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The Canterbury earthquakes — lessons for construction lawyers

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Introduction

The Canterbury earthquakes in 2010 and 2011 were a tragedy that resulted in substantial loss of life and property damage. Eighteen people died in one building (PGC), and 115 in another (CTV). A further 42 people died from the failure of other buildings, and many more were injured. The New Zealand government implemented a Royal Commission that issued its final report in December 2012.

The Royal Commission report, in seven volumes, contains a wealth of information of interest to construction lawyers. This paper provides a brief overview of several of these issues, and some background technical details that are relevant to an understanding of the construction law issues.

The Royal Commission

The Royal Commission was chaired by a High Court judge, its other members being engineers experienced in earthquake engineering. The Royal Commission had wide ranging terms of reference requiring it to make recommendations on:

(a) measures necessary or desirable to prevent or minimise the failure of buildings due to earthquakes likely to occur during the lifetime of those buildings;
(b) the cost of those measures; and
(c) the adequacy of legal and best practice requirements for building design, construction and maintenance related to managing the risks of building failures caused by earthquakes.

The terms of reference required the Commission to investigate the performance of a reasonably representative sample of buildings in the Christchurch CBD, including four nominated buildings that collapsed totally or partially. In the event, the Royal Commission decided to investigate all buildings that caused a fatality, and this included five outside the CBD. The representative sample also included 15 buildings that did not cause fatalities, covering buildings designed before the introduction of the 1976 Loadings Code, and buildings designed to the 1976, 1984, 1992 and 2004 loading standards.

The Royal Commission was also required to make an inquiry into the adequacy of the current legal and best practice requirements for the design, construction and maintenance of buildings in central business districts in New Zealand to address the known risk of earthquakes.

Royal Commission Report

The Royal Commission Report contains invaluable technical details on the current "state of the art" of earthquake engineering, as well as a summary of the current New Zealand legal and regulatory background on the regulation of building approvals. Volume 1 contains the recommendations made in vols 1–3, and includes background material on seismicity, the seismic design of buildings and soils and foundations. Volume 2 covers the performance of Christchurch CBD buildings. Volume 3 discusses the engineering technologies available to reduce earthquake damage to buildings. Volume 4 reviews the issue of existing buildings in New Zealand that are likely to perform poorly in earthquakes. It outlines the building standards, legislation and policies in New Zealand, and reviews the characteristics of unreinforced masonry buildings, which form a significant proportion of earlier buildings and lack the capacity to resist seismic actions when compared to more recent structures of steel and reinforced concrete.

In vol 5 the Royal Commission makes a number of recommendations for changes to the legislation, policies and practices to prevent or minimise the failure of buildings in earthquakes and on the legal and best practice requirements for the management of buildings after earthquakes and for the design of new buildings. This volume also sets out the Commission's approach to the Inquiry and describes the way in which it managed the thousands of documents it received and the reporting structure it followed.

Volume 6 details a comprehensive investigation of the collapse of the CTV building, and identifies those previous design, certification and construction errors and failures of process that doomed the building. Volume 7 addresses the adequacy of the current legal and best practice requirements for the design, construction and maintenance of buildings.

The Royal Commission made a total of 189 recommendations. These include 29 detailed recommendations in respect of site investigations, ground improvement and foundation design. Thirty four recommendations were made on changes in the design of buildings for earthquake resistance, including changes in the way that seismic design is undertaken and changes to structural Standards. Volume 4 contains 36 recommendations on treating the earthquake risk of existing buildings. A total of 75 recommendations were made in vol 7 on roles and responsibilities in relation to building management after earthquakes, the regulatory framework for buildings and the training and education of civil engineers and organisation of the civil engineering profession.

Expert evidence in the Royal Commission

Unsurprisingly, much of the evidence before the Royal Commission was highly technical. The Commission considered the current practice of structural design of buildings in New Zealand in the context of the current "state of the art" of earthquake engineering. The procedures adopted by the Commission for submission and testing of expert evidence were a text book application of current best practice in this area.

A substantial number of eminent experts, both local and international, gave opinion evidence on particular issues. In some cases these were in support of parties appearing before the Commission, in other cases the experts were engaged directly by the Commission, and in other cases the Commission considered written expert reports written for other organisations and purposes. In view of the number of different experts, and the complexity and "cutting edge" nature of the issues involved, it is not surprising that the opinions were sometimes contradictory.

The Commission used at least three "best practice" techniques for critically assessing the expert evidence put before it. The first of these was peer review — the engagement of international experts to independently review and comment on reports prepared by prominent experts in the field. The second technique was to use an independent facilitator in a conference of experts that had addressed a common issue. The facilitator's task was to assist the experts to reach agreement if possible, and prepare a joint report identifying areas of agreement and disagreement. The third technique was to have expert evidence presented orally to the Commission in a "hot tub" — all experts giving evidence on a particular issue appearing before the Commission simultaneously, and subject to questioning by the Commissioners and the other experts.

The Commission used a further technique for expert evidence that is not available to judges in litigation or arbitrators in arbitration. On a number of issues, the Commission used its own expertise to carry out independent analyses to determine for itself the cause of failure of some buildings. This was done in cases where the Commission apparently did not agree with the findings of the expert reports and reviews submitted to it.

This approach was clearly within the Terms of Reference that enabled the Commission to "conduct, where appropriate, your own research". It was made possible through the appointment of highly qualified engineer Commissioners who had the experience and ability to carry out detailed analyses using state of the art analytical tools and assumptions. Such a "hands-on" approach by the tribunal may be possible in an expert determination, and is certainly provided for in many Dispute Board procedures for determining disputes, such as the FIDIC "rainbow" suite of standard contracts.

The earthquakes

The sequence, location and magnitude of the earthquakes considered by the Royal Commission were significant in the resulting loss of life. A magnitude 7.1 earthquake occurred at 4.35 AM on 4 September 2010, a magnitude 4.9 after-shock at 10.30 AM on 26 December 2010 (a public holiday), a magnitude 6.3 after-shock at 12.51 PM on 22 February 2011 (a working day), and a magnitude 6.3 aftershock on 13 June 2011.

These details of the earthquakes underline the random nature of earthquake risk. The time of an earthquake's occurrence may have a considerable influence on the incidence of death and injury. The original earthquake in the early morning did not cause any casualties, whereas the February 2011 "aftershock" in the middle of a working day resulted in 185 fatalities. The exact location of an earthquake's epicentre determines its damaging effect on property — the February magnitude 6.3 after-shock caused more property damage than the September 2011 magnitude 7.1 earthquake because the epicentre was much closer to the Christchurch CBD.

Although New Zealand is an in an area known to be susceptible to earthquakes, and has a well developed "state of the art" earthquake design code, the magnitude of the Canterbury earthquakes was unexpected. They resulted from previously unknown faults which had not ruptured for more than 8000 years, and have resulted in a reassessment of the seismicity of the area.

Earthquake loads on buildings

Subject to some qualifications, the shaking in the September earthquake was comparable to that anticipated for a design 500 year return period earthquake for Christchurch. Thus the earthquake resulted in loads on Christchurch CBD buildings that was approximately equivalent to the current design load specified in the New Zealand Earthquake Code for buildings of "normal" importance. The accepted risk level implicit in this code is based on an earthquake with a "return period" of 500 years. That is, an earthquake of this magnitude would be expected at least once in 500 years. Put another way, a 500 year return period is approximately equivalent to a 10% chance of being exceeded during a building life of 50 years.

However, the February 2011 aftershock subjected Christchurch CBD buildings to loads greater than the current "design level". The loads generated exceeded those from a 1 in 2500 year return period, the design earthquake for structures with important post-disaster functions, which are designed for higher earthquake loads than "normal" structures.

All structures are designed for earthquake loads arising from an earthquake of a certain magnitude. As a natural, random phenomenon, there can be no guarantee that a structure may not be subjected to an earthquake of a higher magnitude during its life. That is, there is a certain probability (perhaps unquantifiable) that the structure may be subjected to earthquake loads greater than it is designed for. In the case of some building types (particularly older unreinforced masonry buildings), loading significantly in excess of their design load capacity is likely to result in complete failure.

The magnitude of the earthquakes in relation to the prevailing New Zealand design standards is summed up in the Royal Commission statement: "The Canterbury earthquakes have tested CBD buildings in excess of their ultimate limit state".

Safety assessments of buildings after the earthquakes

The Government declared a state of emergency after the September earthquake, and the initial assessment of the safety of buildings was carried out under a legislated framework. Before buildings were put back into service, they were subject to a visual inspection and posted with a green, yellow or red card. Buildings in imminent danger of collapse and unsafe to enter were red carded, and those buildings which required remedial work before normal use were yellow carded. A green card permitted normal use of the building, but owners were encouraged to obtain a more detailed assessment by a qualified engineer.

The Royal Commission was generally complimentary about this process of the rapid assessment of buildings to enable an immediate return to normality to the extent prudent. A number of experienced engineers assisted in the rapid assessment on a voluntary basis. Under the declared state of emergency, they were indemnified against liability arising from their assessment.

No state of emergency was declared after the December after shock, and not surprisingly, engineers were reluctant to volunteer their services for building assessment in the absence of and indemnification against liability. This issue was one of the many on which the Royal Commission made recommendations for a change in the legislative environment, to ensure that in the future volunteers prepared to assist in the important task of recovery after a disaster are not inhibited by concerns over their liability.

Design standards

New Zealand has had standards for the design of buildings and structures to resist earthquakes since 1935. The design loads and criteria for earthquake resistance have changed and evolved considerably over the years, including requirements for ductility and capacity design introduced in the 1970s. The most recent design standard is NZS1170.5:2004 "Earthquake Actions Standard", containing 153 pages of Standard and Commentary. Prior to the 1960s there was little knowledge of the principles of designing structures to resist the horizontal (and vertical) forces generated by earthquakes. The modern approach to earthquake resistant design is to build ductility into the structure — a capability to undergo repeated deformation whilst dissipating substantial energy through the deformations of the structure.

Steel and properly designed reinforced concrete are inherently ductile materials; unreinforced masonry (brick and stone) is not. A well-designed ductile structure to modern standards will be able to withstand moderate earthquakes without significant structural damage, and a severe earthquake even greater than the "design earthquake" with substantial damage, but without collapsing. Such a damaged building may need to be demolished after the earthquake, but it will have performed its most important function of protecting the lives of its occupants.

Assessment of existing buildings to modern standards

The damage caused to many older buildings in Christchurch highlights a dilemma in determining where the balance should be struck between the risk of death and injury from the collapse of unreinforced masonry buildings in an earthquake, and the costs to the community in strengthening or demolishing them.

In circumstances where an unreinforced masonry building is required to be upgraded to improve its capacity to resist earthquakes, the current New Zealand practice is that it must be strengthened to resist only 34% of the current design load (new building standard). Whilst that increased load capacity may be able to be implemented at a reasonable cost, it is not usually possible to significantly improve the ductility of such buildings. The consequence is that an earthquake imposing significantly lower loads than the new building standard may cause collapse of a strengthened unreinforced masonry building, because it has insufficient ductility to deform and absorb energy. By contrast, a modern building with adequate ductility may still provide life safety to its occupants when subjected to significantly higher loads than it was designed for.

It is interesting to note that the New Zealand Society of Earthquake Engineers consider that 67% of NBS is a reasonable level of strengthening to reduce the risk posed by existing buildings. The Christchurch Council proposed that this level of strengthening should apply in circumstances where it issued a notice to strengthen an earthquake prone building under its Earthquake-Prone, Dangerous and Insanitary Buildings Policy. However, in a judicial review of this policy in the High Court of NZ, Panckhurst J determined that Councils can enforce compliance with the code by issuing s 124 notices but they may not require work to achieve criteria which are higher than those specified in the code:

> The building code governs building requirements in New Zealand. Compliance with the code is required in relation to new building work. Persons may not be required to achieve performance criteria above those prescribed in the code. … It would be anomalous if territorial authorities could as a matter of policy utilise s 124 notices to achieve a strengthening performance criteria higher than that used to define an earthquake-prone building.[1]

Design risk

The Royal Commission Report highlighted a number of areas of design risk via its discussion of the behaviour of a number of buildings in the Canterbury earthquakes. Some of these are inherent in designs being prepared by fallible human beings, some are related to the prevailing state of knowledge (or lack of it) and others are related to the procedures adopted for procurement of design, checking and certification. Substantial earthquakes, equal to or greater than those in the prevailing design standards, when they impact a major city, provide a load test that will result in many design risks eventuating. In addition to the two major modern buildings that failed with substantial loss of life, there were other buildings that were so severely damaged that they were subsequently demolished. The Royal Commission's investigation of these buildings drew attention to the following design risks.

Design of buildings to resist substantial earthquakes requires a high level of engineering design skill. Inadequate understanding of the behaviour of building when subjected to lateral earthquake loads from any direction, or failure to follow load paths through all the structural elements into the foundation may result in under designed structural members, or connections between members that cannot transmit the required loads. These issues are particularly acute in geometrically complex buildings in which torsional behaviour can induce much larger member forces than are revealed by simple analysis.

Every earthquake that results in the failure of modern buildings adds to the knowledge of the behaviour of buildings under earthquake loads, and how to design them to preclude complete collapse. Inevitably, design standards evolve to include the lessons learnt, and the results of further research. Thus, a building designed in conformance with the standards prevailing in the 1970s or 1980s will not perform as well as a building designed in accordance with the current standards. Even though the earthquake design loads may not have increased substantially, some of the newer code provisions, such as the requirements to provide ductility or the amount of movement to be provided for, may mean the difference between a building which survives largely intact, and one in which there is major structural damage which may result in partial or complete collapse or subsequently require demolition. This "design code risk" would require a detailed engineering investigation to quantify.

Notwithstanding the very sophisticated computer programs that are available to analyse structures under earthquake loads, it still remains very difficult to properly model the complete building performance. Further, the time and expense of such analyses can rarely be economically justified for routine design of typical commercial buildings. Engineers rely on the requirements in design codes, which are typically regarded as defining the approach that should be followed by the ordinary competent engineer. The process of reviewing and revising design codes takes into account the views of the various stakeholders who have an interest in designing buildings, and typically involve many compromises between reducing risk and the cost of doing so. It is suggested that the current design codes represent the community's view on the acceptable level of risk that it is prepared to pay for. As the failures that occurred in the Canterbury earthquakes have shown, there are many areas that may require further review and revision, and these will no doubt be considered in the light of the economic cost to the community.

Other issues of interest

In such a wide ranging and comprehensive Royal Commission, and a Report in seven volumes that total more than 1100 pages, there are many more issues of interest to construction lawyers than were touched on here.

Other topics to be the subject of subsequent articles include:

- legal and statutory requirements, including the extent to which the regulation of "social" issues may be in conflict with the fundamental requirements of ensuring human safety;
- engineer's duty to warn of risks, and the communication of their findings to other, non-technical, people;
- the lessons that can be learned from case studies of buildings that collapsed or were severely damaged.

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Footnotes

1. *Insurance Council of NZ Incorporated v Christchurch City Council* [2013] NZHC 51 at [43].