LEARNING FROM EARTHQUAKES: UNDERSTANDING THE REAL LESSONS AND THE ROLE OF URBAN PLANNING IN MITIGATION

David Brunsdon[1] and Andrew King[2]

Abstract

The New Zealand Society for Earthquake Engineering has organised field reconnaissance missions following virtually all of the major international earthquakes over the past two decades. A range of lessons has been identified, predominantly in relation to the physical and built environments. As technical understanding of the issues in these areas has matured, awareness of the need for greater emphasis to be given to establishing and communicating the economic and social lessons has emerged.

The lack of recent damaging earthquakes in New Zealand and Australia has tended to shape perceptions of earthquake risk which are much lower than the actual risk. These perceptions affect key decisions made on earthquake risk mitigation. It is thus imperative that we learn from major international events and communicate the relevant messages to all sections of the community, particularly key decision makers and their advisers.

It is a cause for increasing concern that this 'gap' exists between the high quality of seismic hazard and risk information and the general earthquake risk perception of the wider community. Urban planners have an important role to play in assisting engineers, scientists and emergency managers to close this risk communication gap.

1. Introduction

A range of lessons has been learned from the field reconnaissance missions organised by the New Zealand Society for Earthquake Engineering (NZSEE) over the past two decades. Multi-disciplinary teams have visited the scene of virtually all of the major international earthquakes in this time.

In the early stages of these reconnaissance visits, the lessons predominantly related to the physical and built environments, and their relationship with building regulations. This has led to a certain amount of physical mitigation, but not as much as NZSEE would like to have seen. There has however more recently been recognition of the need for greater emphasis to be given to establishing the lessons in the economic and social areas. Greater involvement of urban planners in communicating and applying the lessons is therefore seen as being essential.

This paper reviews the key lessons learned over the past two decades from major earthquakes both here and overseas with respect to the physical, built and social environments. The mitigation achievements are highlighted, as are the challenges in communicating the risk issues more widely. The role that urban planners can play in this process is discussed.

2. Seismic Hazard and History in New Zealand and Australia

The seismic hazard in the central part of New Zealand where the Pacific and Indian plates meet is high, and comparable to California. However since European colonisation in the mid-1800s, there have been relatively few damaging earthquakes. The devastating Hawke's Bay earthquake of 1931 caused the death of 256 people, and was the last earthquake to have affected a major metropolitan area in New Zealand.

---

[1] Spencer Holmes Ltd, Wellington and President, New Zealand Society for Earthquake Engineering drb@spencerholmes.co.nz
[2] Building Research Association of New Zealand, Wellington and Immediate Past President, New Zealand Society for Earthquake Engineering a.king@branz.org.nz

Earthquakes of magnitude M_w greater than 7 occur on average once every decade in New Zealand. There have been only five such events subsequent to the Hawke's Bay earthquake, with the loss of only 9 lives. This favourable recent seismic history has tended to shape the perceptions of earthquake risk by many, contrary to the actual risk. An earthquake of magnitude 7 or more affecting a major urban area is likely to cause the loss of hundreds of lives, and cause major social disruption.

The seismic hazard in Australia is appreciably less than in New Zealand, due to its distance from the plate boundaries. However as the magnitude M_w 5.6 1989 Newcastle earthquake amply demonstrated, moderate earthquakes can cause loss of life and considerable physical damage due to the extensive use of masonry construction. Although not the strongest urban earthquake in Australia's history, the human toll (13 lives) and direct losses ($1.2 billion) make it the most significant. An earthquake of this magnitude occurs on average once every year somewhere in Australia.

It is important to appreciate that low seismicity does not mean that large earthquakes cannot occur – it means that they occur less frequently.

3. NZSEE and the Earthquake Reconnaissance Process

3.1 About NZSEE

The New Zealand Society for Earthquake Engineering was established in the mid 1960s in recognition of the seismically active environment that is New Zealand. NZSEE's objective then and now is "to foster the advancement of the science and practice of earthquake engineering" and in accordance with the International Association for Earthquake Engineering "to promote international co-operation among scientists, engineers and other professionals in the broad field of earthquake engineering through interchange of knowledge, ideas, results of research and practical experience." A particular area of emphasis is on the mitigation of the effects of earthquakes on people and the built environment.

Membership of NZSEE now numbers around 660, with approximately 200 members resident offshore. While scientists and engineers still make up the bulk of the membership, representation from other professions including the insurance industry, civil defence, local authorities and the social sciences is growing rapidly as the Society's role in providing direction and a forum for interaction between people with an interest in earthquakes becomes more widely recognised.

NZSEE and its members maintain a close relationship with the Australian Earthquake Engineering Society (AEES), formed following the 1989 Newcastle earthquake.

3.2 NZSEE Reconnaissance Aims and Objectives

The importance of first-hand experience in post-earthquake environments was recognised from the outset, and reconnaissance continues to be a key activity of the Society.

The aim of each reconnaissance mission is "*to investigate damaging earthquakes that occur in New Zealand and where important lessons can be learned, those that occur overseas*". The investigation usually takes the form of a reconnaissance or field inspection of the damaged area, and is carried out soon after the event in order to record information that might otherwise be lost due to demolition, repairs or weathering.

The objectives as stated in the Society's Reconnaissance Manual are:

- To carry out a field investigation of the performance of buildings, civil engineering construction, foundations, lifeline services and plant with emphasis on those items which have survived the earthquake with or without damage.
- To investigate the characteristics of the ground motion, to collect, examine and interpret the available strong motion records, and seismological records including foreshock and aftershock sequences, and obtain information on the tectonic setting, faulting, surface manifestations and other scientific data.
- To collect relevant information from Territorial Authorities, other reconnaissance teams, local engineers and scientists
- Establish contacts for later communication with the objective of collecting additional information, the exchange of ideas, follow-up information on particular assessments

- To record the human and social experiences resulting from the event including Civil Defence preparedness and actions during the response and recovery phases, earthquake preparedness, mitigation of hazards and response to predictions and warnings, casualties, search and rescue, medical and health care response, evacuation and emergency shelter
- To disseminate the initial results of the reconnaissance on return by reporting to the Management Committee, presentation at public seminars, liaison with Civil Defence and Building Industry Authority and preparing a detailed reports for publication in the Bulletin of the Society.

The presentations following the return of the teams are a very important component of the process of communicating the lessons observed. Increasingly these presentations have been attracting members of the public, which indicates a growing wider curiosity about earthquakes and their effects. Equally, if not more important, is the first-hand experience obtained by each reconnaissance team member. At the very least, this motivates them to support overall earthquake risk reduction initiatives in their communities.

The reconnaissance missions organised by NZSEE have received strong financial support from the Earthquake Commission, for which the Society is extremely grateful. In recent years the Building Industry Authority has also contributed towards reconnaissance activities in recognition that many of the technical lessons feed into new building design standards. In many cases, NZSEE contribution to this effort is through the deliberations of NZSEE Study Groups set up on key issues.

Table 1 lists the earthquakes investigated under the NZSEE Reconnaissance Scheme.

Table 1: Earthquakes Investigated by NZSEE

Mexico, 1985	Guam, 1993
Edgecumbe, NZ, 1987	Northridge, Los Angeles, 1994
Armenia, 1989	Kobe, 1995
Loma Prieta, San Francisco, 1989	Papua New Guinea (tsunami), 1998
Newcastle, 1989	Colombia, 1999
Baguio, Philippines, 1990	Marmara Sea, Turkey, 1999
Weber, NZ, 1990	Taiwan, 1999
Hokkaido, 1993	Nisqually, Seattle, 2001

4. Overview of Key Lessons

The key lessons are summarised briefly under the headings of *physical*, *built* and *social* environments in Table 2. Progress and achievements are noted alongside each lesson. Additional issues arising for each of these categories are discussed below.

While the focus of these lessons is on the implications for New Zealand, it should be remembered that most of these lessons are equally applicable to all countries, including Australia with a lower seismic hazard.

4.1 Physical environment

With new methods and techniques for determining seismic hazard, the results are expressed in terms that indicate greater certainty. However the means with which to convey this sophisticated information to audiences as diverse as owners of key facilities and the general public in terms that they can understand has not advanced in a similar fashion. This risk communication ‘gap’ remains.

An example of the challenge of filling this gap is liquefaction hazard. Further consideration needs to be given to how broader-scale liquefaction hazard information should be used by planners and designers. This information is general in nature – just because an area is shown as having a high liquefaction vulnerability, it doesn’t mean that the whole area would ever liquefy in a single event.

Table 2: Summary of Key Lessons From Major International Earthquakes

Aspect	Lessons	Actions/ Outcomes
Physical Environment		
Permanent Ground Deformation (*fault rupture, liquefaction, landsliding*)	• The extent of physical damage to both natural and man-made facilities due to ground deformation is much greater than that from ground shaking	• Greater awareness of the dangers of building new facilities in areas with the potential for permanent ground deformation, and the nature of damage that can be expected
Seismic hazard assessment	• The importance of identifying and mapping seismic hazard and sound land use practices • The uncertainty associated with recurrence intervals - just before the 1999 Taiwan earthquake, the Chelungpu Fault was assessed to have a frequency of rupture of more than 10,000 years	• Seeking responsible risk disclosure and appropriate land development • Awareness of the need to not be dismissive of the consequences of assessed low probability events
Built Environment		
Buildings and bridges	• Many early concrete and steel structures designed prior to modern seismic codes (mid-1970s) contain critical structural weaknesses – NZ and Australia has these buildings too • Buildings and bridges designed and constructed according to modern seismic standards generally survive major earthquakes well in terms of life safety. • Modern buildings do however sustain appreciable damage which can render many unoccupiable for quite some time • The importance of maintaining a presence by the designer during construction to ensure specific seismic resisting design features are properly constructed	• NZSEE & the Building Industry Authority have undertaken a major programme to widen the legal definition of earthquake prone buildings beyond early masonry buildings • Justifies the design and construction provisions of current standards (which are much more onerous than older standards) • Owners and tenants do not expect or understand this • Building codes on their own are not sufficient to ensure construction quality – codes and compliance go hand in hand
Lifeline utilities	• The Lifeline utilities of cities are highly vulnerable to the effects of earthquake. A city will suffer severe economic loss and disruption if the utilities are disabled and transport is not flowing freely in the days following an earthquake • Port facilities are particularly vulnerable to liquefaction due to their use of hydraulic fill and location on reclaimed areas	• Lifelines Projects in NZ have developed a collaborative regional approach to co-ordinating utility mitigation activities

Table 2 (continued): Summary of Key Lessons From Major International Earthquakes

Aspect	Lessons	Actions/ Outcomes
Social Environment		
Response	• The value of high-quality real-time earthquake data in rapidly establishing the scale of a major earthquake in order to mount an appropriately scaled response • The necessity of having a heavy rescue strategy, including a management plan for handling international rescue teams • Communities with advanced disaster preparedness awareness and arrangements were able to recover much more rapidly	• In 2001, a significant upgrade and extension of the national hazard monitoring network (Geonet Project) was announced • In 2000, a project was initiated to establish a national urban search and rescue (USAR) capability
Economic	• The scale of economic losses from earthquake are considerable, noting that indirect (non-quantifiable) costs are often as significant as the direct (measurable) costs	• An appreciation that a major earthquake in NZ would have a far greater effect on the national economy (in % of GDP) than in larger countries

4.2 Built environment

The technical improvements resulting from the physical lessons have been incorporated into design standards for new buildings. As New Zealand earthquake engineers have been at the forefront of seismic code development, our design standards are equivalent to those in earthquake prone countries such as the United States and Japan. Damaging earthquakes in these countries, where much of the built environment is similar to New Zealand, have generally confirmed that buildings designed and constructed in accordance with modern seismic standards (ie. post mid-1970s) can satisfy life safety objectives by withstanding moderately intense shaking without collapse. The effect of a large earthquake (M7+) within an urban area has yet to be determined.

The challenge of addressing the large range of existing buildings constructed prior to modern codes however remains. Major overseas earthquakes have repeatedly highlighted the sudden and brittle failures of concrete and steel buildings that feature what are now recognised as critical structural weaknesses.

The degree of physical earthquake risk mitigation undertaken in New Zealand varies considerably. While sectors such as commercially focused lifeline utilities have invested in significant 'network toughening' over the past decade, individual building owners have not tended to be so willing. The consents and compliance arm of city and district councils have an important leadership responsibility in applying national regulations, which is often at odds with the economic development role of local authorities. This issue is as much one of risk perception amongst owners, tenants and politicians as it is a technical question.

4.3 Social environment

Previous NZSEE reconnaissance teams have involved representatives from the Emergency Services and Civil Defence Emergency Management to cover emergency response issues. Lessons and recommendations from NZSEE reconnaissance teams relating to the social environment have therefore tended to relate to response and economic issues.

Given that the majority of lessons listed in Table 2 were observed at all earthquakes indicated in Table 1 (ie. since 1985), the considerable time period involved in achieving action and outcomes is readily apparent. In New Zealand, the prime example of this are the projects to develop an urban search and rescue capability and to upgrade the seismic monitoring network, which have taken until 2001 to be commenced.

5. Earthquake Issues for Urban Planners to Consider

Like those working in the field of Emergency Management, planners need to consider their involvement in natural disaster aspects in the context of both pre-event (reduction (mitigation) and readiness) and post-event (response and recovery) situations.

Pre-event Considerations

The present-day pressures to develop urban land are acknowledged, as is the fact that seismic hazard represents just one consideration in the land development process. However a baseline approach for sustainable development must involve conscious planning for low probability hazard events with high physical and social consequences such as earthquake.

The key issue here is ensuring that information known about seismic hazards is appropriately taken into account at the time of land development. For this to happen, provision must be made the in the legal framework governing urban planning.

A prime example of this is of the use and development of land close to active earthquake faults. Last year, the office of the Parliamentary Commissioner for the Environment issued a report which found that few territorial authorities have identified seismic hazard in their district plans (PCE, 2001). While the focus of this report was on active earthquake faults, it has highlighted a much wider concern relating to other forms of seismic hazard such as liquefaction, landsliding and amplified ground shaking due to weak subsoils. The associated aspect is that despite the high quality seismic hazard evaluation work that has been undertaken at regional level in most areas, this has typically not reached down to planning provisions at city or district level (Becker & Johnston, 2000).

While on the face of it the planning issues (permission to develop) are separate from the building issues (permission to build), the absence of any consistent approach around the country introduces confusion on this aspect. Planning issues and building issues are separately considered but should not be – after all it is the total risk that must be minimised, not just components of it.

The Ministry for the Environment has established a project with the Geological Society of New Zealand and NZSEE to develop planning guidelines for the use and development of land close to known active earthquake faults (Nathan et al, 2002). The objective is to enable informed and appropriate development using a risk-based framework rather than a rigid set of rules. It is intended that these guidelines will establish a template for dealing with the other earthquake hazards noted above.

Another important pre-event consideration is in planning the location, distribution and accessibility of emergency services in relation to post-earthquake needs. This applies particularly to hospitals.

Post-event Considerations

Some of the issues and conflicts that planners will face after a major earthquake are:

- The immediate pressures for reconstruction to get people re-housed and business underway *vs* the opportunity for considered planning in a modern context. The worst affected areas in major earthquakes are often the older precincts that are constructed at a time before modern planning principles evolved. The opportunity to redevelop those areas using modern planning principles is tempting, but there is an equal need to have respect for remaining and displaced citizens, and for the significance of the cityscape
- Many people will also want to immediately reconstruct in areas of permanent ground deformation (eg liquefaction), despite the damage caused by the earthquake there. This reflects the ‘lightning can’t strike twice in my lifetime’ philosophical outlook, and also the significant value of urban land
- Handling the vexed question of partially damaged historic structures where considerable sums of money will be needed to deal with the danger they pose (this is equally an everyday pre-event issue)
- Finding acceptable locations for disposing of very large quantities of demolition material. The immediacy of this highlights the question of ‘which planning procedures can be fast-tracked after such an event?’

In order to explore these issues and develop consistent solutions, it is suggested that urban planners should actively engage in discussions with scientists, engineers and emergency managers. New forums may need to be established to encourage this multi-disciplinary dialogue.

6. Future Directions for Earthquake Reconnaissance

A review is currently underway into the effectiveness with which the key findings from previous NZSEE reconnaissance missions have been implemented. This review is expected to be completed later this year and will be used as the basis of modifying the 'rules of engagement' in an endeavour to ensure that:

- Value is being achieved for the cost of supporting the missions
- Adequate use is being made of modern communication techniques (particularly the internet and the expectation of immediate information availability)
- The reporting and communication effort following a mission is focused and commensurate with the key findings from the mission.
- The motivating influence of first-hand experience is put to effective use to implement lessons learned.

A Natural Disaster Investigation Co-ordinating Group is being developed under the leadership of the Ministry of Civil Defence and Emergency Management. The established NZSEE reconnaissance framework is being used as the basis for an all-hazards, inter-agency, multi-disciplinary approach to reconnaissance visits.

This proposed new approach will enable researchers and practitioners from the social sciences and urban planning sectors to become more actively involved in the process of identifying lessons and communicating the messages. One of the key benefits of this more integrated approach will be the ability to send different disciplines at appropriate time periods after the event. Urban planners, for example, may obtain optimum benefit by visiting 6 or even 12 months after a major earthquake, when the wider social and planning impacts are more clearly evident.

7. Summary

It has been New Zealand's good fortune not to have experienced a damaging urban earthquake since the 1931 Napier event. Similarly, apart from the 1989 Newcastle earthquake, Australian cities have yet to experience the full impact of a major earthquake. This favourable recent seismic history has tended to shape the perceptions of earthquake risk by many, contrary to the actual risk. Accordingly, neither Australians nor New Zealanders can be complacent in their consideration of earthquakes. The imperative that we learn from major international events places a high value on the reconnaissance of overseas events.

A range of lessons has been identified from international field reconnaissance missions organised by the New Zealand Society for Earthquake Engineering over the past two decades. These lessons predominantly relate to the physical and built environments. There is recognition of the need to place greater emphasis on establishing and communicating the social and economic lessons.

A 'gap' exists between the high quality of seismic hazard and risk information and the general earthquake risk perception of the wider community. Urban planners have an important role to play in assisting engineers, scientists and emergency managers to close this *risk communication* gap. This challenge is interdisciplinary, and involves two key objectives. Firstly, there is a need to ensure that seismic hazard information is made available to planners in a suitable form for incorporation in planning policy documents. The second objective is for appropriate and consistent application of seismic hazard information through the urban planning process.

Urban planners are an important part of the overall process of mitigating earthquake risk to the community. The involvement of planners in the reconnaissance of major international earthquakes is one way of assisting this process.

References

Becker, J.; Johnston, D. 2001: District plans and regional policy statements: do they address earthquake hazards? *Planning Quarterly:* 22-23

Nathan, S.; Stirling, M., Brunsdon, D., and Webb, P. 2002: Guidelines for the use and development of land close to active earthquake faults. *New Zealand Society of Earthquake Engineering conference*

Parliamentary Commissioner for the Environment 2001: Building on the Edge: the use and development of land on or close to fault-lines. *Office of the Parliamentary Commissioner for the Environment*, 30pp.