State of California
Seismic Safety Commission

Memo

To: Seismic Safety Commission

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Subject: **Update on Enhancements to CalEMA's Safety Assessment Program Emerging from Recent Earthquakes in New Zealand and Japan**

On September 1, 2011, the Commission entered into an interagency agreement with CalEMA for $31,380 to facilitate the development of interim, short-term enhancements to the state's building Safety Assessment Program (SAP). Local and state governments use SAP-certified volunteers to placard buildings with green, yellow or red tags that help speed recovery while ensuring that the public avoids exposure to unsafe buildings during recovery after earthquakes.

Task 1 of our agreement calls for CalEMA to produce a report that analyzes lessons learned from building safety assessment practices in Japan and New Zealand that are potentially relevant to California practices. The report also proposes interim, stop-gap or long-term recommended changes to California's Safety Assessment Program (SAP) or related emergency response activities such as road clearing, barricading, cordoning, and stabilization. CalEMA's Task 1 report is attached. In addition, an paper soon to be published by the American Society of Civil Engineering summarizing what happened in New Zealand is attached for background information.

CalEMA expects to issue a new SAP Coordinator training manual on January 9th. This manual will be used by CalEMA to train SAP Coordinators throughout the state during train-the-trainer workshops that will be partially funded by the Commission in February and March.

Mr. Jim Barnes, CalEMA's SAP Coordinator, will present a progress report to the Commission at our hearing on January 12th.

Staff Recommendation

The staff recommends that Commissioners become familiar with the attached Task 1 report and background paper and come prepared to the January 12th hearing to advise Mr. Barnes and Commission staff regarding this effort.

CAL EMA REPORT TO THE ALFRED E. ALQUIST SEISMIC SAFETY COMMISSION ON LESSONS LEARNED FROM SAFETY ASSESSMENT PRACTICES IN JAPAN AND NEW ZEALAND

November 23, 2011+ Suggestions by Fred Turner & Dick McCarthy

Executive Summary

Cal EMA will be improving its Safety Assessment Program (SAP) Coordinator Manual and related training incorporating lessons learned from the application of Applied Technology Council (ATC) Pamphlet 20 principles and practices used in Japan and New Zealand in response to their catastrophic earthquakes of 2011. This report summarizes the findings of investigations performed by Cal EMA staff on safety assessment responses in both countries, and identify those practices which will improve California's Safety Assessment Program. These improvements will be captured in a new version of the SAP Coordinator Manual and training, which will be presented in training throughout the state in the months of January through March 2012.

Background

On February 22, 2011, a shallow M6.2 earthquake on an unknown fault struck 6 km southeast of Christchurch, NZ, causing widespread destruction and loss of life. This earthquake was probably triggered by the larger M7.1 Darfield Earthquake that struck on September 4, 2010 on the Greendale Fault originating 40 km west of Christchurch. While the February earthquake released 30 times less energy, it generated shaking within Christchurch's Central Business District that was about twice as intense as the September earthquake because of the closer distance to the epicenter and rupture propagation effects. New Zealand authorities started up their ATC-20 based building safety assessment program in September and later tagged 72,000 buildings in the ten days following the February earthquake, coming up with some interesting and remarkable innovations in the process.

On March 11, 2011, a M9.0 subduction zone earthquake struck 60 miles offshore of Northern Japan, resulting in earthquake damage and a devastating tsunami that wrecked coastal communities and caused extensive loss of life. Japan has had an ATC-20 based national program for many years, and used its well-established procedures to assess building safety after this cataclysmic event.

An interagency agreement was signed between the Seismic Safety Commission (SSC) and the California Emergency Management Agency (Cal EMA) for Cal EMA to review the safety assessment practices of the two counties and review what might be useful to improve the processes in California. The working period for this contract is from September 1, 2011 to March 31, 2012.

Review of Japan's Safety Assessment Methods

Cal EMA reviewed documents describing the safety assessment methods used in Japan in general, as well as descriptions of the March 11, 2011 Tohoku Earthquake.

The Japanese methods used for its safety assessment calls for three stages of inspection:

- **1st Stage** is a Quick Inspection done within seven days of the event to determine safety against aftershocks.
- **2nd Stage** is a Damage Classification to survey the class of damage, and the necessity of restoration work, performed within 7 to 60 days of the event.
- **3rd Stage** is the Restoration Plans or Demolition Work considering cost and feasibility of same, and is performed after 60 days from the event. Retrofit is done to ensure earthquake resistance stipulated in the national Aseismic Retrofitting Expedition Act.

The Damage Classification Survey (2nd Stage) includes:

- overall damage (six classifications)
- foundation damage (within set deformation angles, four damage classifications, then a sliding scale for damage classifications for foundations with greater deformation angles)
- concrete building damage classification (six classifications)
- steel rigid frame building classification (six classifications)
- steel brace frame building classification (six classifications)
- nonstructural wall damage classification (six classifications)
- door damage classifications (six classifications)
- wood building damage classifications (six classifications, performed with a long checklist and two summarizing approaches. Approach 1 estimates the extent of damage with percentages for damaged foundation length, first floor length, number of columns, nonstructural wall finish area, and roof area. Approach 2 generalizes a worst case damage level for each of those elements.)
- special buildings damage classifications (high rises, long-span buildings, ancient structures).

After review and consideration, Cal EMA believes that Japan's program, while articulate and extensive in its data recovery, would be too time-consuming for use in California, and would require almost exclusive use of structural and civil engineers to accomplish. Also, many disasters, such as the Northridge Earthquake, took longer to do the "quick inspection" than seven days. Finally, safety assessment in California does not lead directly to restoration or demolition decisions, as these are made by building owners in consultation with their hired engineers or architects as economically driven (cost-effective) decisions.

Cal EMA also reviewed the safety assessment process and procedures used in Italy and Greece. The Italian process is reminiscent of the Japanese system, with a very detailed approach to analyzing the buildings and their damage. The Greek methodology was similar to the Italian

system for several earthquake disasters, but in 1996 a much simpler system was adopted; the Greek authorities felt that simpler, streamlined approaches were better for the purpose of readily identifying usable buildings as well as dangerous ones. Historically, fifty percent of Europe's earthquakes occur in Greece.

Review of New Zealand's Safety Assessment Methods

Cal EMA's lead statewide SAP coordinator traveled to New Zealand in late June 2011 as a private citizen, and as part of an ATC reconnaissance team. Firsthand knowledge of safety assessment procedures was therefore accessible.

While there were various problems with how the post-earthquake building safety assessment was done in New Zealand, the authorities accomplished a very difficult task in a short period of time. Many innovative ideas were used in response to the February 22, 2011 earthquake. It was possible to learn from the problems experienced by New Zealand authorities as well as from their successes. A list of potential improvements for the Safety Assessment Program and related emergency management issues in California follows. These are grouped into those items directly related to coordination of safety assessment in the field, and those that fall into emergency management factors related to building safety, such as cordoning and shoring below:

Safety Assessment Coordination

- Organize SAP inspector strike teams to assess specific occupancies for safety. For examples, teams of structural engineers could be used to clear high rises, while other teams would clear essential services facilities, still others low-rise apartment buildings, while the majority of the teams would be looking at one- and two-family residential buildings. This approach would be useful particularly for catastrophic earthquakes, as it assesses higher priority sectors of the community speedily.
- Include among the essential services facilities (along with police and fire stations, the Emergency Operations Center, and local government administration centers) for early safety assessment: pharmacies, grocery stores, hardware stores, water treatment plants, and wastewater treatment plants. By clearing these, the public can have ready access to medicine, food, bottled water, and repair supplies. Public health will also be enhanced by assuring the safety of water and wastewater treatment.
- Emphasize the importance of placard adoption by local government ordinances before disasters.
- Encourage the local government Building Official to be the safety assessment coordinator and remain in the operations office. (Note to Jim: This recommendation may be effective for small jurisdictions with limited damage, but for large jurisdictions with extensive damage, multiple coordinators that operate 24/7 are likely to be required to effectively manage assessment efforts that could occur over the course of weeks. Would ICS/NIMS

also require at the very least a backup SAP coordinator be designated in addition to a primary SAP Coordinator?)

- Suggest the use of smart phone applications for safety assessment, such as the free ROVER program available from FEMA. These are used to gather field data without the use of paper forms, and to upload SAP evaluation information from the field to local governments as work progresses. This has the advantage of reducing or eliminating data entry, and being able to upload photos of the affected structures as well.
- Review the meaning of the "Inspected" (green) placard in the Coordinator manual. An "Inspected" placard does not mean the building is safe against future earthquakes, only that it survived the last one in usable form. Building safety is always the responsibility of the building owner, who must make the building as safe as financially possible. Material in the Coordinator manual should emphasize this. Existing structures often fall behind modern building codes as these improve, and the building codes are a minimal life-safety standard that allows people to escape without the building collapsing. However, such a building may not be usable after a strong earthquake and face demolition and rebuilding, at great expense. It is therefore in the best interests of the building owner to mitigate the seismic hazard by having a professional engineer design a seismic retrofit beyond the code requirements, so the building not only does not collapse after an event, but can also be used. The "Inspected" placard only means that the building survived the last event and could be used as it was before, as of the date and time it was evaluated. It does not guarantee safety against future events.
- Use only permanent ink markers on placards.
- Always remove old placards when updating a posting on a structure.
- Jurisdictions should be aware of the location of all their most vulnerable structures, such as unreinforced masonry buildings, non-ductile concrete frame buildings, and buildings in liquefaction zones.
- Field equipment, such as placards, caution tape, forms, pens, staple guns or package tape, etc., can be broken down into backpack sized units set up to supply one team for five days of inspection. A list of suggested materials will be included in the new Coordinator manual.
- Recommend use of flyers for the following: information on how to arrange for help to enter unsafe buildings for possession retrieval; general information on recovering from the disaster, including the building department's standard procedures; and how to have the red or yellow tagged building changed to a green tag by abating the hazards through repair.
- Recommend that the safety assessment teams check in with the SAP Coordinator every ninety minutes or two hours, by phone call or text message. This can be used as a safety check, as well as an opportunity to revise assignments for assessment teams and provide a miniature progress report, if time allows. It also reduces travel times for assessment teams to and from the EOC and assignment locations.

- The SAP Coordinator should arrange with the Public Information Officer that a press release go out which explains what the placards mean, along with a review of the proper identification badges that the teams will have, and that the safety assessment service from local government is always free, so beware of persons trying to charge for this service!
- Discussion of the use of "monitor buildings" as they were used in New Zealand. Buildings of various construction types were used to observe the effects of aftershocks; if buildings of a certain type showed excessive damage, then all buildings of that type would be re-examined. Discussion would include the proper and improper use of this method, as well as the alternative, that of sending out SAP evaluators to re-examine all buildings after a strong aftershock, with its disadvantage of re-examining buildings that have no appreciable damage.

Related Emergency Management Issues

- Discussion of cordoning practices to fence off blocks or sections of a city when conditions merit. Such conditions that would warrant cordoning could include: dire collapse hazards from single or multiple buildings; demolition activities; extensive debris in streets requiring use of large equipment; extensive shoring that encroaches into traffic or public right-of-way; necessary security to prevent looting, vandalism, or arson; or non-structural hazards that present a danger to the public, such as hazardous materials or damaged utility systems.
- Note the use of shipping containers to create shoring for buildings, barricades against falling debris, and debris sheds to allow entry into buildings with nonstructural falling hazards, such as failing parapets.
- Include some basic guidance on bracing and shoring damaged structures, such as from Urban Search and Rescue training and other publicly available documents.
- Discussion of shelter-in-place options for temporary housing of affected populations. This would involve setting up temporary toilet and shower facilities, and potable water made available either by water stations or by flexible piping to homes from working or temporary water mains.

Conclusion

Cal EMA will begin work on rewriting the SAP Coordinator manual in the month of December 2011 using the information shown above, and will aim for completion of this and its related training presentations by early January 2012. Cal EMA will then embark on training of SAP coordinators throughout the state, to be concluded by March 31, 2012.

Post-Earthquake Building Safety Assessments for the Canterbury Earthquakes

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ABSTRACT

This paper explores the post-earthquake building assessment program that was utilized in Christchurch, New Zealand following the Canterbury Sequence of earthquakes beginning with the Magnitude (M_w) 7.1 Darfield event in September 2010. The aftershocks or triggered events, two of which exceeded M_w 6.0, continued with events in February and June 2011 causing the greatest amount of damage. More than 70,000 building safety assessments were completed following the February event. The timeline and assessment procedures will be discussed including the use of rapid response teams, selection of indicator buildings to monitor damage following aftershocks, risk assessments for demolition of red-tagged buildings, the use of task forces to address management of the heavily damaged downtown area and the process of demolition. Through the post-event safety assessment program that occurred throughout the Canterbury Sequence of earthquakes, many important lessons can be learned that will benefit future response to natural hazards that have potential to damage structures.

INTRODUCTION

In the early morning of September 4, 2010 a M_w 7.1 earthquake struck in Darfield, approximately 25 miles (40 km) west of Christchurch, New Zealand (GNS, 2011a). A significant amount of structural and geotechnical damage occurred due to this event, although no lives were lost. A M_w 4.7 aftershock was the largest of a series of events occurring on Boxing Day, December 26, 2010 which resulted in further

damage but no declared state of emergency. Nearly two months later, February 22, 2011, a M_w 6.2 earthquake occurred at 12:51 pm local time. Although this earthquake was smaller, it was closer to Christchurch and resulted in much higher population exposure (over 90,000 people) to Modified Mercalli (MM) intensity IX compared to other earthquakes (Table 1). The earthquake caused significant damage resulting in 182 deaths and multiple collapsed buildings (Royal Commission, 2011).

TABLE 1 – Comparison of Christchurch Earthquakes Columns

Event	Local Time	Population exposure at MMI			Fatalities	Major Injuries
		VII+	VIII+	IX+		
M_W7.1 Sept 4, 2010	04.35 am	298k	20k	2k	0	few
M_W 6.2 Feb 22, 2011	12.51 pm	64k	228k	92k	182	164
M_W 6.0 June 13, 2011	14.20 pm	236k	55k	0	0	0

Note: Columns labeled as "Population Exposure at MMI" are obtained from U.S. Geological Survey's PAGER system.

Many other aftershocks followed including a M_w 5.5 event that occurred at 1:00 pm followed by a M_w 6.0 at 2:20 pm on June 13, 2011 that caused further structural and geotechnical damage. Figure 1 shows the location of the aftershocks and triggered earthquakes that occurred in the Canterbury Region from September 4, 2010 until November 2011.

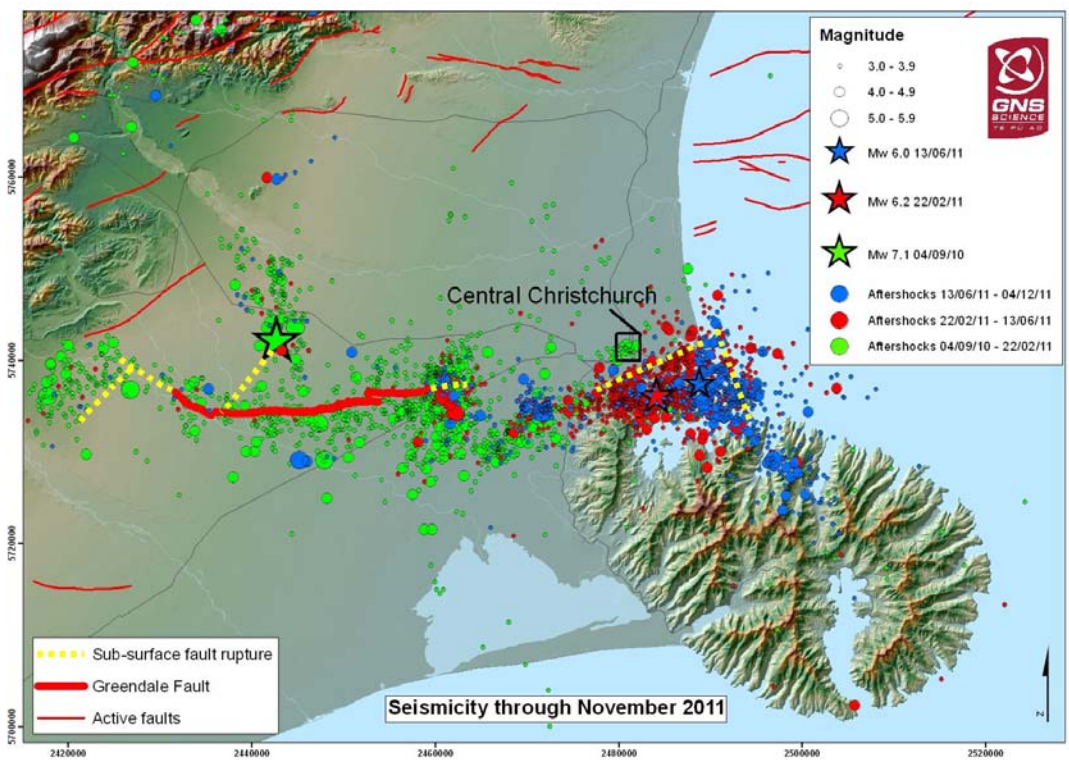

FIGURE 1 – Map of Seismic Activity in Canterbury Region (GNS, 2011b)

In addition to the many other societal and economic issues following natural disasters, one of the critical needs is the determination of building safety. The challenge is to quickly, efficiently and safely inspect buildings and differentiate between buildings that can be re-occupied and those which may pose threats. The Canterbury earthquakes present a unique opportunity to study the post-event safety assessment program utilized in Christchurch in order to further refine procedures for future events. One source utilized to develop the program in New Zealand is ATC-20 *Procedures (and Addendum) for Post-Earthquake Safety Evaluation of Buildings* (ATC 1989; 1995) which has been used in the U.S. since the 1989 Loma Prieta earthquake in Northern California. While this paper focuses on earthquake hazards, recent events such as the tornadoes in the southeast have demonstrated the need for an effective and efficient organization of qualified personnel to expedite safety assessments to allow people to safely re-enter their homes and businesses.

Due to the closely spaced sequence of significant earthquakes and the density of damage in the Central Business District (CBD) of Christchurch, the assessment procedure evolved from the initial earthquake in September through the final evaluations due to the June event. This paper will explore the timeline of the assessment program as well as the procedures used during the assessment and discuss which of these may be useful in U.S. communities for post-event safety assessments. A discussion of the procedures for building owners to repair buildings assessed with yellow and red placards will also be presented.

All the authors of this paper have been involved in some portion of the post-earthquake building safety assessment program in Christchurch, New Zealand. Several authors were part of teams assessing buildings in the CBD following the February event. Two of the authors were present at a workshop in Christchurch in June 2011 specifically aimed at learning from what happened and making recommendations for best practices for future planning.

SAFETY EVALUATION PROCEDURES

ATC-20 was published initially approximately one month prior to the 1989 Loma Prieta earthquake in Northern California. It was used during the response to Loma Prieta and improvements were made based on the experience. The next phase of the project resulted in ATC-20-2 (ATC, 1995), an addendum to the original document which made improvements to the procedures and updated the red, yellow and green placards posted on buildings following assessments. In 2005, ATC updated the ATC-20-1 Field Manual (ATC, 2005). This update summarizes the latest ATC-20 methodology and includes topics and discussion not covered in the ATC-20 series documents. Throughout this paper, the references to ATC-20 will include the addendum (ATC-20-2) and the second edition of the Field Manual (ATC-20-1) unless noted otherwise.

The assessment procedures in ATC-20 have different levels of building evaluations. The evaluation results are used to determine which structures can be classified as Inspected (green placard) and returned to normal usage and those that are either Restricted Use (yellow placard) or Unsafe (red placard). The quickest procedure, the “windshield” or reconnaissance survey is the initial step in

determining the severity and extent of the damage. As the name implies, this is essentially a “drive-by” assessment to assist in planning for more detailed analyses. The next level of evaluation is the Rapid Evaluation which typically includes only an exterior evaluation of the structure and can be carried out by building inspectors or properly trained personnel who do not need to be engineers. It is expected that a building can be assessed in 10 – 30 minutes. The evaluators initially determine the appropriate tag for each building. The yellow- and red-tagged buildings will be re-inspected later in greater detail.

The final two evaluations referred to in ATC-20 are the Detailed Evaluation and the Engineering Evaluation. Detailed Evaluations are typically done for buildings classified as Restricted Use or Unsafe by previous assessments. This more in-depth evaluation should be completed by a team of two structural engineers familiar with seismic design and includes both exterior and interior inspection of both the gravity and lateral systems. This type of inspection could take one to four hours depending on the size and geometry of the building and does not require exposing structural systems in most cases. It is likely that drawings would not be available during these evaluations. It should be noted that safety is paramount when entering damaged buildings. Engineering Evaluations are mentioned in the ATC-20 documents, but they are not described in detail. This inspection should be done by a qualified engineering consultant hired by the building owner to analyze the structure and design the required repairs.

The first document dealing with post-earthquake inspection in New Zealand was published in 1990 (Works). A team from New Zealand had deployed to Loma Prieta and used this experience to develop procedures based on the original ATC-20 document. One unique adaptation included an orange placard to provide another damage classification between the yellow and red tags. These procedures were later updated by a group from the New Zealand Society for Earthquake Engineering (NZSEE). This document was sent to all territorial authorities to provide a framework for post-event response planning (NZSEE, 1998).

Another update was undertaken by NZSEE in 2004. Two primary issues initiated this action. First, the Civil Defence Emergency Management and the Building Acts were revised and implemented in 2002 and 2004, respectively, which provided a legal basis for the procedures. The second issue was the city of Auckland purchasing a customized ATC-20 training package based on the original three placards causing potential conflicts with the four placard system. The resulting document (NZSEE, 2009) became the basis for New Zealand. Although the 2009 document returned to the three placard system it established minor differences. In lieu of the Rapid and Detailed Evaluation procedures, two types of rapid assessment were created. Level 1 corresponds to the Rapid Evaluation. Level 2 replaces the Detailed Evaluation but is not as comprehensive. An additional issue which came from this revision is the restriction that the building safety evaluation procedure can only apply during a formally declared state of emergency (NZSEE, 2011).

Additional updates based on usage of the procedures in the 2009 Padang, Indonesia and 2009 L’Aquila, Italy earthquakes had been completed but were unpublished at the time of the Darfield event. The first modification is the Level 2

Usability Categories which are shown in Table 2. These categories were developed to provide more details on structure conditions after Level 2 assessments. The second modification is the practice in Italy where a building is classified as "unusable for external risk only." This situation occurs if a normally safe building is threatened by an adjacent building or geotechnical damage and is expressed as the R3 category.

TABLE 2 – Usability Categories in 2010 NZSEE Guidelines (unpublished)

Placard	Usability Category (Safety Focus)
Green	G1 - Occupiable, no immediate further investigation required
	G2 - Occupiable, repairs required
Yellow	Y1 - No entry to parts until affected section repaired or demolished
	Y2 - Short-term entry only
Red	R1 - Significant damage - repairs/strengthening possible
	R2 - Significant damage - demolition likely
	R3 - At risk from adjacent premises or from ground failure

CHRISTCHURCH POST-EARTHQUAKE SAFETY EVALUATION

At 4:35 am local time on September 4, 2010 the M_w 7.1 Darfield earthquake struck. The epicenter was approximately 25 miles (40 km) west of Christchurch. The resulting structural and geotechnical damage was significant. Fortunately this earthquake resulted in no fatalities although two unoccupied URMs collapsed following a 5.1 magnitude aftershock within 3 miles of the buildings (5 km) (Wood, Robins and Hare, 2010). The Emergency Operations Center was established at 5:30 am that morning and was manned continuously until September 17. The official end of the state of emergency was at noon on September 16. Building assessments began the day of the earthquake and by the following morning at 6:00 am over 500 damaged buildings had been identified of which 90 were in the CBD (NZSEE, 2011). One of the challenges in the assessment process was having a sufficient number of Chartered Professional Engineers (CPEngs), the New Zealand equivalent of the U.S. Professional Engineer (PE) certification. This was not previously specified but was desirable for the experience and knowledge represented by the certification. In order to solve this problem the Institution of Professional Engineers New Zealand (IPENZ) was active in finding 94 volunteer engineers from around the country who served as inspectors over the course of the emergency period. Table 3 shows the statistics of the number of buildings evaluated after the September earthquake (NZSEE, 2011).

The Boxing Day series of aftershocks included a M_w 4.7 earthquake that occurred at 10:30 am. The epicenter of this event was only 3 miles (5 km) from the center of Christchurch. Additional damage to structures occurred, yet since many buildings were not occupied due to the holiday season there were no fatalities from this event. A formal state of emergency was not declared which meant that the assessment program was not utilized.

TABLE 3 – Building Assessments After the September 4, 2010 Earthquake

Placards	Buildings Inspected			
	Commercial		Residential	
Green	873	71%	5498	82%
Yellow	275	22%	937	14%
Red	88	7%	251	4%
Totals	*1236*		*6686*	

While not the largest energy release or longest duration of the Canterbury Sequence, the triggered earthquake that occurred at 12:51 pm on February 22, 2011 centered near Lyttleton (M_w 6.2) was by far the most damaging. Dozens of commercial buildings collapsed or partially collapsed. Additional geotechnical damage also occurred in the form of liquefaction, landslides and rockfalls. The state of emergency was officially declared the following day, the same day that planning was taking place for the post-earthquake assessment program. Due to the damage, the CBD was evacuated and fenced for safety. A major Urban Search and Rescue (USAR) operation was conducted to search for the injured and dead trapped in the rubble. The experience from September led to a more effective initial plan for what would be the largest effort in building assessments. One of the critical parts to this plan was to mobilize qualified CPEngs, especially those who participated previously in the assessment process. The process of bringing volunteer engineers from other areas of New Zealand continued for several weeks. Several engineers volunteered multiple times over the course of the effort. Members of the Earthquake Engineering Research Institute (EERI) reconnaissance team volunteered to be part of the assessment teams when they initially arrived. At that time, the Level 1 inspections had been completed within the CBD and the engineers were conducting Level 2 assessments. The buildings selected for Level 2 assessments were done on a priority basis. The first step included all buildings in the CBD and along primary arterial routes in the following categories (NZSEE, 2011):

- Buildings with a Level 1 red or yellow placard
- Green placarded buildings with four or more levels
- Green placarded buildings with high occupancy levels
- Green placarded buildings where a Level 2 assessment had been recommended

The following step was to assign a priority category to each building including: Very High (VH), Medium High (MH), Medium (M) and Low (L). Yellow placards were assigned to the M category, and red placards were assigned L. As the red and yellow tagged buildings were already identified as requiring action, their priority was not critical. Buildings most likely to be utilized in recovery or that would result in the ability to reduce the cordon around the CBD were given the highest priority.

The assessments continued through the end of March. On or around March 15th, the Christchurch City Council (CCC) started contracting assessment work to consulting engineers due to the challenge of finding volunteer CPEngs. The number of assessments performed between February 23rd and April 4th are shown in Table 4. A total of 66,242 buildings were assessed. In addition to those shown in the table,

over 72,000 residential structures were visited in less affected areas. As assessments following the Lyttleton event were the largest effort, discussion of particular elements of this effort such as the different operations organized by the Christchurch City Council (Cordon and Access, Suburbs, Shops and Critical Buildings), rapid response teams, indicator buildings and risk assessments for demolition of red-tagged buildings are discussed further.

TABLE 4 –Assessments After the February 22, 2011 Earthquake (CCC, 2011a)

Building Type	Assessment Placard			
	Red	Yellow	Green	Total
Commercial	977	1,093	3,221	5,291
CBD	1,058	1,005	2,253	4,316
Residential	1,776	Not Recorded	Not Recorded	60,951
Heritage	377	Not Recorded	Not Recorded	1,086

June 13, 2011 brought two additional damaging aftershocks. A M_w 5.3 occurred at 1:00 pm followed by a M_w 6.0 at 2:20 pm. Several buildings within the CBD experienced further damage or collapse as well as additional liquefaction, landslides and rockfalls in the hills surrounding Christchurch. Forty-six people suffered injuries and one elderly man passed away after being knocked unconscious by falling debris (GNS, 2011a; Wikipedia, 2011). There was no further state of emergency declared but engineers in the employ of the Canterbury Earthquake Recovery Authority (CERA) and the Department of Building and Housing (DBH) at the time performed assessments of buildings within the CBD to identify structures that had either become more critical or were now dangerous due to the aftershocks.

BUILDING ASSESSMENT FOLLOWING THE FEBRUARY 22, 2011 EARTHQUAKE

As the February event resulted in the most damage and greatest need for post-earthquake assessments, several unique aspects of the procedures used by the Christchurch City Council are discussed in more detail including the task specific operations, selection of indicator buildings, and the use of rapid response teams.

OPERATION CORDON AND ACCESS

Due to the large amount of damage in the CBD following the February earthquake, the decision was made to cordon off the district for safety and security reasons. The cordon operations included fencing of the central portion of the city and only allowing entry for official business such as building assessment. As the situation improved and hazardous buildings were remediated and Level 2 assessments were completed for all the buildings in a certain section, those sections were then opened to the public. The Level 2 inspection process required entry into possibly unsafe buildings. This was carefully controlled by the two USAR personnel attached to each team and the EOC. Anytime an unsafe building was entered, only one engineer and one USAR team member could enter the building while the others would inform the EOC of personnel in the damaged building. Professional locksmiths were employed

to open doors and allow inspectors to enter the buildings for which access was impeded. Each team was required to send a text message at regular intervals to the EOC to maintain accountability. The EOC allowed certain building owners or tenants into their buildings to retrieve important documents with an escort consisting of USAR personnel and a CPEng. Another operation going on within the CBD was removing vehicles which had been stranded. Some of the assessment teams were responsible for evaluating the garages and determining the safest routes for vehicles to be removed from multi-story parking structures.

OPERATION CRITICAL BUILDINGS

In the first few days and weeks after the February 22, 2011 earthquake, teams of specialists were established to focus on evaluating the safety and developing interim stabilization measures for 40 major damaged mid-rise buildings in the CBD. Several of these buildings were initially considered at risk of collapse and others had damage that could not initially be readily judged based on Level 1 inspections. Their risk of falling was in some cases impeding the safety assessments and recovery of smaller buildings nearby. Operation Critical Buildings teams visited the buildings, reviewed drawings made available by the Christchurch City Council building consent authorities (building officials), and attempted to judge the extent and seriousness of the damage before rendering Level 2 assessments and stabilization advice. While these Detailed Engineering Evaluations are more typical of assessments ordered by building owners, the hazard many of these buildings posed to surrounding buildings or public areas was significant enough to merit this analysis by the EOC.

OPERATION SUBURB

The large number of residences that were damaged due to both structural and geotechnical effects necessitated an enormous effort. Operation Suburb began on February 24, 2011 with 40 teams consisting of engineers, building inspectors and welfare officers visiting many of the suburbs surrounding Christchurch. The operation had a specific goal of assessing residences throughout the damaged area. A Level 1 assessment was carried out for all residences while a Level 2 was only carried out if evidence of significant damage was found. One primary difference was that the yellow and green tags were replaced with a white leaflet which said that the building had been inspected and was not considered hazardous. The leaflet did encourage building owners to hire a structural engineer to do a more detailed inspection. The red tag was still utilized for unsafe structures. This operation resulted in over 72,000 assessments of residential structures.

OPERATION SHOP

The purpose of Operation Shop was to quickly get suburban commercial buildings assessed so these facilities could be opened to serve the public. This included malls, grocery stores, hardware stores, surgeries and pharmacies.

OPERATION DEMOLITION

Due to the significant danger posed by many severely damaged structures, the need to demolish structures to allow access to roads and otherwise safe buildings prompted Operation Demolition. A primary avenue for determination of buildings

needing deconstruction or demolition was the assessment teams. During Level 2 assessments, any building receiving a red placard also required a blue risk assessment form. The content of the form evolved during the process. The primary information needed for the form included details of the structure, evaluation of the risk to other structures or public areas, and overall building damage classified by percentage.

As of March 31, 2011, 184 buildings had been identified for demolition. This number included critical need, total demolition, partial demolition and make safe categories. The distribution of buildings on the March 31 list included 106 non-historic, 70 heritage and 8 unclassified. The current list includes 796 buildings. The last group was added December 14, 2011. (http://cera.govt.nz/demolitions/list) The demolition operations were a controversial topic early on as heritage buildings were demolished without the due process typical of these types of buildings. There were also cases where building owners claimed they had not been informed prior to the demolition of buildings. Each building that was demolished had gone through review by the Civil Defence National Comptroller.

RAPID RESPONSE TEAMS

Rapid response teams were assigned at the beginning of each day. The teams had the same composition as other assessment teams. In lieu of having an assigned group of buildings to assess, these teams were placed on call in the EOC. Citizens in need of engineering services could call the EOC and request the services of an evaluation team and the rapid response teams would be sent. Common calls were for engineering investigation of residences or small businesses instigated by owners seeking to determine the status of their building which may not have been inspected previously. The rapid response teams were also used in some cases to allow owners or tenants to enter buildings and retrieve critical belongings. For these cases, the engineer and USAR personnel would make a decision as to how long the owner could remain inside the building and the areas within the structure that were accessible. The engineer and USAR personnel would then accompany the owner throughout the process. Close communication with the EOC was maintained throughout the process of entering possibly dangerous buildings.

INDICATOR BUILDINGS

The process of selecting indicator buildings was initially used in the September event. It was formalized following the February event (NZSEE, 2011). Eight buildings were selected to include representative samples of building types and damage levels. After any strong aftershock, the eight buildings were reassessed specifically to determine whether further damage had occurred. Based on the response of the indicator buildings, a re-inspection of similar nearby buildings would be required. Specific evaluation teams familiar with the selected structures were assigned each morning to be deployed to the indicator buildings in the event of an aftershock.

TRANSITION TO RECOVERY

The state of emergency was lifted on April 30, 2011. The Canterbury Earthquake Recovery Act was effective on April 18. One provision of this act was to extend the

life of posted placards by twelve weeks to July 12, 2011. During this time Canterbury Earthquake Recovery Authority (CERA) engineers posted notices to replace the previously applied red and yellow placards. Information was provided to building owners in two forms. The first, a four page pamphlet, "A Guide to Structural Assessments and Repair Work" (CCC, 2011b) gives general information about the process and requirements of the recovery act. The pamphlet states that "if a building has been structurally damaged it will require a structural assessment to indicate the building strength and may require an upgrade prior to occupation in accordance with the [Christchurch City Council's policy that] aims to get buildings strengthened to 67% of the New Building Standard" (CCC, 2011b). The second element is a guide to the requirements for detailed engineering evaluations prepared by the Engineering Advisory Group of the Department of Building and Housing (EAG, 2011).

LESSONS LEARNED

As with any significant undertaking, there was a combination of success and areas needing improvement. Some of the lessons learned throughout this process are listed below. It should be noted that many of these lessons are being included in an update of the California Emergency Management Agency's "Safety Assessment Program Evaluator Student Manual" (Cal EMA, 2011).

- Field equipment, such as placards, caution tape, forms, pens, staple guns or package tape, etc., can be broken down into backpack-sized units set up to supply one team for five days of inspection. Only permanent ink markers should be used for the placards.
- Inspector strike teams can be organized to clear specific occupancies for safety. For examples, teams of structural engineers could be used to clear high rises, while other teams would clear essential services facilities, still others low-rise apartment buildings, while the majority of the teams would be looking at one- and two-family residential buildings. This approach would be useful particularly for catastrophic earthquakes, as it clears up sectors of the community speedily.
- Include among the essential services facilities (along with police and fire stations, the Emergency Operations Center, and local government administration centers) for early safety assessment: pharmacies, grocery stores, hardware stores, water treatment plants, and wastewater treatment plants. By clearing these, the public can have ready access to medicine, food, bottled water, and repair supplies. Public health will also be enhanced by assuring the safety of water and wastewater treatment.
- The use of indicator buildings to observe the effects of aftershocks could be valuable. If buildings of a certain type showed additional damage from significant aftershocks, then all buildings of that type nearby would be re-examined. The challenge is to ensure that buildings are selected with similar height, site condition, structural system and construction period to achieve meaningful post-aftershock assessment results. Otherwise, either too many or too few re-assessments could result.

- A regular check-in with the assessment program coordinator every ninety minutes or two hours, by phone call or text message provides a good safety check. This can be used as an opportunity to provide a miniature progress report, if time allows.
- Clear communication to the public is critical. It is recommended that flyers be used for the following: information on how to arrange for help to enter unsafe buildings for possession retrieval; general information on recovering from the disaster, including the building department's standard procedures; and how to have the red or yellow tagged building changed to a green tag by abating the hazards through repair.
- The meaning of the "Inspected" (green) placard and the leaflet used for Operation Suburb caused confusion. An "Inspected" placard does not mean the building is safe against future earthquakes, only that it survived the last one in usable form. Building safety is always the responsibility of the building owner, who must make the building as safe as financially possible. This information must be clearly communicated to the public.
- If the impacted region includes a large number of heritage buildings (commonly referred to as historic buildings in the US), representatives from the heritage building community should be engaged early in the evaluation process to establish a process where these types of buildings can evaluated for safety while considering the historic nature of the structure.

CONCLUSIONS

Building safety assessment following the February Lyttleton earthquake was an enormous task which was carried out effectively. The experience from September served as an initial preparation. Several unique and effective procedures resulted from this effort. More will be learned as time goes by and as the recovery continues. Many of these experiences can the used to ensure that recovery from future events such as this one will be more easily facilitated.

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