DAVID HOPKINS Consulting Limited

1 October 2011

Canterbury Earthquakes Royal Commission

Christchurch

Dear Commissioners

Technical Papers on Royal Commission Website – Comment

This letter is to provide comments on the technical papers on the Royal Commission website.

I am a consulting engineer specializing in earthquake risk management and have been professionally involved in a wide range of issues on this subject throughout my career. Attached is a CV which gives an indication of this involvement.

After the 4 September earthquake, I was one of seven commissioners on the Canterbury Earthquake Recovery Commission. Immediately after the 22 February earthquake, I helped lead a team assigned to the assessment and stabilization of "critical buildings" – nominally more than 6-storeys high. This work included the Grand Chancellor Hotel, the Copthorne Hotel on Durham Street and many others. Through briefing of teams from the field, and my own site visits, I witnessed details of the performance of many of the important buildings. As a consultant to the Department of Building and Housing, I am responsible for managing the investigations into the four buildings – PGC, Forsyth Barr, Hotel Grand Chancellor and CTV.

These roles, together with my background of experience, have provided strong insights into the many issues being tackled by the Commission. I offer the comments in the hope that they may be of assistance.

The comments below are from my personal perspective and are not given on behalf of any organization.

1. General

The Commission is to be commended for having the technical papers prepared. The impact of the earthquakes has been overwhelming and the papers will assist those involved in shaping the recovery and learning from the events.. The papers will provide information and, hopefully, promote debate. Although the overall effect will be positive, I do have reservations:

- Even though the papers are promoted as being for discussion purposes, they may be regarded by many as being the views of the Commission and as having more authority than intended.
- Those best able to comment are those already involved in post-earthquake work and the opportunities for them to comment in depth will be limited.

51 The Crescent, Roseneath, Wellington, New Zealand | Tel +64 4 384 3903 | Fax +64 4 384 3431 | Mobile +64 27 2468 922| dhcl@xtra.co.nz

2. Performance of URM Buildings – Ingham and Griffith

This is a very informative and interesting paper.

There are valuable statistics on the numbers and types of URM buildings in New Zealand. ***Section 2*** will be of particular value in this respect. ***Section 3*** provides some useful information about the types of failures. ***Section 4*** gives some insights into techniques used, but lacks a historical perspective. New Zealand has had legislation for URM buildings since 1968.

I recommend that peer review of this document by selected designers and territorial authorities to provide a better perspective on the overall issues.

Section 5 gives a useful selection of case studies. What is needed as follow-up is a closer look at the correlation between performance and strengthening levels.

Section 6 includes information on costs of retrofit and the benefits versus costs. This highlights the greatest challenge facing the community in respect of earthquake risk.

Measures need to be introduced which develop an approach in the market place for property that values good seismic performance. At present, property values do not reflect the quality of seismic performance. Retrofitting required by legislation is a poor substitute for market-driven activity. If buildings rated low in seismic performance had lower values than buildings of higher seismic rating, there would be financial incentives to invest in strengthening – the money spent would be recouped immediately through higher market value. (In most benefit-cost analyses, the benefits only accrue when the earthquake occurs.)

Section 7: Recommendations and Closing Remarks

Specific comments on these are given below. On the whole, though, the recommendations are not backed by supporting evidence.

Recommendation 1: I agree that buildings should be identified. TAs should have lists.

Recommendation 2: Successful retrofits: There needs to be more work to back this recommendation. It would be good to have some analysis of level of strengthening versus level of performance in the 4 September and 22 February events.

Recommendation 3: Staged approach: The overall thrust is hard to argue with, but the approach recommended is not practical. **The views of owners, TAs and designers should be sought**. It is worth noting that the NZSEE 1986 Guidelines included "interim securing" which allowed increased time frames for full strengthening if the walls, floors, and roofs were tied together. Unfortunately this option was dropped in the 1995 revision of the Guidelines. Owners may or may not favour a staged process. It is good to have this option available but it should not be mandatory.

Recommendation 4: All buildings for 1st two stages: Needs input from owners, TAs and designers. The aim for 100% of NBS is in line with the Department of Building and Housing approach. There needs to be strong emphasis on the fact that a 67% NBS building may not be safe in a design (major) earthquake. There is a case for dealing with obvious things such as parapets and gables. This was identified (again) after the Gisborne earthquake. But any move in this direction needs input from others and recognition that such an option has been available to our communities since 1968. The reasons for inaction need to be addressed, and these are social/economic rather than technical.

Recommendation 5: National requirement: Similar comment to Recommendation 4. The requirement of the Building Act 2004 for TAs to each have a policy on earthquake-prone buildings has been very successful in raising awareness of earthquake risk. It could be argued that a stronger national drive would have helped. But if there is a move to impose a national requirement, it should be carefully considered so that the benefits of the last five years of TA policies is built upon and not lost. TAs, owners and structural engineers should be involved.

Recommendation 6: Technical capability for seismic assessment: I agree with this, but **the answer to the reduction seismic risk lies more with the community than with the technical expertise.** Practical techniques have been used successfully in the past and most NZ engineers have some experience in them. **The weak link in the chain is not the lack of technical skills but the lack of**

economic and social drivers to insist that work be done to improve buildings. Market forces in other words.

The Royal Commission could help immensely by promoting the concept of market-driven seismic strengthening. Particular points that could be considered include:

- Supporting and promoting a grading system for earthquake risk of buildings. Yes, there are downsides, but there are also consequences of doing too little retrofitting – as we have just seen.
- Encouraging tenants and building purchasers to ask questions about seismic rating, and drive prices and rents down for buildings which are substandard.
- Putting pressure on banks to lend on friendlier terms for high-rated buildings. For instance, they could lower the amount lent by the estimated cost of strengthening
- Supporting incentives for some owners, particularly of heritage buildings

Recommendation 7: Field testing: It would be useful to do some testing, but **it would be more productive to examine more closely the performance of those that survived and the effectiveness of various strengthening measures.** Again, the weak link in the chain is not lack of knowledge on masonry strength (which can be measured for any particular job), but the fact that too few owners (and TAs) are asking for / requiring work to be done. A better knowledge of what techniques have worked would be more helpful.

Recommendation 8: Budgeting constraints: Market forces come to mind again.

The best way of justifying strengthening is to assume that a major earthquake will occur in the first year after retrofitting. This is what the Berkeley campus of the University of California did. The cost of retrofitting was less than the economic impact if an earthquake had occurred, so they justified retrofit on that basis. The benefits, as I understand it, included the very significant costs of business disruption. Assuming that a major event will occur in the first year is the easiest way to demonstrate positive benefit to cost ratios.

I was involved in some recent work in Turkey as resident project manager for Beca Consultants in a feasibility study of 369 apartment buildings – of usually 6 storeys. For that project I developed a benefit cost analysis process to compare options for retrofitting and replacement. The process provided some interesting insights. The study assumed a major earthquake would occur at some time after retrofitting – as a single event. The costs of retrofitting were compared with benefits up until the event. Most, but not all of the benefit came from the reduction in damage in the earthquake, but there were other benefits such as increased rents from day one.

The study showed that all options were better than the "do-nothing" option even if the event was 30 or 40 years away. The results were presented in one graph and thus provided a quick way to compare the relative benefits of two retrofitting options and a replacement option. People can grasp these concepts better than probabilistic concepts. Convincing people to take action even when the benefits are clear is a major challenge, and it is fair to say that little actual work has been done – apart from some demolitions. We tried to interest the government in providing incentives but they were not keen. It is a pity because a small incentive may have been enough.

We in New Zealand would face a similar challenge in persuading people (government and owners) to take action. But if we cannot do it after Christchurch, then we will never do it.

Closing comments:

- There is a need for a public awareness initiative, using the Christchurch experience, to persuade the community that there is value in good seismic engineering.

  (In Taiwan, apartment owners pay a premium (well in excess of the additional cost) to live in base-isolated apartments. The market puts a value on good seismic engineering. Why shouldn't New Zealand be able to achieve the same situation?)

- The Report by Ingham and Griffiths provides some useful background information but further input, particularly from TAs, owners and practitioners is needed before practical steps are contemplated.

3. Inelastic Response Spectra – Athol Carr

This report is comprehensive, insightful and authoritative. It will provide a good basis for further debate on what I believe is **the main challenge of the Canterbury earthquakes – the gap between theoretical assessments of building response and reality.** Elastic response spectra, on the face of it, suggest that the 4 September event should have been more damaging than it was. Dr Carr's inelastic spectra provide some clues on how to reconcile these differences. But there are other considerations of a fundamental nature needed. For instance, the effects of efficiency of ground coupling, influence of soil characteristics, and duration of shaking, need to be examined more closely in the light of the recent events and the amount of ground motion data available. **(What a pity that we had so few instruments in buildings – that should be mandated in future.)**

One of the most baffling examples from 4 September was the Christchurch Women's Hospital. This is seismically isolated and was designed to displace 300 to 400mm in a design earthquake. The elastic spectra from the nearby Botanical Gardens instrument suggest the response should have been much greater than the design value. But it was about 25mm. It was not much more in the 22 February event.

Dr Carr's reference to base isolation on page 8 is somewhat dated at 1991. The number of base isolated buildings has grown exponentially since 1994 and 1995 with the Northridge and Kobe earthquakes. There are probably about 10,000 base isolated buildings in the world today. Perspectives on this technology have changed immensely since 1991.

In this respect, it was interesting to note that the equal energy / equal displacement "theories" date from 1960 – Dr Carr refers to them as Newmark's "observations". Dr Carr's derivation of inelastic spectra assumes that these observations are true. With today's computer power, one wonders if such an assumption is necessary. Analysis programs can take account of non-linearity.

4. Structural Design for Earthquake Resistance – Rajesh Dhakal

This is a most interesting paper and provides a good overview of seismic design approaches over the years. The Department of Building and Housing did some interesting work in 2007 to revise the Building Code. It looked to develop and promote the concept of comparing capacity with demand as noted in Section 2 of the paper. It is a pity that the Department's work did not see the light of day, because the basic concept can deliver consistency of performance across different materials and structural types.

The so-called "loss optimization seismic design" covered in Section 9 should be viewed with considerable scepticism. The Canterbury earthquakes have just reminded us of the pitfalls of probabilistic approaches to seismic design. Earthquakes will not be tamed. Engineers and scientists have tended to think that with all the probabilistic analysis, they have earthquakes under control. Unfortunately this is not the case. Earthquakes don't punch with the gloves on, or above the belt, and will punch outside the ring as well. Probabilistic analysis is fine for developing broad insights and building code approaches, but as a basis of design of individual buildings is not appropriate. I have done many Probable Maximum Loss studies for insurance purposes and am happy to use probability data as a basis for broad estimates - but for groups of buildings not for individual buildings. Even then one needs a healthy regard for the huge unknowns and lack of supporting data that lie behind the sophistication of the analysis methods.

Table 2 on page 25 and subsequent material is well presented and has its uses in underpinning design approaches, but to suggest that LOSD is a design basis for an individual building is going too far in my opinion. We seem to be putting too much emphasis on the science of engineering rather than on engineering itself. Computers are in danger of leading engineers to regard the mathematical models as being reality. The Canterbury earthquakes showed us what reality is. Structural engineers deal with real buildings for real people. We need the analytical skills, but we need more engineers with practical experience and skills.

The Canterbury events provide a unique opportunity to test the community view on earthquake standards. There is a need determine community expectations and modify approaches in our building codes and standards – as necessary. The Building Act and Code are intended to deliver buildings suitable for New Zealanders and to meet their expectations. Do those fundamental settings need adjustment? It is vital that some serious research is done on this.

5. Foundations on Deep Alluvial Soils – Cubrinovski and McCahon

This is a most welcome and encouraging paper. The effects of liquefaction have been particularly extensive and severe in both earthquakes. The opportunities to learn from this event are huge, particularly as we have ground motion records and soils data. The authors are to be complimented for bringing together an authoritative overview and providing some telling insights into the phenomenon of liquefaction. The results will be valuable for Canterbury, the rest of New Zealand and internationally.

The authors' comparisons between the Canterbury earthquakes and the Alpine Fault event are particularly interesting – the Alpine Event would not be as severe in its impacts. (This may not be the case for buildings. For example, the longer duration of the Alpine Fault Event could have a much greater impact on the integrity of buildings. Certainly, extensive investigation and research are warranted in the effect of the Alpine Fault on structures, particularly to make a comparison with the 4 September and 22 February events.)

6. SESOC Preliminary Observations

Although this paper raises some important points, it is essentially a compilation of mostly detailed issues encountered by the authors. A much more fundamental approach is needed if we are to learn the lessons from the Canterbury earthquakes. It would be dangerous to draw conclusions on the meaning of this or that failure without examining closely the performance of buildings in the Canterbury earthquakes and developing a better understanding of how well our previous approaches have served us. This is a considerable exercise.

There are plenty of good points made, but the lack of some fundamental thinking on what the earthquakes mean for structures and our approach to design is of concern. There is thread running through the comments which suggests that structural engineering is a matter of complying with code requirements and nothing more – if it is not in the code you don't have to think about it.

As an instance, Section 3.3.1 points to the need for serious review of precast flooring systems where elongation occurs and proceeds to list 5 sub-items for consideration. The narrow view evident in this section is a concern. The problem is much wider.

The fundamental lessons from the Canterbury earthquakes from a structural point of view are:

- **We have a lot to learn about how we estimate structural response to earthquakes.**
- **Earthquakes will shake buildings apart. They are severe test of integrity.**

As an example, number of older in-situ reinforced concrete buildings survived very well. This is a reminder of the value of the integrity (tying together) that they possess. Precast floors, whether subject to beam elongation or not, are another matter. Precast floors have been used in New Zealand for some 40 years. The intention has been to replace in-situ construction, but it is difficult to replace the full integrity of in-situ construction. As precast floor spans have become longer, the relative integrity has been reduced. Hollow-core floors started at 200mm deep with 70mm topping. We now have 400mm and deeper units with 70mm topping. Maintaining the integrity of the in-situ equivalent is challenging. There is at least one instance in the Canterbury earthquakes that point to the need to review the way we design and construct these floors.

7. Stairs and Access Ramps – Des Bull

This paper highlights some issues with stairs and ramps. It seems to me that a more comprehensive study is needed to do justice to the issues. The detailed provisions of Section 4 seem to assume that our current way of estimating displacements is as accurate as it needs to be. Though the figures in Table A provide some insights into relative provisions of various standards, it all seems rather precise and unnecessarily detailed.

The Department of Building and Housing has produced a Practice Advisory on this subject which is a rather more general alert until more thorough reviews are available.

8. Canterbury Earthquake Sequence – TH Webb et al

The work of GNS even before the earthquakes has been of the highest quality. Their work since 4 September last year has been outstanding. It has served the community and the nation well.

Having said this, it is up to engineers and community leaders to define how best to use the information generated by GNS and others in the design of buildings and infrastructure. As noted above, earthquakes have just shown us that they are not to be tamed. Seemingly accurate calculations of probability, smooth-looking response spectra and single line attenuation relationships have lulled engineers into thinking that earthquakes have been tamed.

We need to examine the merits of the probability basis for setting design standards. There needs to be a conditional probability option, at the very least.

It can only be hoped that the investment in understanding the science we have seen since 4 September 2010 will be matched or even exceeded by the investment in understanding building behavior and how to design better buildings and infrastructure through the lessons that Christchurch offers.

(I have commented to colleagues that when the leaky buildings problem hit us, there was no difficulty in recognizing that it was the buildings that had to be fixed. We did not need more research on how often it rains or how hard. Sometimes it seems that the response to the Canterbury earthquakes has placed undue emphasis on the probability of another earthquake while not enough attention is paid to the performance of buildings and infrastructure. We do not have to know everything about earthquakes to design safe buildings.)

Research Programme Recommended

When I was a member of the Canterbury Earthquake Recovery Commission (CERC) following the 4 September earthquake, I proposed a 5-year Canterbury Earthquake Research Programme. This proposal was approved by the CERC and recommended to Government. To my knowledge nothing has been actioned. I commend the Canterbury Earthquake Research Programme to the Royal Commission and trust that the Commission will see fit to support it. The proposal is attached to this letter.

I regret that this letter and comments are not as structured as I would like. Nevertheless, I trust that the comments will be helpful to the Commissioners in carrying out their tasks.

Yours sincerely

David Hopkins

David C Hopkins

Director