Defending NZ communities from earthquakes: outcomes and discussions from recent workshops with earthquake engineering practitioners and communities

R.J. Bentley

Centre for Advanced Engineering

2015 NZSEE Conference

ABSTRACT: The CAE recently held two workshops on the earthquake threat to New Zealanders and this paper summarises these discussions. The earthquake threat to NZ in economic terms is clearly substantial, but there appear to be ways to contain and possibly mitigate this. Current initiatives include strengthening existing buildings, improving design practices and occupational licensing of engineers. It is argued that more important initiatives may be available, for example, the strengthening of communities and organisations, the introduction of more resilient building technologies, pre-disaster response planning, earthquake forecasting systems, and the strengthening of infrastructure, systems and networks. A more comprehensive approach, informed by an economic assessment, would put some scale on the problem, establish the components of a mitigation strategy that most benefits communities, and assist national lifelines groups communicate and promote their implementation. Greater in-house capability in earthquake engineering disciplines would facilitate local and central government approach to the planning required and its implementation.

1 INTRODUCTION

1.1 Planning for Earthquakes

There are a range of measures available to defend NZ communities from earthquake. At one end of the spectrum is the strengthening of existing buildings, and at the other end is the building of resilience into utility networks such as electricity, water and telecommunications and food supply chains. Low damage technologies could be made mandatory for certain classes of structures. The response to earthquake and the assessment of damage could be undertaken within previously agreed frameworks to avoid some of the issues that arose in Christchurch. Community awareness and building community resiliency seems especially important. Increased community awareness of the post-earthquake environment and the issues that arise, as we saw in eastern Christchurch, would also assist build a greater awareness of the importance of communities acting now to benefit later.

Many of the really important ways to defend NZ communities from earthquake require good planning and often upfront investments. For example the cost of a low damage technology building may be slightly higher than a traditional building – but the benefits to the owner and the community only accrue when there is an event, which is why most buildings are still being designed in the traditional way and adding to the liability of future communities.

Is significant benefit actually there? The strengthening of the road, telecom, electricity and other utility systems in and around Canterbury following the completion of the ground breaking Risk and Realities report in 1997 appears to have generally paid off, as damage was minimal and systems and networks were quickly up and running after both the local M7 Darfield earthquake in September 2010, and the Christchurch earthquake in February 2011. In contrast the original city water systems were very badly damaged by liquefaction, and are costing $3 *billion* plus to repair. The replacement of these systems with HDPE before the event would have cost a fraction of this.

However, given the pressure on central and local government finances, significant investments in earthquake resiliency will need to demonstrate substantial risk weighted benefits to attract political support. Proposed investments can be best informed by formal economic analysis, to ensure a sensible level of investment is committed relative to the threat, and that a balanced approach across potential alternative mitigation strategies is achieved.

1.2 **The CAE Workshops**

To progress thinking around these and many other ideas, the Centre for Advanced Engineering ran two workshops in November 2014 – one in Christchurch with the Quake Centre and one in Wellington - with the common theme 'defending NZ communities from earthquake'. The workshop objectives were to discuss the mix of policies and practices being taken by government and local government to defend communities from earthquake and to identify gaps and opportunities for improvement and the basis for an agenda of actions for follow up. Attendees included senior Christchurch and Wellington Regional Councillors and City Councillors, the Chairman of the EQC, leading consulting engineers, CEO's from private companies, leading city managers, senior academics involved in earthquake relate research, and Treasury and MBIE officials.

The full record of the discussion is available as referenced, but the main issues raised are covered below.

2 **DISCUSSION**

2.1 **The Canterbury Earthquakes**

Observations concerning the Canterbury earthquakes and potential learnings included:

- Engineers seem reasonably satisfied that buildings of all types and infrastructure systems performed much as expected in the September 2010 and February 2011 earthquakes. There was widespread failure of unreinforced masonry buildings (URMs), although many strengthened URM's performed well. Utility and horizontal infrastructure that had been strengthened progressively over the last 20 years performed well. However there was significant non-structural damage everywhere in both major events and many buildings were unable to be re-occupied because of this. Perhaps surprisingly, owners and insurers embarked on an extensive demolition programme of partly damaged buildings. It seems that even in a magnitude 6 event, buildings close to the epicentre can be stressed close to the ultimate limit state design spectrum, and extensive liquefaction of saturated soils can occur causing really significant damage to housing, engineered structures, and horizontal infrastructure.
- There is emerging evidence that Christchurch communities have been significantly disrupted by the event, that this may have a long term effect on the region and that new ways to assist these communities may be desirable. The slow resolution of some domestic housing repairs and reconstruction seems to have exacerbated this. There is also concern about the introduction of extensive no go zones in the CBD after the February 2011 earthquake and the delays in allowing access to assess damaged buildings.
- There appears to be an expensive overreaction by policy makers to the problems of dealing with existing buildings, apparently due to overly cautious perceptions of life risk in earthquake. In fact with two notable exceptions, few buildings collapsed during the Canterbury earthquakes.
- The earthquakes revealed the importance of having the appropriate and trained engineering capability in government, local government, and in network organisations to deal with the earthquake hazard and in the response to earthquake.

- There is an increasing realisation that the costs of the Canterbury earthquakes to NZ at around $40 billion (and 20% of GDP) is a lower bound for a similar event elsewhere in NZ. This is because there was minimal disruption to the main South Island supply routes and minimal impact on the Canterbury economy. Extensive property insurance was in place but paradoxically this appears to have contributed to a lengthy rebuild process. Given the potential costs of earthquake to NZ communities both directly and indirectly, there is a need to urgently review the approach to building resiliency into buildings, infrastructure and networks, and into supply routes generally.
- Of concern is that for many of these opportunities there does not appear to be any obvious accountability or process for dealing with them.

2.2 **Existing Buildings**

The poor performance of non-structural components in the Canterbury earthquakes and in Wellington in the more recent Seddon July/August 2013 earthquake is a stark reminder of the scale of the issue building owner's face. It appears likely that non- structural damage will be the main impediment to a return to normality of city economies after moderate earthquake. Remedial works of substandard installations could generate an attractive payback for businesses and communities. Additionally owners and managers will soon need to address the provisions of the proposed Health and Safety Reform Act, where all reasonably practical measures need to be taken to protect employees.

There are many building owners who have already lost hundreds of millions of dollars in building value through the flight of tenants from buildings classed as 'earthquake prone', and the liability to strengthen contained in the proposed amendments to the Building Act. However the Christchurch experience suggests that modest improvements that deal to appendages and which generally tighten up a building can definitely improve the behaviour of URMs in earthquake.

This evidence is surely enough to justify a comprehensive programme to design and test simple systems that would improve the resiliency of URM's to the point they could be codified as approved processes for complying with the Building Act. The cost of such a programme even if it involved full scale testing on the big tables in Japan is a minute fraction of the potential cost of implementing the 34% NBS (new building strength) rule, or as many engineers are recommending 67%. And these technologies could become a major NZ export product into the many countries with URMs and earthquakes, looking for smarter solutions than lateral strengthening.

A further concerning aspect of the proposed amendments to the Building Act is the tying of the strengthening loadings to the building code provisions for new buildings in regions of less seismic risk. The evidence is quite clear that these loads are far above that justified by any risk based analysis.

2.3 **New Buildings**

In the Christchurch CBD, nearly all damaged buildings have been demolished and not repaired. The impression is that engineers were not expecting this outcome. Is this a one off situation, or is this now the norm. And if it is what are the implications for the way buildings are conceived and designed. Should quick demolition be planned for. Does the loadings code make buildings too strong when we know that properly designed modern buildings exhibit significant ductility and resiliency.

Rather obviously, so called low damage design technologies appear to be an important way forward, and it is unclear why the proper commercialisation of these is not being treated as a matter of priority by local and central government. Once there is agreement on practice and appropriate standards in place, city authorities can start insisting on their use. Why, in 20 or 30 years would any community want to go through the process of demolition and the destruction of a city's fabric as is occurring in Christchurch. Perhaps the best approach here is to draft a new code for resilient engineered building design, and cascade down to standards and practice guidelines for the very many different techniques emerging and for the much wider use of engineered timber structures.

2.4 **System Resiliency**

The problem is that Local Government finds it hard to justify funding significant resiliency investments while dealing with ageing infrastructure and capped rates rises, and regulated electricity utilities can have difficulty getting resiliency based investments accepted by the Commerce Commission. The Canterbury experience does show that methodical progressive reinforcement - dealing with the obvious - can pay off. Should utilities be *required* to undertake this work. Should system resiliency be reported against performance requirements agreed with local communities.

Given the potential massive costs of earthquake to NZ communities both directly and indirectly, there appears to be a need to urgently review the economics of building resiliency into infrastructure and networks, and supply routes generally, so as to inform community understanding of the issues and the opportunity to undertake mitigation planning.

The concept of resilient systems extends to the way city centres are organised. What are the weak links in cities – is it access, or the likely extended no go zone around buildings likely to be demolished and its impact on restoration, or the likely performance of utility systems and networks. In Wellington for example there are quite a number of electricity substations in basement situations. A further feature of the Wellington CBD is the gas pipeline network, and the lack of any secondary water supplies to fight fires, for example from pre organised sea water based systems.

Despite the local coordinating activities of lifeline groups, few regions have completed the kind of strengthening programme undertaken under the Canterbury Lifelines Group programme since 1990. Few District Plans appear to focus on resilience issues. Is there a need for a national policy on reporting on the state of systems, networks and utilities, for example – to give some simple examples – where liquefaction is possible, where disruption of loosely jointed waste water systems is possible, where landslide may occur, and where strengthening has been undertaken. MCDEM has the power to seek disclosure of emergency response and resiliency planning by lifeline utilities but declines to get into this area, and there are no penalties for non-disclosure.

The delivery of infrastructure resilience remains a commercial matter, but it is actually a community issue.

The American Society of Civil Engineers has developed a ‘Report Card’ which is a 4 yearly survey of the condition and performance of a wide range of infrastructure across the US. A cut down version focussed on resiliency could be implemented relatively easily in NZ.

Resiliency issues exist around national supply chains. Fortunately the resilience of food supply chains was never an issue in Christchurch, although there were hassles around the availability of petrol and diesel in damaged communities for some weeks. However, the NZ food supply chains are linear – Auckland/Palmerston North/Christchurch, and the vulnerability of the central North Island transport networks is obvious. A national resiliency review might throw up some important possible initiatives. For example - the desirability of making the Te Kuiti/New Plymouth road available to truck and trailer units at the small cost of removing the tunnels and building a bridge north of New Plymouth to bypass Mt Messenger. This would give some redundancy to the central plateau road and rail networks, and open up Port Taranaki in the event of disruptions to the east coast export ports at Auckland, Tauranga and Napier.

2.5 **Resilient Communities**

Recent Canterbury University based research on resilient organisations suggests that in Christchurch human/organisational issues have been the most disruptive of organisations. Organisations with a more resilient leadership and culture, where people are trusted, that have strong networks, and that are change ready, were better prepared. This is about having adaptive capacity. Dealing with things you can forecast is handled by planning – things you can’t plan for need to be handled through adaptive capacity.

The same clearly applies to building community resilience – the preparedness of communities to build networks, to be ready to support each other by coordinating resources, and by having awareness of those who will have special needs such as the elderly. Communities need to be empowered but

supported to build their own resiliency. The harrowing experiences of the communities in east Christchurch in the weeks after the February 2011 earthquake, lest we forget, could provide a significant useful guide to other communities, and a basis to frame proposals that enable local government to be more facilitative in building more resilient communities.

One way to facilitate community resilience planning is to proactively undertake earthquake forecasting. There are extensive efforts underway in the US and Japan to develop more reliable forecasting procedures. The USGS promote a sequence involving hazard assessment which looks out 10 years, forecasts which deal with months and years, and predictions over hours to weeks.

It is not hard to think of the numerous initiatives that might be triggered by a prediction that could save lives and minimise post event economic disruption. This includes refreshing community and organisation response networks, refreshed civil defence preparedness, and individual enterprises might build up stocks of especially critical business inputs. NZ has an earthquake forecasting research project in GNS but there has only been tentative discussion about a more formal system.

Early warning systems are also being developed in the US and Japan, and one is in evaluation for NZ. These provide automatic warnings of up to 30 seconds via radio, alarms, and text of approaching seismic waves. This is possible as a near fault seismograph can trigger the alarm, while the seismic waves (traveling around only 5km/sec say 75km in 15 secs) are still in transit.

Perhaps priority needs to be given to an early warning system for central NZ for an Alpine fault rupture and for locally generated tsunami.

2.6 **Response Aspects**

The response in Christchurch, especially to the February 2011 event, appears to provide extensive learnings for many NZ cities and towns, similarly threatened. Building inspections, building assessment, reoccupation decisions, demolition decisions, and the complex interplay with insurers and building owners, make for a heady mix.

The evidence from Christchurch appears to be that there is a clear need for a predetermined codified streamlined building consent process for the repair of earthquake damaged buildings, and that this should not include upgrades to fire systems or access upgrades to accelerate recovery. Further, streamlined provisions should also be included for the erection of temporary buildings following a disaster. The expectations of post-earthquake building safety evaluations could be defined in formal regulations. The Building Act should define the minimum acceptable seismic capacity for occupation of buildings, trigger levels for full seismic upgrades, minimum levels for strengthening and timeframes in which to carry this out. Preferably Local Government's individual policies in this area should be limited to outlining how they will enforce national standards and we can note here the Court of Appeal's recent rejection of the Christchurch City process to attempt to enforce higher strengthening requirements.

There has also been quite a lot of discussion as to whether a publically available database on buildings and infrastructure could have led to a more deliberate and professional response to damage assessment. Apparently this is an idea being adopted in some parts of California.

A further issue arose in Christchurch around when to keep a damaged heritage building and when to demolish it. The problem in Christchurch was compounded by what is regarded as a general lack of experience of NZ earthquake engineers with especially stone masonry and really old URM buildings. Because of its importance, a more measured and systematic approach to this area should be devised before the next event. Perhaps a small task force of engineers with specialist knowledge of old buildings needs to be formed to assist authorities oversee assessments of this kind.

Immediately after the February 2011 event extensive no go zones were introduced in the CBD and Port Hills. This complicated assessment processes and access to buildings by owners and advisors. The standard practice in this area is to no go dangerous zones, not to no go cities. This no go zone lasted 860 days. CERA was created by government four weeks after the February 2011 event as the government's controlling entity in the response and rebuild, and it was given extraordinary powers to accomplish this. The government's intense involvement may have set a precedent for future

emergencies and may lead to the unfortunate view that preplanning by local government is somewhat pointless. However this might be avoided if the response phase including building assessments and reoccupation policy is pre-planned to as greater extent as possible.

2.7 **Leadership Aspects**

Recent earthquakes have highlighted the lack of in-house engineering expertise in key institutions such as Ministries and in Local Government, and there is a view amongst engineers who have participated in the response and recovery in Canterbury that the lack of engineering trained leadership in permanent positions in the key government and local government agencies in Christchurch contributed adversely to the quality and timelines of the decisions taken and the processes followed. Recent MBIE recruiting has increased their technical capability, and a stronger sense of public service career paths can/should now be built. But there are still relatively few permanently employed professional structural/civil engineers in any of these organisations and even in the larger NZ city councils.

If an agency has a significant asset portfolio or consenting responsibilities (or both, such as Councils), then they need good technical capability and leadership. Having a respected person in these roles will elicit improved performance from the engineering and construction community. The lack of technical direction to practitioners has also led to excessive conservatism and lack of consistency. The Ministry of Education is understood to have saved $750 million in avoided seismic assessment and strengthening costs through technical leadership and targeted research. Other savings are ongoing from better standards setting for social housing stock and more effective management of the engineers and other consultants working for them. Leadership has also been lacking in dealing with the multi-disciplinary issues such as the restraint of non-structural / content items and effective and consistent implementation of low damage technologies. Consultants provide capacity, but not necessarily capability or leadership.

2.8 **The Current Approach to Planning for Earthquake**

The Royal Commission on the Canterbury Earthquakes were asked to investigate the specific building failures, the adequacy of requirements for the design, construction and maintenance of buildings, and to make recommendations. Many of the Commission's recommendations are therefore of a technical nature. The more policy orientated recommendations cover three areas – EPBs, post disaster building management and property identification and information systems, and occupational regulation of engineers involved in design and build. Government subsequently endorsed these findings and embarked on a programme of policy development and legislative change in EPBs and occupational licencing. During 2014, MBIE also started to review some of the Commission's engineering design recommendations and response issues. In regard to resiliency aspects, the Treasury Infrastructure Unit have a programme now several years old to document resiliency issues facing NZ.

At a regional level, there are 16 Lifelines Groups of which the most active are in Auckland, Wellington and Christchurch. These groups mostly comprise representatives of local utilities and local government agencies and they facilitate discussions on local hazards and collaboration toward building more infrastructure resilience, and response planning.

3 CONCLUSIONS

Earthquakes pose a significant threat to life and the economy. The Canterbury earthquakes need to be seen as a wake - up call. The scale of the disaster is still being revealed. From a NZ perspective the event was probably a near miss.

The 2014 CAE workshops on defending NZ communities from earthquakes were notable for the wide range of parties and organisations participating, and the diverse range of proposed initiatives to better manage the earthquake threat. The main themes from these discussions can be grouped under three headings:

3.1 Community

A wider community awareness of the threat and the issues communities may have to face is needed, along with wider development of community and organisation preparedness programmes. The implementation of an earthquake forecasting/prediction/warning system could stimulate a more informed and targeted discussion. Community support for investments by Local Government and private sector utilities in more resilient utilities and other mitigation strategies, with all the implications for price and rate rises, needs to evolve from informed community discussion. Measures of infrastructure resiliency, agreement on acceptable performance, and incentives to achieve agreed performance standards are needed as part of this. An early initiative would be to review and publish information on the resiliency of important utility services.

3.2 Response planning

The effective and efficient response to earthquake is facilitated by building earthquake engineering capability into key central government agencies, local government, and in network organisations. This will also facilitate the planning for the response phase after earthquake, including agreement on building assessment processes, strengthening standards, simplified consenting, and reoccupation decisions.

3.3 Buildings

New codes and practice guidelines for emerging low damage building technologies are required. For existing buildings the priority is to adjust down the proposed requirements for strengthening buildings in lesser seismic zones. It is proposed that a major programme be undertaken to demonstrate ways to make typical URMs sufficiently resilient, and therefore to allow early adoption of procedures that would be much easier and economic to implement than lateral strengthening, and that could be codified as a means of compliance with the Building Act.

Many of the issues noted in this paper can only be progressed with the collaboration of many parties including especially local and central government, the relevant professional engineering organisations and the Universities. Resources everywhere are stretched. However there appear to be real benefits available from a more coordinated and objective approach. Perhaps a taskforce of engineers, scientists and economists could identify the possible strategies, oversee an economic assessment, recommend priorities, and suggest implementation strategies.

In the final analysis, the implementation of the kind of programme envisaged here would require the strong support of senior Ministers. Perhaps it is time to recreate a modern version of the Ministry of Works, with a cabinet level Minister, or a Chief Hazard Advisor reporting to the Prime Minister, in the style of the current Chief Science Advisor, with a specific mandate to lead this process.

4 ACKNOWLEGEMENTS

Thanks to the presenters and all those attending the CAE Workshops for the stimulating discussions on which this paper is based.

5 REFERENCES

Bentley, R.J. 2014. Defending NZ communities from earthquake, A report on the CAE Workshops, Dec 2014 Newsletter, Centre for Advanced Engineering.

Christchurch Engineering Lifelines Group, 1997. Risk and Realities, published by the Centre for Advanced Engineering.

NZSEE Bulletins Vol 43, No 4 Dec 2010, and Vol 44, No 4 Dec 2011 on the Canterbury earthquakes.

Tony Fenwick, Editor, Lifelines, Lessons from Natural Hazards in Canterbury, Document Summaries, December 2012 found in Centre for Advanced Engineering Lifelines Archives at www.cae.co.nz

Hare, H.J. & Galloway B.D. 2012. A review of post- earthquake building control policies with respect to recovery of the Christchurch CBD, NZSEE Bulletin, 45(3): Sept 2012.

Canterbury Earthquake Royal Commission, Cabinet paper dealing with recommendations found at http://www.dbh.govt.nz/cerc-cabinet-paper.

Once in a Lifetime, City Building after Disaster in Christchurch, Freerange Press 2014, contains 55 articles on the rebuild.

Fraser, S.A., Power W.L., Xiaoming Wang, Wallace, L.M., Mueller, C & Johnston D.M. 2013. Tsunami inundation in Napier, New Zealand, due to local earthquake sources, Nat Hazards (2014) 70:415–445.

Seville, E., Giovinazzi, S., Stevenson, J., Vargo, J., Brown, C. 2014. Disruption and resilience: how organisations coped with the Canterbury earthquakes, Economics of Resilient Infrastructure Research Report 2014/002.