Learning from Earthquakes, Chile, 2010

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Abstract

Over the past 100 years, only four earthquakes have exceeded the magnitude of the Mw 8.8 event in Chile on 27 February 2010. There was considerable damage from Santiago in the north, to south of the city of Concepcion. Although many buildings were seriously damaged, very few collapsed, leading to a low death toll, considering the magnitude and proximity of the earthquake. The majority of the 500 deaths due to the earthquake were along the coast, resulting from the tsunami.

The "Learning from Earthquakes" mission to Chile was arranged a few weeks later. This emphasised structural engineering aspects, but the team of 15 members covered other aspects including geotechnical, seismological, life-lines, town planning, and regulation. A brief summary of the main findings is given. A comprehensive final report for the mission will describe the results in detail.

Our ability to learn from earthquakes depends greatly on preparation. Some observations about the organisation of such a mission are presented. We conclude with the suggestion that preparation must commence well before the next earthquake occurs.

Keywords: Chile, learning from earthquakes, lessons

LEARNING FROM EARTHQUAKES

Practically all of our knowledge about earthquakes is derived from the study of past earthquakes, either from the effects of particular earthquakes, or the cumulative effects of many earthquakes. Invaluable knowledge and experience can be gained from detailed study of significant events, considering both "what happened that was expected, and what was not expected". For engineers the additional questions of "what worked, and what did not work" can be very useful.

The New Zealand Society for Earthquake Engineering (NZSEE), like the Earthquake Engineering Research Institute (EERI) in USA, has conducted intensive and detailed "Learning from Earthquakes" missions over recent years. The Australian Earthquake Engineering Society participated in the NZSEE mission to Chile following the 27 February 2010 earthquake, undertaken in late April and early May 2010, when the author joined the mission representing Australia and the discipline of seismology.

"Learning from Earthquakes" missions can emphasise many aspects of the events and their effects, seismological, engineering aspects of structures and life-lines, geological, geotechnical, plus emergency response and recovery. The mission to Chile was primarily concerned about structural engineering aspects, but with a large team of 15 members, it was possible to cover other aspects. The different perspectives provided much food for thought, both during the field visits by day and during the evening briefing sessions.

The chief of the mission was John Hamilton (Director of NZ Civil Defence Emergency Management) and co-leaders were Peter Smith (Spencer Homes) and Hugh Cowan (Earthquake Commission, EQC).

Figure 1: Some of the team members at a temporary school, Dichato.

Planning
In a non-English speaking country, language difficulties can limit a wide range of activities, from arranging visits, explaining the purpose of the mission, obtaining

permission to enter premises, to buying bus and train tickets. The team included two PhD students from Chile, both studying in New Zealand, Claudio Oyarzo Vera (University of Auckland) and Patricio Quintana Gallo (University of Canterbury). Together with many of their friends in Chile, and with Spanish-speaking co-leader Hugh Cowan, plus the good-humour and patience of almost everyone in Chile, the team experienced few significant language problems.

All team members participated in planning prior to the mission, and lists of questions were prepared before departure. The New Zealand embassy in Santiago provided very useful support, especially for arranging senior-level meetings

An advance party consisting of Peter Smith and Patricio Quintana Gallo arrived in Santiago about six days before the main party, to prepare the schedule of visits. This resulted in maximum efficiency for the mission as a whole, with minimal wasted time.

Implementation

The main mission activities took place on 14 consecutive days, with half-days of unscheduled activities every few days. This involved an early start each morning, and activities continued usually until sunset, followed by briefing and planning meetings. The large group, together with the preparation already undertaken, meant that many activities could be undertaken. These varied widely, with some including all team members, and others with sub-groups, including two-person and individual activities. The evening briefing and planning meetings meant that everyone could learn from the experiences of others, and everyone knew what other activities were taking place, and why.

Invaluable assistance was provided by the home team, before, during and after the mission, and all travel and accommodation arrangements went smoothly, from the perspective of the participants.

Reporting

Notes prepared during briefing and planning meetings provided the basis for later reports. Most of the mission members downloaded their digital photographs each night. Some did preliminary processing of photographs, and some developed comprehensive notes.

Team members submitted their best photographs, plus reports and other references, and these were shared with other team members. Everyone then reported on their area of activity for the final report. The final report has been delayed following the Christchurch earthquake, but will soon be available.

EARTHQUAKE CHARACTERISTICS

The 27 February 2010 earthquake of magnitude 8.8 was the fifth largest recorded world-wide since seismograph recording began in the 1880s. Alternative descriptions are “since 1900”, “during the past 100 years”, or “since the 1868 North Chile EQ”. The Utsu catalogue and others include eight events with a larger magnitude since 1687, making this one equal 9th (with four others at either Ms 8.8 or Mw 8.8) over the past

333 years. All events before 1900 are highly uncertain, and those before about 1960 still have considerable uncertainty. The lack of seismological discipline over magnitude continues to this day, and comparisons between scales are regionally dependent. Chile 1960, Alaska 1964, and Sumatra 2004 are definitely larger, East of Honshu 1933 MS 8.8 or Ms 8.9 probably was larger, making the Chile 2010 event equal fifth largest.

The earthquake struck during the early hours of the morning (3.34am local time), rupturing a section of the Nazca-South American plate boundary, 500 km long and 100 km wide, mainly beneath the offshore and coastal regions of central Chile.

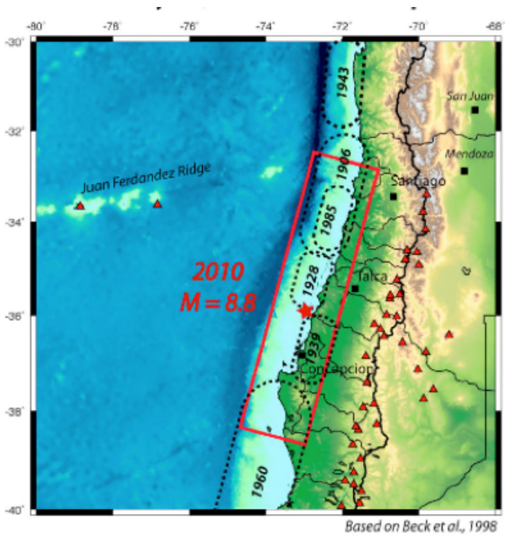

Figure 2: The earthquake rupture was about 500 km long and over 100 km wide. The epicentre was near the centre of the rupture, and the earthquake ruptured to both the north and south.

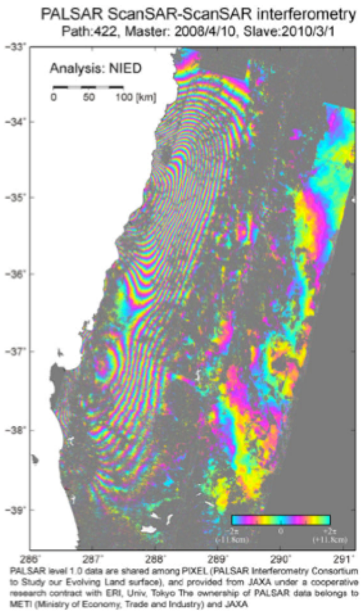

Figure 3: Satellite interferometry showed maximum vertical deformation north and south of the epicentre.

Teleseismic analysis of the earthquake occurred very quickly, with preliminary fault rupture models, GPS and satellite deformation results and indications of the aftershock distribution appearing within days. Figure 2 shows the approximate rupture region, and Figure 3 shows the vertical deformation of the earth's surface using satellite interferometry. Local seismograph data produced by the Geophysics Department of the University of Chile gave much better resolution of aftershocks, especially depths, than the teleseismic data. The earthquake occurred before implementation of a significant planned improvement in the local seismograph network.

Strong shaking lasted for more than 90 seconds, affecting approximately 80% of Chile's population and damaging at least 200,000 households. The fault rupture also warped the ocean floor and produced a tsunami. The local effects of the tsunami were devastating at various points along the coast in Chile but a damaging Pacific-wide tsunami was not generated, tide gauge records showed the waves were relatively minor in New Zealand.

The long period and long duration of shaking affected larger buildings more than smaller buildings such as homes. This contributed to a lower casualty rate than might otherwise have been expected, because fewer commercial or industrial facilities were occupied at that hour, and fewer people were out walking in the streets.

Liquefaction, spreading or settlement of soils was widespread and locally severe, indicating either strong amplification of shaking in soft soils and/or deformation with correspondingly more severe damage to structures and buried services in such areas.

Few seismic recordings were obtained locally due to relatively sparse local instrumentation, a deficiency that is now being rectified. Strong motion has never been recorded by instruments close to such a large earthquake in the past, so those records that were obtained will be unique and useful indicators of the motion expected from great earthquakes.

LESSONS LEARNED

Performance of Buildings and Infrastructure

The majority of buildings performed well, but widespread damage to non-structural elements such as suspended ceilings, glazing, partition walls and building services, highlights a serious vulnerability that is common elsewhere. The failure of non-structural elements contributed more than any other form of damage to downtime, displacement of occupants and loss of income and employment. This is a crucial area for reassessment of risk and improved awareness and practice.

Preparedness

In the coastal communities a large percentage of the population self-evacuated and survived the tsunami attack, although, tragically, some returned to the coast soon after, on hearing that a warning had been cancelled and were among the ~500 killed in this event.

Figure 4: Tsunami damage at Dichato.

The importance of household and neighbourhood arrangements to get through the first few days following a major event was exemplified by the low personal preparedness of citizens in the largest urban community affected (Concepcion/Talcahuano) and the insecurity that followed the breakdown of basic public services.

Master plans and guidance material for the reconstruction and recovery process are underway. More pre-event planning would have helped, and the issues identified highlight the importance of:

- Insurance - very low rates (3-4%) of voluntary residential insurance in Chile carry financial and social risks to an entire society.
- Exercising and coordination of disaster plans encourage risk reduction activities and improve the effectiveness of response.
- A robust understanding of hazard, risks and community identity are needed in order to harmonise urban planning with environmental capacity. Pre-event planning in these areas would have been helpful.
- Manual systems which are still operable to ensure that critical services can be maintained even if degraded.

Recovery

The redundancy of network elements, where available, facilitated quicker restoration of services. Examples include: double-bridging on principal highways, spare parts for substations, parallel elements for water supply.

Figure 5: The highway system in Chile is now dual carriageway, and most bridges come in pairs, one old and the other newer. About 16 highway bridges were seriously damaged, but in no case were both damaged disrupting traffic. The damaged bridges were more often the newer.

Figure 6: Innovative temporary measures were common. A failed bridge span near Concepcion was provided with a temporary Bailey Bridge to maintain traffic south of the city (photo: Noel Evans).

Other recovery-related factors include:

- The disaster opens a window of opportunity to build back better, with design solutions, so transitional arrangements and plans should be adopted to avoid inappropriate solutions.
- Disposal of waste is a major problem and can be done inappropriately, so plan for it prior to the event.
- Environmental management – non-compliance with consenting rules is inevitable in the early days/weeks following the earthquake, so there is a need to develop transition arrangements while upholding objectives.

LEARNING FROM FUTURE EARTHQUAKES

Engineers

Engineers experienced in the effects of earthquakes can assist local authorities from immediately after the main shock. Tagging buildings, supervising temporary repairs, devising alternative systems, and other tasks. The Learning from Earthquakes, Chile, 2010 mission was primarily about engineers seeing what worked and what did not work, in order to reduce vulnerability and risk in future earthquakes.

Seismologists

Seismologists can provide some assistance to local authorities by providing information about the earthquake and its aftershocks, but this is more psychological than practical. It is easier for the public to deal with something they know about than something they don't understand, but seismologists cannot provide specific information about what is likely to happen next.

Collection of data may not be of immediate help to people affected by the earthquake, but it will significantly help increase our knowledge and understanding of earthquakes, allowing a reduction in the impact of future events worldwide.

In a seismically stable country like Australia, there is not sufficient strong motion data to produce a local ground motion model (ground motion as a function of earthquake magnitude, distance and other factors). This, together with an earthquake recurrence model, forms the basis of earthquake hazard and risk estimates. To produce a ground motion model, motion should be recorded at approximately logarithmically increasing distances (say about 2, 4, 8, 16, 32, 64, 128… km from the epicentre). This should be repeated across the two-dimensional earth's surface for a range of azimuths. It is not possible to design an array of instruments that will do this for all locations, so our very sparse strong motion instrumentation will only allow minimal verification of ground motion models.

However, after a main shock has occurred, such an array can be deployed in time to record the largest aftershocks. Since these often occur soon after the main shock, the array needs to be deployed rapidly, within hours rather than within days. As well as having such instruments available, it is essential to have people who are very familiar with the instruments, and with the requirements of a good strong motion site.

Emergency Response

Apart from obvious direct assistance in rescue and recovery, observations from those experienced in emergency response may be useful in improving standard procedures.

Future Earthquakes Elsewhere

We can help the people affected, answering questions and perhaps making suggestions. Our professional colleagues are usually under some stress following a major earthquake, and appreciate being able to discuss their problems, ideas and perspectives.

What can be learned from the earthquake will often have much wider applicability than to the particular event itself. The information density following a major earthquake is much higher than that from a smaller earthquake.

One of the frustrating aspects of post-earthquake monitoring is when the visiting team arrives with their instrumentation, often seeking assistance, then departs without sharing data with local researchers.

Our Own Future Earthquakes

We must be prepared for rapid deployment of instrumentation for both high resolution geological aspects and strong motion recording for ground motion models. The possibility of a large aftershock provides a unique opportunity for installing a strong-motion network optimised for ground motion data, with station spacing increasing with distance from the earthquake.

The people deploying the instrumentation must be skilled, experienced and self-sufficient (to minimise the impact on rescue and recovery activities).

Communication with local authorities is usually welcomed, and may be essential.

CONCLUSION

The Chile earthquake was a major event that was very costly in terms of damage, left many people homeless, but caused relatively few casualties. It showed that risk mitigation measures, especially improved building standards, can save lives.

The huge cost of the earthquake, with preliminary estimates over US$30 billion, shows that economic factors should also be considered in developing building standards.

There is little doubt that the key to a successful "Learning from Earthquakes" mission is preparation. It is essential that response is rapid and largely self-sufficient. Preparation needs to occur *before* the next earthquake.

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