with at least one volunteer organization offering funds directly to homeowners who had homes posted UNSAFE. This caused an undue interest in getting one's home tagged UNSAFE, which is not in line with the objective of making as many homes as possible available for use. Officials expressed concern about this, and the volunteer organization discontinued this policy.

### 5.7 Laws Hampered the Placarding Process

The posting of buildings following safety evaluation had the force of law only during the term of the New Zealand government's "emergency declaration". This activity was authorized under the Civil Defence Emergency Management Act of 2002, and not under the national Building Act of 2004. The Civil Defence placards expired on July 12, 2011. As such, a building owner could in theory remove an UNSAFE placard, for example, without legal consequence once the term of the emergency passed. The CERA website (as of November 9, 2011) addresses this as follows:

> ***Expiry of Civil Defence Placards***
>
> *As part of the response to the national emergencies following the Christchurch earthquakes, Civil Defence placed placards on residential and commercial buildings. The placards indicated that a basic safety assessment had been carried out and as a result, structures were classified as either red, yellow or green.*
>
> *The Civil Defence placards expired on 12 July 2011, however, identified dangers may still be present. You are advised to not reoccupy buildings that have been red placarded, to continue to follow yellow placard restrictions, and not to remove Civil Defence placards until you have arranged for structural assessment and work to be completed.*
>
> ***CERA notices and access prohibition list***
>
> *CERA notices replace the red and yellow placards posted by the National Controller during the national emergency which expired on 12 July 2011.*
>
> *They will be progressively posted on the listed buildings to replace the placards.*

To properly post a building so as to invoke the "Dangerous and Insanitary Building Section 124" of the Building Act required a separate posting by the Christchurch City Council. Only a small number of buildings had been posted in this way by the time the ATC team left the country.

The ATC team suggested that this issue be revisited by New Zealand authorities so as to include posting authority language in the Building Act.

### 5.8 Lack of Guidelines for Engineering Evaluations of Damaged Buildings

Both ATC-20 and the NZSEE Building Safety Evaluation guidelines (NZSEE, 2010) lack detailed guidance for conducting an "engineering evaluation" of a damaged building. This evaluation typically involves review of plans (if available), preparation of calculations, and may involve destructive exploration and materials testing. It is normally done after visual examinations cannot provide the information needed to properly assess the safety of a building.

After the highest level of visual examination has been done (this is a Detailed Evaluation under ATC-20 procedures, and a Rapid Evaluation Level 2 under NZSEE procedures), the engineer performing the "engineering evaluation" must decide on how further to assess the safety of the building. If drawings are available, the engineer can use the drawings, together with observations of the damage and prepare calculations to assess building safety and gage the capacity of the building to resist further aftershocks. The "engineering evaluation" is also used to determine shoring needs and emergency repairs.

Guidance for conducting an "engineering evaluation" is generally lacking in the U.S. except for steel moment frame structures, concrete and masonry wall structures, and that provided by a recent ATC document. FEMA 352 provides complete guidance for the evaluation and repair of earthquake-damaged steel moment frame structures (FEMA, 2000). FEMA 306 provides guidance for the evaluation of damaged concrete and masonry wall structures (FEMA, 1999a), and repair guidance is given in the companion FEMA 308 document (FEMA, 1999b). ATC-52-4 (ATC, 2010) provides guidance for the three model building types discussed below. In New Zealand, the Engineering Advisory Group of DBH has been developing guidance for conducting engineering evaluations, with draft updates being issued periodically (EAG, 2011).

### 5.9 Lack of Repair Guidelines for Damaged Buildings

After the September 2010 Canterbury earthquake, guidelines were developed for house repairs and reconstruction (DBH, 2010). Unfortunately, there was little or no published guidance for repairs to buildings other than residences. This is also a problem in the U.S.

The DBH guidelines were largely prescriptive, and much responsibility was placed on the user. After review of these guidelines, the ATC team felt that the guidelines may be difficult to use without expert assistance.

The Engineering Advisory Group (EAG) of DBH proposed guidelines that could be followed by the Canterbury Earthquake Recovery Authority (CERA) for repairing structures as part of the EAG (2011) draft guidelines on engineering evaluations. These draft guidelines were reviewed in a presentation on June 29, 2011 while the ATC team was in New Zealand.

Repair and strengthening requirements have been in U.S. building codes for many years, but are typically vague and general. More recently, more specific provisions have been added to model U.S. codes, such as Chapter 34 of the 2009 International Building Code (ICC, 2009). The ATC-52-4 document (ATC, 2010) has provided much more detailed repair and strengthening provisions for three model building types: single family residences; multi-unit multi-story wood frame residential buildings; and older concrete buildings, but much work remains.

# 6. Research and Development Needs

A number of research and development needs have been identified. These involve both postearthquake building safety evaluation as well as the subsequent evaluation, repair and rebuilding of damaged buildings. The reconnaissance team also identified collaboration opportunities and the recommended next steps and priorities for ATC.

## 6.1 Research Needs

### *6.1.1 Understanding Fractured Bars in Shear Walls*

Identification of the cause of the fractured vertical bars in shear walls is an urgent need. This is crucial for arriving at the correct finding when making visual safety evaluations (e.g., using the ATC-20 Rapid and Detailed Evaluation methods).

It is recommended this phenomenon be duplicated in laboratory tests to confirm its cause and identify those concrete strength and vertical reinforcement situations that create the conditions for this to occur.

### *6.1.2 Seismic Strengthening of URM Cavity Walls*

There were over 900 unreinforced masonry buildings (URM) in Christchurch (Ingham and Griffith, 2011a). The susceptibility of URM walls to out-of-plane failure has been correlated to the height-to-thickness (*h/t*) ratio. A taller, thinner wall has a higher *h/t* ratio and is more likely to be damaged. Many of the URM buildings in Christchurch utilized hollow cavity wall construction for the exterior walls. The exterior and interior wythes of these walls were separated by a air gap and typically interconnected by nominally-spaced metal ties. As a result, they may behave more like two walls with high *h/t* ratios than a single solid wall with a lower *h/t* ratio. Many of these walls experienced spectacular failures with the exterior wythe spalling, and often large portions of the wall suffering significant damage. The failures in cavity walls were numerous and occurred throughout the city, particularly in the Central Business District where there was a very high concentration of URM buildings.

Hollow cavity wall construction is common in the eastern U.S., particularly in colder winter regions. To date there are no guidelines for seismically strengthening this type of construction. ASCE/SEI 41 (ASCE, 2007) and the 2009 International Existing Building Code (ICC, 2010) do not mention it.

ATC-20 also lacks guidance for evaluating these buildings after earthquakes and does not address the significant life safety risks associated with them.

Cavity wall URM construction is an important topic to be addressed in future versions of both ATC-20 and ASCE/SEI 41.

### *6.1.3 Investigation of the Performance of Adhesive Anchors*

Ingham and Griffith (2011a) noted that there are reports of poor performance of adhesive anchors that are widely used in the seismic rehabilitation of URM buildings. A study between the University of Minnesota and the University of Auckland is underway. It will be important to determine if observed poor performance is due to poor installation practice, to failure of the adhesive, to failure of the substrate to which the dowel is attached, or to a failure of the other aspects of the wall-to-diaphragm assembly. In the U.S., manufacturers are required to perform extensive standardized testing through organizations such as the International Code Council Evaluation Service. This testing covers the dowel-to-masonry connection, but not the other portions of the connection assembly.

### *6.1.4 Strong Motion Instrumentation of Buildings in New Zealand*

New Zealand has a fairly robust network of strong motion instrumentation at ground sites, but a more limited network of instrumented buildings. The continuing aftershocks in Christchurch provided an excellent opportunity to instrument buildings that would experience strong shaking. This opportunity was largely missed.

In the future, much greater instrumentation of buildings is recommended to provide building officials, structural engineers, and researchers the opportunity to study building behavior during earthquakes and to identify needed code changes.

### *6.1.5 Performance of Building Shoring and Stabilization Methods*

The September 4, 2010 Darfield earthquake and the February 22, 2011 Christchurch earthquake just 5½ months later provide a unique laboratory to investigate and evaluate the performance of temporary building shoring and seismic stabilization methods. Many of the buildings damaged in the 2010 Darfield earthquake had seismic stabilization and shoring installed that had varying levels of success and performance from the stronger 2011 Christchurch earthquake. This research can lead to much needed building shoring and seismic stabilization design guidelines for structural engineers, public officials and building owners (Swanson, 2012).

### *6.1.6 Building Damage Assessment by Instrumentation and Measurement*

Some buildings are so large that detailed visual examination becomes very difficult and time consuming and can require a substantial effort. Ceilings, interior walls and exterior cladding can conceal damage to structural elements and connections. For example, a 40-story steel moment frame building can experience significant inelastic deformations in an earthquake and be left with permanent residual story drifts. Connections can be highly deformed or even broken. These can be difficult to locate.

Research is needed to devise and develop practical ways to find, measure, and report building damage. This topic has not been sufficiently addressed and needs development.

Some initial thoughts are presented below. For purposes of this discussion, structural damage can be simplified into "global" and "local" damage. Global damage includes entire building leaning, or an entire story offset significantly from the one below. This type of damage can be easy to find if it is severe, but can be difficult to find if it is not. Local damage consists of damaged and failed structural members and connections. This includes buckled steel braces, fractured or buckled reinforcing steel in concrete members, seriously cracked masonry and concrete shear walls, and local wall-roof separations (without the obvious roof or wall collapse). Local damage can be much harder to find.

Examples of some possible techniques and technologies that can be used to find and report global damage are listed below. Many of these are suitable for large buildings, particularly high-rise structures, but some can be used on low-rise buildings:

- Laser measurements in elevator shafts to locate and measure permanent story displacements at any level.
- GPS measurements on the roofs of buildings to compare before and after changes in roof horizontal position and any "twist" in plan that may have occurred.
- Three-dimensional laser scanning of building exteriors to detect changes in geometry and possible on-going creep (e.g., progressive lean).
- Comparison of recorded base spectra with the design base response spectra for the building to determine if structural damage is likely.
- Strong motion instrumentation of buildings sufficient to enable "forensic" modeling using the actual recorded earthquake time-histories to predict (i.e, help find) and assess difficult to locate structural damage.
- Development of cost effective of personal computer (PC)-based monitoring/recording systems located in the building to collect and store information in a retrievable, useful form.
- Development of cost effective of PC-based programs to process and report on building structural damage from information obtained by various measurement/recording devices based on validation studies that reliably associate the changes in measured engineering demand parameters such as acceleration and drift with observed damage.
- Wireless strong motion sensors to reduce costs of instrumentation associated with cabling.

Local structural damage is often hidden from view by finishes, but it might be found by such methods as:

- Strain gages on steel braces to measure and report maximum strains experienced in a bracing system.
- Continuity gages on braces to determine if a brace has fractured.
- Tests that can determine the extent of strain hardening in reinforcing steel that has occurred and its remaining capacity to undergo further strain.
- Viewing "hatches" that open and close for visual observation of key structural members and connections so as to avoid the need for destructive exploration. In steel frame buildings, this may require specifically designed, locally removable fire-proofing.

- Comparison of before and after foundation measurements. For example, comparison of reference footing elevations at selected points to determine if pile, caisson, or spread footing settlements have occurred. These could be due to subsurface structural failure (e.g., pile failure) or permanent ground settlements caused by liquefaction or ground consolidation.

Development of new techniques and technologies cannot eliminate the need for visual examinations, but these can greatly assist in postearthquake safety evaluation of large buildings.

The above lists are preliminary. There are no doubt more techniques and technologies than those listed that can become tools for enhanced safety assessments and assist in the determination of needed structural repairs. Research and development is needed to make these available for postearthquake use. A key issue will be to identify and categorize technologies that can be used after the event versus those that need to be in place prior to the event to provide a baseline for comparison.

A workshop of interested parties (building officials, researchers, structural engineers, instrumentation manufacturers, and building owners) would be a logical next step in a path to develop new instrumentation and measurement "tools" for building safety evaluation.

## 6.2 Guideline Document and Training Needs

### *6.2.1 Guidelines for Engineering Evaluations and Repair of Damaged Buildings*

There is a lack of written guidelines for the evaluation and repair of damaged buildings for many building types, but guidelines are available in the U.S. for steel moment frames, and concrete and masonry wall buildings. Two excellent resources are FEMA 352 (FEMA, 2000) for the evaluation and repair steel moment frames and FEMA 306 (FEMA, 1999a) and FEMA 308 (FEMA, 1999b) for the evaluation and repair of concrete and masonry wall buildings.

ATC has recently prepared the ATC-52-4 document (ATC, 2010) as part of the Community Action Plan for Seismic Safety (CAPSS) project in San Francisco, California. It provides recommended repair and strengthening requirements and associated code language for three model building types: single family residences, multi-family wood frame residential construction, and some older concrete buildings.

Similar guidelines, however, are lacking for braced steel frames, older concrete tilt-ups, URM buildings, and some other building types. Lack of a complete, coordinated set of guidelines for all major types of construction is an important gap between the time when a building is initially posted and when full restoration of building use is achieved. Filling this gap is considered an urgent need.

An Engineering Advisory Group to the New Zealand Department of Building and Housing has been drafting a document for detailed engineering evaluations of damaged buildings to assist in determining if they can be occupied (EAG, 2011).

### *6.2.2 Guidance for Repairing or Removing Buildings Damaged by Liquefaction*

Liquefaction can result in differential settlements and lateral spreading that can damage structures. The damage can be so severe that the structure is a total loss and must be removed, or it can be quite slight. Obviously, there are degrees of damage between these two extremes.

After the 2010 Canterbury earthquake, the Department of Building and Housing developed guidance on house repairs and reconstruction due to liquefaction damage (DBH, 2010). This document provided some guidance, but considerable additional coverage is needed.

Other than these initial DBH guidelines for residences, there are no guidelines available to advise engineers and building officials on how to repair damage caused by liquefaction. Guidance is needed on such things as: (1) when a building should be demolished because it cannot be economically repaired or strengthened; (2) when an area is unfit for future or rebuilt underground utilities; (3) how and when to re-level a house; and (4) recommended soil mitigation techniques to prevent or minimize differential settlements in the future (to avoid recurrence of liquefaction-induced damage).

### *6.2.3 Guidelines for Management of Postearthquake Safety Evaluations*

A devastating earthquake like the February 2011 Christchurch event is generally a “once in a lifetime” experience for local jurisdictions. After the event, those that have gone through it become quite knowledgeable about what is needed. Unfortunately, this “knowledge” is generally not available before the event. What is needed for future managers are written guidelines on how to manage safety assessments, and the rebuilding process that follows. Any such guidelines need to draw heavily on experience (i.e., lessons learned) from past events.

A document needs to be developed that summarizes lessons learned and provides advice on how to do things. The document needs to cover a variety of topics. A partial list adapted from Kornfield (2012) of these is given below.

Who is in charge?
Emergency response plan
Initial “windshield” surveys to find areas of damage
Determining what areas should be systematically inspected
Making an initial “triage” assessment
Use of city personnel
Use volunteers
Use of outside contractors
Communications (e.g., field to office)
Supplies to be maintained (placards, forms, caution tape, etc)
Dispatch of safety evaluation teams to the field
Transportation means
Public contact procedures
Media contact and public information

Cordoning, barricading and emergency stabilization
Emergency orders (e.g., emergency demolitions, falling hazard abatement, shoring)
Documentation and recordkeeping (e.g, data bases, red-tagged building reports)
Legal issues and emergency powers
Change of building status – what are the rules?
Issuance of emergency permits
Attention to on-going, required functions (e.g., resuming normal operations)
Mutual aid agreements
Re-inspections after aftershocks
Establishing an Emergency Operations Center (and back-up EOC)

Written guidelines for managing the safety evaluation and rebuilding process after earthquake disasters is a significant and generally missing “link” in the U.S. This is a high priority for future development. The New Zealand building safety evaluation guidelines (NZSEE, 2009 and NZSEE, 2010) have sections “Management of the Process” and “Planning Before an Event” that contain a number of the elements needed in a U.S. document. Cal EMA has had a “Coordinator” manual since 2004 that will be updated with insights from the New Zealand experience. The ATC team considers this to be a high priority, and additional broader efforts beyond those planned by Cal EMA may be needed, particularly for areas without them.

#### *6.2.4 Guidelines for Cordoning, Barricading, Shoring and Emergency Stabilization*

Additional guidelines should be developed on cordoning, barricading, shoring and emergency building stabilization. The 2005 ATC-20-1 Field Manual (ATC, 2005) has some guidelines on barricading, but only briefly mentions cordoning areas. Similarly, the whole topic of emergency building stabilization and shoring needs to be addressed in a document that can be used after an earthquake to draw on previous experience and successful practices.

Because of the potentially severe impact of cordons on individuals and businesses, particularly prolonged closures, advice on this topic needs to be carefully developed.

#### *6.2.5 Guidelines for Private Engineer Posting of Buildings*

Local jurisdictions utilize their own staff as well as staff obtained from such sources as other communities (by mutual aid agreements) and volunteers to make safety evaluations. Often safety assessments made by these personnel concentrate on unsafe buildings, buildings that threaten streets, and residential structures. Commercial structures, unless they are threats to occupants and the public, frequently receive a lower priority.

In Christchurch, the local jurisdiction “signed-up” and authorized private structural engineers to inspect and post commercial buildings under the authority of the Christchurch City Council. The private engineers were paid by the building owners.

Provision for this concept, or some variation of it, should be added to the ATC-20 procedures. Using private engineers to inspect and post buildings on behalf of the owners will reduce the demand on the manpower resources of the local jurisdictions, and this can speed the emergency shoring and stabilization process, and also speed the repairs necessary to get the building back in full use. This is a high priority.

The City of San Francisco has form of private engineer posting. This is the Building Occupancy Resumption Program (BORP). Under this program, a pre-event inspection plan is developed for a building and approved by the City, and engineers to make the inspections are pre-qualified. At least one other California city has adopted this program.

### *6.2.6 Development of Seismic Design Criteria for Stairs*

Stairs collapsed in eleven buildings (Hopkins, 2012). Two high-rise buildings in Christchurch, the 22-story Grand Chancellor and the 19-story Forsyth Barr, had precast stairs that failed (see Figures 6-1 and 6-2). In both buildings, occupants were trapped in the upper stories. Several reports (BECA, 2011; Bull, 2011; and Dunning Thornton, 2011) provide additional details, and DBH has issued a Practice Advisory (DBH, 2011b).

Without electric power to run elevators, stairs are the only means of egress in high-rise buildings. The issue of designing stairs to withstand, and be usable, after the worst expected earthquake shaking needs to be addressed. This topic is not fully addressed in either U.S. or N.Z. codes with rigorous design criteria. Existing buildings in the Midwest and eastern U.S. with precast stairs may be particularly vulnerable to similar damage.

### *6.2.7 Training of Personnel in Making Detail Evaluations*

An ATC-20 Detailed Evaluation of a building is a thorough visual examination generally made by structural engineers (i.e., those individuals qualified to design the building in the first place). In the case of soil movements, landslides, and slope failures, geotechnical engineers and/or geologists are required.

In the U.S. presently, there is no publically available program for training structural engineers (or geotechnical engineers) in performing ATC-20 Detailed Evaluations. Similarly, there was no such program reported in New Zealand. Currently, most ATC-20 training consists of a four to six hour basic introductory program.

Given the difficulties and challenges of performing ATC-20 Detailed Evaluations, it is thought that at least a four-hour program for structural engineers would result in a much better trained workforce to work off the inevitable backing of Detailed Evaluations following earthquake disasters. A similar program for geotechnical engineers and specialists in liquefaction, subsidence, and landslide/slope stability problems is also desirable.

### *6.2.8 Usability Categories*

When updating ATC-20, consideration should be given to the introduction of Usability Categories, or something similar. Use of these may provide additional information to both the local jurisdiction (by being entered in a database) and to the owners or occupants of the buildings. Obtaining this information can often be done at the same time as the initial posting with little or no additional effort.

### *6.2.9 Aftershock Risk*

Christchurch suffered greatly from aftershocks, and there are lessons to be learned by the experience there. Relatively large aftershocks occurred that produced new significant damage and required re-inspections.

The ATC-20-1 Field Manual (ATC, 2005) provides guidance with “wait periods” before entry and “time limits” on the length of entry. These are from ATC TechBrief 2 (ATC, 1999) and are based on aftershock research by the U.S. Geological Survey, primarily for California earthquakes. The guidance given in the Field Manual (and TechBrief 2) should be updated for new information and research broadened for applications beyond California. Discussion of “foreshocks” should be included.

ATC-20 advice on aftershocks can also be expanded to include discussion of those buildings and situations (e.g. URM falling hazards, nonductile concrete buildings) most susceptible to further damage of a life-threatening nature. Those making safety evaluations, particularly of damaged buildings, need to have in mind the remaining capacity of the seismic force-resisting system. A current practice in the U.S., and one not written down, is that the building being inspected must be capable of surviving another event of the same intensity without collapse (i.e., a repeat of the earthquake that caused the damage in the first place).

### *6.2.10 Shelter-in-Place Guidelines*

Formal guidelines need to be developed to allow shelter-in-place for those homes and residences safe to do so. This involves not only building structural and nonstructural safety, but includes concerns about public health, sanitary issues, and fire protection concerns. Can a toilet be used, or must portable toilets be brought in? Are the electrical and gas services safe to use? For densely populated urban areas such as San Francisco, this is a major post-event concern (Kornfield, 2012). If shelter-in-place can be used, the number of public shelters needed can be lessened, perhaps substantially.

### *6.2.11 Digital Records*

With the rapid evolution of digital phones with GPS and picture capabilities, ways of conveying building assessment information to emergency centers needs to be further developed. One practice reportedly used in Christchurch was taking a photograph of the building and the resulting placard and forwarding this to the EOC.

### *6.2.12 Postearthquake Safety Evaluations and Long Term Recovery Issues*

The primary focus of postearthquake safety evaluations is on rapid evaluations to determine which buildings have suffered significant damage that should prevent reoccupancy. The evaluations are intended to occur quickly, in the aftermath of the event and take place when aftershocks pose potentially significant risks. As time passes, aftershock potential diminishes, recovery becomes the primary focus, and yet the placards may remain. The sheer scale of damage and the number of red-tagged and yellow-tagged buildings in Christchurch has meant that there are still many tagged buildings nearly two years after the initial 4 September 2012 event. There has been a constantly evolving set of policies and ordinances related to addressing placard status and requirements as recovery has proceeded. The interrelationship between the original placard; changing seismicity; and the community's recovery goals, policies, and legal requirements is an issue that bears discussion from a diverse set of stakeholders.

## 6.3 International Collaboration Opportunities

There are many significant lessons that can be learned from the Christchurch earthquake damage, postearthquake safety evaluation process, and the repair and strengthening that will occur as the city recovers. Some lessons can be shared now, and an international workshop is recommended where detailed discussions can take place. Findings from longer term research will take more time and might best be shared in future conferences.

As New Zealand has investigated the causes behind the damage that occurred and what steps should be taken, it has shown significant interest in involving international researchers and practitioners in reviewing reports and recommendations. By the same token, New Zealand researchers and practitioners should be encouraged to serve as reviewers of U.S. documents and those of other countries. Shared production of documents of mutual interest may be possible.

Potential collaborating organizations in New Zealand include the New Zealand Society of Earthquake Engineering (NZSEE), the Department of Building and Housing (DBH), the Structural Engineering Society of New Zealand (SESOC), the Institution of Professional Engineers of New Zealand (IPENZ), and the Building Officials Institute of New Zealand (BOINZ).

## 6.4 Recommendations for ATC

Some of the above recommendations are best done by academic researchers in collaboration with practicing engineers, likely in New Zealand. The reconnaissance team, however, believes that ATC is an excellent organization to lead the development of the guideline documents noted above in Section 6.2, provided funding can be obtained. While all of the activities noted above are considered important, the reconnaissance team has prioritized its recommendations into initial steps, high priority items, and other important items.

### *6.4.1 Initial Steps*

The following initial steps are recommended to be done within the next year.

- Continue to foster interest with potential collaborators and funders.

- Convene a small working group to establish goals, an agenda, and identify potential participants for a focused workshop to initiate the ATC-20 update process. For this, international participation is desired.
- Conduct the workshop. At the workshop, solicit ideas for the future of ATC-20. For example, should it be a large single document, with many chapters covering the topics noted above, or should it be a family of related ATC-20 documents, or some combination? The workshop should consider recent experiences in Italy and Japan, in addition to New Zealand.

### *6.4.2 High Priority Guideline Documents and Training Programs*

The following guideline documents and training programs are considered to be of high priority. It is recommended these be developed within two to four years.

- Update the basic ATC-20 document guidelines and the ATC-20-1 Field Manual. The two documents need to be consistent and current. This would include more research and observations made since the 2005 update of the Field Manual, and provide additional detail on such issues as liquefaction-induced damage, nonductile concrete building evaluation, and cavity wall URM building inspection.
- Guidelines for managing the postearthquake safety evaluation process. Identify steps needed to run a successful program and the preparations required before the event
- Guidelines for private engineer posting of buildings. This will relieve the manpower shortage and speed the restoration of damaged buildings and facilities, particularly the larger buildings and the more complex facilities.
- Guidelines for cordoning, barricading, shoring, and emergency stabilization.
- Seismic design criteria for stairs in new construction, and criteria and methodology for evaluating the safety of stairs in existing buildings (and mitigating their deficiencies).
- Guidelines for sheltering residential occupants in place.
- Training of structural and geotechnical engineers on conducting Detailed Evaluations.

### *6.4.3 Other Important Guideline Documents*

The following guideline documents are considered important to develop, but these may not have the same priority as those in 6.4.2, or may take longer to develop. It is recommended these be completed within the next four to six years.

- Guidelines on conducting Engineering Evaluations (as defined by ATC-20) of damaged buildings.
- Guidelines for the evaluation, repair, and strengthening of damaged buildings. This broad topic can take the form of individual documents for a specific building type. A document is also needed to address the evaluation, repair, and strengthening of buildings damaged by liquefaction.
- Seismic strengthening criteria and methodology for URM buildings with cavity wall construction. This task may take some time to resolve, but many parts of the U.S. have the same type of vulnerable URM cavity wall buildings as found in Christchurch.

Today, a large damaging earthquake in the Midwest and eastern parts of the U.S. will likely have similar devastating consequences.

## 6.5 Summary Thoughts for the Future

One enduring observation from the reconnaissance team's visit to Christchurch is that much of the damage and difficulties experienced could have been lessened had measures been taken beforehand.

The first, and probably the most important measure, is to take steps before the event to deal with known seismic risks. This can be done by identifying vulnerable buildings at risk of collapse and mandating that they be retrofitted to appropriate levels, and by limiting development in areas with liquefaction and other geologic site hazards. For example, lacking mandatory strengthening requirements, many of the URM buildings in Christchurch had not been retrofitted, and they performed noticeably worse than those that had been strengthened, particularly compared to those strengthened to relatively high levels (Ingham and Griffin, 2011b). The extensive URM damage had an enormous effect, both on businesses and the entire community.

Second, measures must be taken before the earthquake to prepare for "the after event situation", thereby lessening its effects. Things in this "preparation" category include having a comprehensive earthquake disaster plan, maintaining supplies, and training safety evaluation personnel and managers. For example, summarizing the experience of those who have managed damaged assessment and recovery efforts can provide future managers with the knowledge and tools needed to effectively deal with the post-disaster situation. Communities must be made aware of what happened in places like Christchurch so they will better grasp why it is so important to adequately prepare.

The research, development, collaboration, and training recommendations proposed above will address a number of these concerns. If these items are not done, then cities in the seismic regions of the U.S. run the risk of repeating all or parts of the Christchurch experience.

Figure 6-1 The 19-story Forsyth Barr building. Occupants were trapped in the upper floors when precast stairs collapsed.


Figure 6-2 Failed precast concrete stairs from the 19-story Forsyth Barr building.

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# Appendix A

## Placards, Checklists and Forms Used in Christchurch

Christchurch City Council

GREEN

# 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

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
CITY COUNCIL · ENVIRONMENT

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

# Christchurch Eq. RAPID Assessment Form - LEVEL 1

Inspector Initials ______
Territorial Authority: Christchurch City

Date of Inspection ______
Time ______

Exterior Only ☐
Exterior and Interior ☐

**Building Name**

Short Name ______
Address ______

GPS Co-ordinates S° ______ E° ______
Contact Name ______
Contact Phone ______

Storeys at and above ground level ______ Below ground level ______
Total gross floor area (m²) ______ Year built ______
No of residential Units ______

Photo Taken Yes No

**Type of Construction**

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

**Primary Occupancy**

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

Investigate the building for the conditions listed below:

| **Overall Hazards / Damage** | **Minor/None** | **Moderate** | **Severe** | **Comments** |
|---|---|---|---|---|
| Collapse, partial collapse, off foundation | ☐ | ☐ | ☐ | |
| Building or storey leaning | ☐ | ☐ | ☐ | |
| Wall or other structural damage | ☐ | ☐ | ☐ | |
| Overhead falling hazard | ☐ | ☐ | ☐ | |
| Ground movement, settlement, slips | ☐ | ☐ | ☐ | |
| Neighbouring building hazard | ☐ | ☐ | ☐ | |
| Other | ☐ | ☐ | ☐ | |

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

**INSPECTED** ***GREEN*** ☐ **RESTRICTED USE** ***YELLOW*** ☐ **UNSAFE** ***RED*** ☐

**Record any restriction on use or entry:**

**Further Action Recommended:**

*Tick the boxes below only if further actions are recommended*

☐ Barricades are needed (state location):

☐ Level 2 or detailed engineering evaluation recommended

☐ Structural ☐ Geotechnical ☐ Other:

☐ Other recommendations:

**Estimated Overall Building Damage** (Exclude Contents)

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

Sign here on completion ______

*Date & Time* ______
*ID* ______

*Inspection ID* ______ *(Office Use Only)*

# Christchurch Eq RAPID Assessment Form - LEVEL 2

Inspector Initials ______ Date ______

Territorial Authority: Christchurch City Time ______

Final Posting (e.g. UNSAFE) ______

**Building Name**

Short Name ______

Address ______

GPS Co-ordinates S° ______ E° ______

Contact Name ______

Contact Phone ______

Storeys at and above ground level ______ Below ground level ______

Total gross floor area (m²) ______ Year built ______

No of residential Units ______

Photo Taken Yes No

**Type of Construction**

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

**Primary Occupancy**

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

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

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

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

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

**INSPECTED** *GREEN* | *G1* | *G2* |

**RESTRICTED USE** *YELLOW* | *Y1* | *Y2* |

**UNSAFE** *RED* | *R1* | *R2* | *R3* |

**Record any restriction on use or entry:**

**Further Action Recommended:**

*Tick the boxes below only if further actions are recommended*

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

**Estimated Overall Building Damage** (Exclude Contents)

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

Sign here on completion ______

*Date & Time* ______

*ID* ______

*Inspection ID:* ______ *(Office Use Only)*

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

General Comment ____________________________________________

____________________________________________

____________________________________________

____________________________________________

## Usability Category

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

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

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

**Recommendations for Repair and Reconstruction or Demolition** (Optional)

# PLACARDED BUILDINGS
## RISK ASSESSMENT

**ZONE:** _____ **Grid ID:**______ **Existing Placard** ______________

**TYPE:** ____________________

**ADDRESS:** ______________________________

**OTHER:** ______________________________

**Type of Construction** (Tick Only One)

☐ Timber frame ☐ Steel frame ☐ Tilt-up concrete

☐ Concrete frame ☐ RC frame with masonry infill

☐ Concrete shear wall ☐ Unreinforced masonry ☐ Confined masonry

☐ Other: __________________________

Detached ☐ Semi detached ☐ Fully Attached ☐

**Risk of building collapsing or part of building collapsing onto adjacent property or public space.**

Low ☐ Moderate ☐ Severe ☐

**Risk of building collapsing or part of building collapsing into itself or onto its own property only.**

Low ☐ Moderate ☐ Severe ☐

**Potential occupancy of Public space and/or adjacent building**

(cul-de-sac, planted area → low), (collector road, house, isolated shop → moderate), (arterial, shopping mall, grandstand → severe)

Low ☐ Moderate ☐ Severe ☐

**Overall building damage** 0 – 25% ☐ 25 – 50% ☐

50 – 75% ☐ 75 – 100% ☐

**Recommend action to address the immediate damage:**

Demolition ☐ RISK#: __________

**OR** Partial Deconstruction i.e. remove parapet

__________________________________________________________________

__________________________________________________________________

**OR** Alternative Options i.e. Prop, Brace etc

__________________________________________________________________

__________________________________________________________________

**Assessors Comments:** ______________________________________________

__________________________________________________________________

FD ☐ PD ☐ OTI ☐ OTI Geotech ☐ MS ☐

FD = Full Demolition, PD = Partial Demolition, OTI = Owner To Initiate, OTI Geotech = Owner To Initiate Geotech investigation, MS = Make Safe

**Assessors Name:** ______________________ **Ph Num:** ______________________

**Assessors Signature:** ___________________ **Time and Date:** __________________

# Christchurch

## EARTHQUAKE RESPONSE

## We called to check on your health and the safety of your property. Unfortunately we missed you.

An external assessment of the building has been undertaken. A red placard has been placed where there is a significant risk of building collapse.

Where a red placard has not been placed, it is considered safe to enter. However there may still be hazards associated with using this building.

It is the owner's responsibility to engage a relevant building professional to make a full assessment of the building and remove any potential hazards.

**If you need help from us please call the City Helpline on 03 941 8999 or the Earthquake Helpline on 0800 779 997**

Visit www.ccc.govt.nz or www.canterburyearthquake.org.nz for more information

| | | | |
|---|---|---|---|
| Council telephone number: | (03) 941 8999 | Orion (electricity) | (03) 363 1286 |
| Earthquake Government Helpline: | 0800 779 997 | Healthline (24hrs) | 0800 611 116 |
| Earthquake Commission (EQC): | 0800 326 243 | Counselling | 0800 777 846 |

# Appendix B

## Private Engineer Posting Agreement

IPENZ ENGINEERS NEW ZEALAND — Te Rākau Whakamarumaru Ministry of Civil Defence & Emergency Management — Local Government New Zealand

# MEMORANDUM OF UNDERSTANDING FOR ENGINEERS VOLUNTEERING TO ASSIST TERRITORIAL AUTHORITIES IN A STATE OF EMERGENCY

The Purpose of this form is to provide standard agreement conditions for engineer volunteers to assess the safety of structures during a State of Emergency

## A THE PARTIES

Between: ........................................................................................................

*(Name of Building Safety Evaluation Leader, for Local Authority)*

And: ........................................................................................................

*(Name of Person Engaged, and Qualifications)*

Situation: ........................................................................................................

Location: ........................................................................................................

## B SCOPE & NATURE OF THE SERVICES: *(Delete those that do not apply)*

1) Rapid Assessment of safety of structures as per NZSEE Guidelines ____________

2) Or specify below:

## C DURATION OF SERVICES:

Start Date: ____________ until ____________ date; or for the maximum period of three days or until the Local Authority notifies the Engineer that the State of Emergency is over (if a shorter duration).

## D INFORMATION OR SERVICES TO BE PROVIDED BY THE LOCAL AUTHORITY:

a) *The Local Authority will provide the Engineer with means of identification to authorise them to undertake this work;*

b) *The Local Authority will ensure the Engineer has, or is provided with, appropriate safety equipment, and will be supported by at least one other person for safety in the field;*

c) *The Local Authority will ensure the Engineer is provided with standard report forms and signage as required;*

d) *The Local Authority will have procedures in place for tracking deployed engineers;*

e) *The Local Authority will ensure that the Engineer is briefed by the Building Safety Evaluation team as to procedures for this Local Authority;*

f) *The Local Authority will actively advise building owners that specific detailed engineering inspections are to be subsequently and separately arranged by the owners*

ADDITIONAL:

## E INFORMATION OR ACTIONS BINDING ON THE ENGINEER:

a) *The Engineer will follow instructions from the CDEM Controller, as provided by the Building Safety Evaluation Leader and by Emergency Services personnel.*

b) *The Engineer verifies that the qualifications stated above and in relation to prior training are correct;*

c) *The Engineer will not operate outside their field of expertise, unless under the supervision of another suitably qualified engineer;*

d) *The Engineer will not pass judgement on any facility that is known to be covered by a Priority Response Agreement unless this is specified under (B) above;*

e) *The Engineer will not release confidential information received in the execution of these duties to any other party, or for any other purpose save Building Safety Evaluation for this State of Emergency;*

f) *The Engineer will not talk to the Press or make any public statement during the work.*

ADDITIONAL:

F SPECIAL CONDITIONS: *Additional conditions that relate to this situation or services may be specified here.*

G PRIOR TRAINING:
The Engineer confirms that they have attended prior training sessions on post-earthquake building safety evaluation procedures YES/NO
If YES, specify date of last course ____________________

H SIGNED BY:

| FOR LOCAL AUTHORITY ON BEHALF OF THE CONTROLLER: | FOR ENGINEER: |
|---|---|
| NAME: ........................................................... | NAME: ........................................................ |
| SIGNATURE: | SIGNATURE: |
| DATE: | DATE: |

## NOTES TO MEMORANDUM OF UNDERSTANDING

1. The Local Authority and the Engineer agree that the services are acquired during a state of local or national Emergency declared under the Civil Defence Emergency Management Act 2002 and relate only to the special case for procuring rapid assessments of safety of structures.
2. This Agreement is for provision of engineering services to a Local Authority for the purpose of assisting in assessment of safety of structures. It does not apply to those personnel working for an Urban Search And Rescue Task Force, or other rescue team.
3. It is understood by both parties that these Services are provided in a voluntary capacity for the duration as specified above, under conditions of a state of emergency. There will be no remuneration for this work. Expenses incurred for travel and accommodation will be met by the Local Authority.
4. Should work proceed beyond the duration indicated or for purposes other than emergency response, a commercial contract must be signed.
5. The Engineer shall perform services for assessment of safety of structures in accordance with Building Safety Guidelines as produced by NZSEE [or other system of classification specified]. No other services shall be supplied without express instructions from the Local Authority.
6. In providing the services, the Engineer shall exercise skill, care and diligence expected of a competent professional. The Engineer should advise the Local Authority of any training or knowledge they have of building assessment systems as in (5) above.
7. The Local Authority shall assist in providing to the Engineer the co-operation of other emergency management personnel and equip him/her as appropriate. This includes providing identification and safety equipment, and providing induction in the Local Authority's emergency procedures, as in (D) on reverse.
8. The Local Authority will ensure that the Engineer is accompanied by another person (not necessarily an engineer) and that communication and tracking procedures are explained and accepted by the Engineer and his/her accompanying person.
9. The Engineer undertaking these tasks is aware of the special safety issues associated with entering or approaching the building or other structure.
10. The Local Authority shall provide to the Engineer, any information in its power to obtain which may relate to the services. Neither the Engineer nor Local Authority will be liable for operating without full information, where it would be impractical to obtain it within the time frame necessary to complete the assessment.
11. The Engineer is protected from liability under Section 110 of the Civil Defence Emergency Management Act 2002 in respect of his or her services carried out under the direction of the CDEM Controller, including liability for Health and Safety.
12. The Engineer shall not be considered liable for any loss or damage resulting from any occurrence during the period where the services are undertaken under the direction of the CDEM Controller.
13. The Engineer will not assume any obligation as the "Client's Agent" or otherwise pursuant to the Health and Safety in Employment Act arising out of this engagement. The Local Authority will be the person who controls the place of work. The Engineer will act in a considered manner regarding his/her own safety in any area which is, by measure of the emergency situation, a hazardous area.
14. The provisions of the Consumer Guarantees Act 1993 do not apply.