Improvements in research knowledge: a challenge for engineering

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R. K. H. Falconer

Group Manager – Natural Hazards Group,

Institute of Geological and Nuclear Sciences Ltd

ABSTRACT: Research on hazard and risk provides continual improvements in knowledge of processes and associated risks. This provides a challenge for engineering as the lifetimes of many structures will be significantly longer than the lifetime of "state of the art" research knowledge. For example we now understand a lot about near fault effects that mean some structures built near faults are not safe according to current knowledge even though they were state of the art structures at the time of construction. We must not feel uncomfortable about new knowledge but we must acknowledge it. We need to consider:

- How do we cope with the changes in research knowledge for structures that are already built?
- How do we respond to the fact that research knowledge will undoubtedly change our views in the future for structures that we are designing now?

1 INTRODUCTION

Research on hazard and risk produces continual improvements in knowledge of hazard processes and the consequent risks. This provides a significant challenge for the engineering community as the lifetimes of many built systems and structures are significantly longer than the lifetime of "state of the art" research knowledge. Take the example of building of structures near fault lines. Engineers have long recognized the hazards of fault rupture ground displacement and high shaking near faults and have taken precautions. However, in the last decade or so the importance of fault rupture directivity and fault fling have become more significant as data have been obtained close to faults in actual events. In the 1999 Taiwan earthquake ground velocities were measured that were at least twice those previously recorded anywhere. How do we cope with this given that there are structures that will be expected to last 50 years or more that are either already in existence near fault lines or are currently being designed?

The problems are probably more severe for the engineering community that any others. Designers of computer hard disks or laser printers are scarcely required to consider issues of how those pieces of equipment may perform in 25 years time, or probably even 5 or 10 years. Engineers must consider the long term.

2 PRESENT KNOWLEDGE: EXAMPLES

To explore further it is interesting to consider some examples from New Zealand where changes in knowledge have impacted built structures. Notwithstanding this being the Earthquake Engineering Society I will give some examples that relate to hazards other than earthquakes. I refer just to natural hazards but clearly technological and social hazards should also be considered. New Zealand has a large number of natural hazards and the engineering community is involved with the issues of all of them. Frequently decisions relating to planning or the economics of building or retrofitting structures involve choices between expenditure on several competing issues. Decision-makers have to balance all risks in many cases.

My choice of examples is not particularly systematic and they vary in the scale of the issues. They are just some interesting examples. Photos and figures for each example are available.

- **Matahina Dam:** Matahina Dam, an 80 metre high 400 metre long earth core dam in the Bay of Plenty was displaced and significantly damaged in the 1987 Edgecumbe earthquake. Repairs to the dam were made during the following two years. In the course of the work it was learned that some of the materials in the core of the dam might be more subject to failure than had been intended in the design. Studies associated with the repairs also looked at the geology around the area. Those and more regional geological studies done on a research basis for understanding New Zealand tectonics led to the conclusion that the potential for significant earthquake fault displacement through the dam site was much higher than had been previously thought. This led to a very major rebuild of the dam in the late 1990s. This was probably one of the most significant dam rebuilds anywhere in the world. Our present state of knowledge of faulting hazard in the area simply was not known at the time the dam was built in the 1950s and the designers built to what was then best practice. There can be no criticism of them, and only praise for those who have taken the decision to invest in the recent upgrade.
- **Haywards Electricity substation:** The Haywards substation in the Hutt Valley is the North Island terminal of the Cook Strait DC power cable and a major substation for the whole New Zealand electricity grid system. It is built only 150 metres from the Wellington fault line. The existence of the fault line was known when the substation was built more than 40 years ago and it was designed for what were assumed to be reasonable ground accelerations. Data from earthquakes over the last few decades have progressively increased expected accelerations close to faults and much work has been done retrofitting the substation. Retrofitting has been ongoing as knowledge has increased. For this structure it has been possible to do this type of retrofitting and so keep up with knowledge.
- **Cook Strait Ferry Terminal:** The Cook Strait Ferry Terminal in Wellington is built on reclaimed land and is right over the trace of the Wellington fault. Geological information now gives us an estimate of a return period for a rupture on the Wellington fault of 400-800 years with the last rupture around 600 years ago. It is interesting to consider whether a ferry terminal would be built there with today’s understanding. Are we, should we be, concerned enough to consider possible relocation?
- **Active Subsurface Faults:** The Institute of Geological & Nuclear Sciences (GNS) has a database of active faults in New Zealand. The database is built from GNS and other organization’s research and is continually updated. Examination of this database and some of the latest geological maps will show for example that there is no significant active fault identified in NW Nelson. However, a very detailed deployment of earthquake monitoring equipment for a research experiment covering the central part of New Zealand in the mid 1990s clearly detected earthquakes that indicate an active fault in NW Nelson that links with the Taranaki fault system to the north and other faults to the south. The faults database and the geological mapping both are state of the art, so how do we have this apparent contradiction? The problem arises because the database is focused on surface faults and this particular one doesn’t have an obvious surface expression. In the NW Nelson case there are no major engineering structures of concern but one can expect that this type of increase in knowledge will occur in many other places where there may be structures of concern.

- **Maui Gas Field:** The Maui A Platform was built in the 1970s. Its location and indeed the existence of the oil are related to the Cape Egmont Fault zone. It wasn't however, until investigation works started for the building of the Maui B platform in the 1990s that it was realized that the fault extends right to the seabed and indeed there is a seafloor offset that can be seen. Maui B and the pipeline from it were designed for this but Maui A was not. In this case it is probably not of concern because the design was conservative for earthquakes given many other hazards of the site.
- **National Earthquake Hazard Model:** The current loadings code takes into account earthquakes and to a large extent was based on hazard maps prepared in the 1980s. New probabilistic seismic hazard assessments carried out in the 1990s dramatically change the expected ground shaking in some areas, particularly around the Alpine fault. New loadings codes being developed now take account of the new data but of course there are many structures built to old codes. They were built to state of the art knowledge then but now the knowledge is different.
- **Retrofitting Buildings:** In New Zealand buildings have generally been built according to the building codes of the time. With respect to earthquake resistance codes have altered several times. There is no discredit to people having built buildings to the codes that nowadays we consider to be insufficient. However, I know it is a source of much concern particularly to many members of this Society, that in spite of intense lobbying some local councils will not put adequate pressure on building owners to upgrade their buildings.
- **Abbotsford Landslide:** The Abbottsford, Dunedin, landslide of 1979 did not injure anyone but destroyed or damaged over 25 houses. The social and political impact was substantial and led to important revisions of the Building Act and application of new measures in many urban plans. It appears to be an unfortunate fact that major changes in codes and regulations often only come about when there are critical incidents.
- **Clyde Dam:** The Clyde Dam was a large hydro-electric dam expected to cost around $500M when construction commenced in the early 1980s. It was only after construction was well underway that it was realized that the filling of the lake behind the dam could create instability in rock slopes that might produce catastrophic landslides into the lake. Stabilization work done on these landslides alone cost more than $500M and delayed the project by two years. The nature of the landslides was simply not understood at the time the project started. Research knowledge dramatically changed about that time and led to the major engineering issues. It is interesting to speculate what might have been done if the landslide issue had not become apparent until after the dam and lake had been completed.
- **Auckland Volcanic Risk:** Geological research in the Auckland region and the central North Island in the last few years provides significant new information on the frequency of eruptions and the dispersal of ash. The probability of significant volcanic impact on Auckland City from either a local event or ash from a distant event is now known to be comparable to the probability of major earthquake impact in Wellington; about 10% in 50 years. It is surely fair to say that engineering projects in Auckland do not give the same attention to volcanic impact as engineering projects in Wellington give to earthquake impact.
- **Tsunami Risk:** The majority of New Zealanders probably think that the major tsunami risk in New Zealand arises from earthquakes far away on the Pacific Rim, for example those from Chile in 1960. However, there is significant risk from local earthquakes. In 1947 there was seaweed in the power lines on the main highway north of Gisborne from a tsunami. Such an event today, particularly on a summer surfing day, would have a significant social if not physical impact. Yet only last year we had Gisborne people driving down to the coast to look for a possible tsunami from an earthquake that occurred offshore. We suspect that ongoing geological research may reveal that the tsunami hazard in some coastal areas is

comparable to the volcanic and earthquake hazard. What of the risk to structures?

- **Flood Risk:** Visibility of risk also seems to influence decisions on planning and mitigation. For example the Wellington Region is happy to spend $100M over 10 years for stop bank strengthening in the Hutt Valley for the 450-year level flood. However, it has not been possible to get acceptance for even a $10,000 study of the fact that the 450-year earthquake will likely alter the level of the land by up to 1.5m, a more than insignificant effect on the river drainage. Is it that the small but frequent and visible floods raise the consciousness far more than small earthquakes?

3 FUTURE KNOWLEDGE

The above examples are for existing structures and known hazards today. How do we cope with the fact that research knowledge is continually improving and may change the future risks for structures that exist now or even for those that we have yet to design? Some hints of significant in current research are as follows:

- A four-month deployment of over 100 earthquake-monitoring systems across the central North Island provides far greater detail on earthquake activity than we have known previously. We have known that there was persistent earthquake activity in the Waiouru area but we now see a much clearer picture of it. It is possible that the activity relates to ongoing deformation from the load of Mt Ruapehu. Will it change our thinking about the Rangipo Power Scheme tunnels, dams and aqueducts?
- Earth deformation measurement with GPS enables us to measure the buildup of strain throughout the country. We can see a very high concentration of strain in the central South Island and to a lesser extent southern North Island. Will we reach the point where we can forecast earthquakes, even if only their high probability in the next months or year rather than shorter term forecasts? Would that have an impact on decisions about the siting or construction of major engineering projects?
- Basin resonance – advances in computing power now enable us to model the 3-D time sequence response of basins to earthquakes. A model of rupture on the Wellington fault shows that the subsurface configuration of the harbour basin produces marked amplification and resonance in earthquake shaking at some areas of the Wellington and Hutt Valley urban centres. The results are not yet fully calibrated but what if they show that possible forces exceed the codes to which existing buildings have been built?
- Modelling of urban fire spread is expected to reveal localities that may be particularly at risk of conflagration following a major earthquake. Will individuals and local authorities take steps to mitigate the risks?

4 COMMENT

Research knowledge is always going to increase. We must not feel uncomfortable about new knowledge but we must acknowledge it. The engineering community understands that structures built as “state of the art” at the time they were built may not be adequate with today’s knowledge. However, many planners, business leaders and decision-makers do not have the same level of understanding. There is a real challenge for the engineering community to bridge the gap in order to have good risk assessments done and acted upon.

Designing today for risks that we don’t yet understand or even recognize but may do in the future, is even more of a challenge. Risk assessment for future risk undoubtedly is difficult. GNS is commencing a FRST funded research programme on decision support modeling for risk assessment. There will be challenge in working on the present day decision making but it is hoped to also consider future decision-making.