Consequences of the Canterbury earthquake sequence for insurance loss modelling

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ABSTRACT: By far the largest insured loss in New Zealand's history, the Canterbury earthquake sequence provided a severe test for insured-loss risk models. This paper describes the model components and discusses how the Canterbury earthquakes revealed shortcomings in nearly every component.

The strength of the ground motions given the magnitudes of the events is an active area of scientific research. The catastrophic liquefaction witnessed in parts of Christchurch was not well represented by loss models. Post-event loss amplification factors in Canterbury included the impact of the CBD cordon, abandoning red-zoned suburbs and controlling the costs of the vast rebuild effort.

Loss models typically assume structures are repaired or rebuilt between events. In Christchurch progressive damage occurred from the sequence of aftershocks. Even the seemingly simple task of how to define "an event" had a significant effect on how the final cost of the damage will be distributed between insurers, reinsurers and ultimately the Crown.

Furthermore, the earthquake sequence has put the spotlight on policy wordings and the way models are used within the local insurance and global reinsurance markets. Notably, damage that might have been repairable elsewhere in the world has led to the demolition of buildings in Christchurch because underinsurance and market claims practices have rendered their repair uneconomic.

Loss models are being rebuilt in light of the data from Canterbury. One challenge is to separate the lessons specific to Canterbury from those that can be applied elsewhere in New Zealand and other parts of the world.

1 INTRODUCTION

The insurance industry uses loss models to quantify the risk to insured property from natural hazards such as earthquakes. Insurers, reinsurers and reinsurance brokers use models as an objective tool in their reinsurance negotiations. Models are produced by independent 'vendor' modelling companies, such as RMS, and several re/insurers have their own in-house models as well[1].

Models consist of a large set of stochastic events, each with its own source location, rupture mechanism, magnitude and annual frequency. This stochastic module is effectively a catalogue of hypothetical, possible events. From the event parameters the hazard module computes ground motions at any point of interest for each event. Users of the model enter the locations, values and descriptions of the buildings they insure and, given that information, the vulnerability module estimates the cost of the damage those buildings are likely to suffer from each stochastic event. Output from the model typically consists of an annual loss exceedance probability curve and derived statistics of losses specific to the user's portfolio of property. The financial module produces results for a variety of financial perspectives: ground up (total loss) or the loss to any particular layer of reinsurance cover.

[1] This paper is intended to address generic issues but is written from an RMS perspective. The paper should not be used to draw conclusions about any other organisation's loss model.

Developing a model and, indeed, using a model requires a number of assumptions. The representation of stochastic events and their ground motions is an evolving science. Loss modellers look to GNS Science as the recognised research authority in New Zealand (Stirling *et al*. 2002, McVerry *et al*. 2006). Vulnerability models are typically developed in closely guarded exercises which rely critically on loss data or, in the absence of data, on loss experience from other countries with similar building inventories, building codes and practices.

To get the most out of a model, users must enter data that accurately reflects their exposure: its location, its construction characteristics and its value. Details for one or more of these inputs are typically uncertain, especially once data have been aggregated up to enable faster calculations of impacts on reinsurance layers for multiple portfolios.

Insurance markets are informed by the output of models but insurance prices are set by market forces. Prices change in years without damaging events and without changes to models. When a damaging event does occur, models come under intense scrutiny.

2 THE CANTERBURY EARTHQUAKE SEQUENCE

The Canterbury Earthquake Sequence (CES), has been described in detail by various authors (*e.g.* Fry & Gerstenberger 2011, Beavan *et al.* 2011, Bradley & Cubrinovski 2011). For the purposes of this paper, we note the peculiar aspects of the events that have affected re/insurers.

- The events themselves were moderate magnitude earthquakes compared to recent events in Chile and Japan.
- The ground motions for the February 22nd Lyttelton event were exceptionally strong for an event of only 6.3Mw.
- Christchurch has been subjected to at least four shake events that caused substantial damage (and many thousands of weaker events).
- The impact on buildings from the severe and widespread liquefaction in the eastern suburbs of Christchurch was on a scale previously unseen.

3 INSURANCE MARKET RESPONSE

More than two years on from the September 2010, Darfield event, more than half of the residential insurance claims are yet to be settled (EQC 2013). As will be discussed further, the complexity of the events has delayed settlement, to the frustration and cost of all parties.

Re/insurers and modellers began estimating industry losses for the events and assessing model performance since the days after the first shake in September 2010. The insurance market is always concerned by anything unexpected. The liquefaction in September 2010 and the very high ground motions in February 2011 sent alarm bells ringing in re/insurance offices around the world. If loss models didn't capture these effects in Christchurch, what else could they be missing? By how much should model output be 'factored up' to get the 'right' number for a NZ-wide portfolio of buildings? That is not an easy question to answer.

The science and engineering required to address that question will take some years. Re/insurers however need an answer immediately because reinsurance contracts are renewed annually, typically in July or January. In the absence of a new scientific answer, market forces took over in the renewals following the events. Reinsurance prices jumped dramatically (driven also by uncorrelated events such as flooding in Thailand and Australia). The spike in reinsurance and its knock-on effect on insurance availability was a serious threat to the New Zealand economy. Banks require their mortgagees to take out insurance. Reinsurance prices are now easing, due to scientific reasoning and a globally quieter 2012 (*e.g.* Aon Benfield 2013) but are not expected to return to pre-2010 levels.

4 MODEL PERFORMANCE

4.1 Stochastic Module

Stochastic events are based on the New Zealand Seismic Hazard Model from GNS Science (Stirling *et al*. 2002) and consist of events on known faults and other, background events, away from these faults which must occur to balance the strain budget. Since these background events occur on 'unknown' faults they are modelled as being distributed uniformly within polygons covering the country, arranged to capture variations in seismic activity. Events of Mw 6-7 on unknown faults near Christchurch were therefore included in the model.

The ongoing aftershock sequence means activity near Christchurch is still higher than its long term average and will remain high for some years (GeoNet 2013). Away from Christchurch though, the CES events were too small to transfer sufficient stress to have any influence on activity along the main plate boundaries (Townend *et al.* 2012). There is therefore no reason to believe the CES affected frequencies of model events in the Wellington region which remain the main source of risk to the country. These events produce the largest expected losses in New Zealand and are of most interest to reinsurers around the world.

4.2 Hazard Module

The very strong ground motions, particularly after February 2011 were unexpected for such moderate earthquakes, particularly in the mid-range periods (Chang *et al*. 2012). The very detailed instrumental record from GeoNet has enabled researchers to explore and explain basin effects such as seismic reflection from the basalt cones of Banks Peninsula and the popularly referred to 'slap-down' of soil layers (GNS 2012). Such a detailed record is a treasure trove for researchers, especially in New Zealand where the instrumental record has lacked near-source observations (McVerry *et al*. 2006, Bradley 2010). The question insurers have is "now that we have near-source observations, what can be said about near-source ground motions for the rest of New Zealand?" If the models underestimated motions in Christchurch, do they also underestimate them in Wellington (and, if so, should insurers be purchasing more reinsurance, and at what cost)? It is too soon to answer these important questions with any confidence but it would be unwise to update a loss model with the assumption that the ground motions observed in Christchurch are representative of all near-source ground motions from all faults in New Zealand. Loss modellers are monitoring developments into Ground Motion Prediction Equation (GMPE) research both in New Zealand and other parts of the world.

4.3 Secondary Perils

Loss models also capture damage from secondary perils, *i.e*. other than the direct physical shaking from the earthquake. In the CES the dominant secondary perils have been liquefaction and rock falls, with liquefaction causing substantial insured losses.

Liquefaction is included in some loss models. Soils susceptible to liquefaction are identified in the model and a modifier amplifies the loss to the structure (*e.g.* Advanced Technology Council 1985). Typically the factors consider damage due to differential settlement and recognise the need for repairs to foundations in addition to the above-ground structure. While current geotechnical engineering knowledge can explain the dramatic liquefaction in the eastern suburbs (Cubrinovski *et al*. 2011) it was not anticipated in loss models even though the soils were identified as being very susceptible.

Loss models do not allow for such extensive liquefaction where houses are flooded by ejected ground water and settle so far that they become flood-prone, whether or not they suffer any substantial direct shake damage. The abandonment of some eastern suburbs will, at least, reduce insurance losses from liquefaction in future events in Christchurch. Insurers and modellers now need to check other cities around the world where similar property developments may have occurred to avoid being caught out again.

4.4 **Vulnerability**

Insurance claims are still being settled so it is too soon to confirm how model damage functions performed. Preliminary, qualitative investigations suggest that, given the ground motions, the levels of shake damage are consistent with those predicted by the model. Of course, as already discussed, the ground motions were higher than expected.

The biggest complication for assessing damage functions in Christchurch is that buildings have been subjected to multiple, damaging aftershocks and the damage has accumulated. Evaluating how much of the loss is attributed to each aftershock is very difficult. Loss models consist of thousands of independent events and typically assume structures are fully repaired between events.

In Christchurch, most houses were made weatherproof between events but did not have structural repairs before the next event struck. In the CBD some retrofitting was carried out after the 2010 Boxing Day event so some structures may have been stronger when the February 2011 event occurred. Others were not repaired and so may have been weaker. The details of individual structural engineering reports and the Royal Commission findings are beyond the scope of this paper. From an insurance loss perspective, it will be challenging to relate ground motion from any one event, or some cumulative ground motion index of the entire sequence, to physical damage in a simple way. Another challenge is to separate flood damage from shake damage in the eastern suburbs.

It will likely require a combined effort involving insurers, engineers and modellers to make headway on this topic.

4.5 **Financial Module**

Perhaps the most surprising aspect of the CES from a loss perspective has been the complexity of converting physical damage into insured loss. It sounds so simple but a number of factors make it very difficult. These factors are discussed in the next section.

5 **INSURED LOSSES**

5.1 **Apportionment**

The sequence of damaging aftershocks has led to progressive or compounding damage (as discussed above). After all the shaking, the owner of an individual building may just see a damaged structure that needs to be repaired. Insurance policies however 'see' a series of damaging events, each of which contributed, by various degrees, to the total damage state. Most policies renewed at least once over the course of the CES. Treating each damaging shake as a separate loss event rather than taking the entire sequence as a single loss event has a significant impact on how the final damage bill is distributed. This is clearly seen in the case of residential damage covered by the Earthquake Commission. EQC is tracking 15 separate loss events in Canterbury (EQC 2012).

Such a series of damaging aftershocks is unprecedented in New Zealand's history. EQC's operation is prescribed by the Earthquake Commission Act (1993) and so EQC and the Insurance Council of New Zealand jointly asked the High Court to determine how EQC's liability should be calculated. The High Court ruled each damaging shake was to be treated as a separate loss event (Judicial Decisions Online 2011).

In a hypothetical example, consider a single house damaged in three aftershocks, without repairs between events, and assessed as having \$150k damage. As a single loss event, EQC would pay out to their cap of \$100k and the homeowner's insurer would pay the additional \$50k. As a series of loss event with loss apportioned as, say, \$90k, \$20k and \$40k, each event falls below the EQC limit and so EQC ends up paying \$150k in total.

It is easy to see how apportionment has complicated the bookkeeping necessary for each insurer to determine their claims on their individual reinsurers. It is impossible to accurately apportion the damage caused to each building in Canterbury by each damaging shake. Given the inherent uncertainty in determining apportionment, it is inevitable some claims will be disputed.

5.2 **Underinsurance and unexpected losses**

It is not at all unusual for buildings and contents to be insured for less than their rebuild or replacement values. Underinsurance is revealed after almost every major insurance loss event around the world. New Zealand has been no exception but some unique aspects of the NZ insurance market have exacerbated its impact.

Nearly all insured houses in New Zealand have open-ended replacement policies where the insurer agrees to replace the house, say in the event of a fire, without specifying a sum insured. (Policies in most other countries have agreed sums insured). Insurers have a pretty good understanding of average rebuild costs across New Zealand so have a fairly accurate internal estimate of the total value of their portfolio, even if the value of any individual building is very uncertain. If an event damages a diverse mix of buildings, an average rebuild cost may be useful. If an event damages properties from only a narrow socio-economic range, the average rebuild cost may not be very relevant and insurers may find themselves over-exposed against their expectation.

Up until the CES, residential earthquake losses in New Zealand have, by and large, been absorbed by EQC. This is not the case in Canterbury as damage to some buildings from individual shake events has been severe enough to exceed the EQC cap and a great deal of damage has occurred to those parts of residential properties not covered by EQC such as fences, swimming pools, non-structural retaining walls and driveway surfaces. It is more difficult to estimate the value of these “non-Act” elements than valuing the houses themselves. All repair or replacement costs for these elements have been borne by private insurers and were not anticipated by many, and not well captured by loss models.

Where building permits are needed to carry out structural repairs, local authorities require buildings to be repaired to at least 34% of the current building code so they cannot be considered earthquake-prone under the Building Act (2004). Furthermore, stricter foundation standards have been introduced in the TC3 zones of Christchurch. The legal and political issues surrounding these requirements are beyond the scope of this paper. From an insurance perspective, the earthquake-prone building and engineered foundation requirements in many cases mean that a building is not only replaced as-new-when-built but as-new-under-current-regulations, at additional expense to the insurer. This distinction was typically not made in the wording of insurance policies.

Over recent years, insurers have deliberately written policies in Plain English to make them more accessible to the public. Just as an earthquake ‘finds’ the weakest element of a structure, it seems they also reveal the loosest wording in a contract.

In contrast to residential policies, most Commercial policies typically specify a sum insured. The sum may be, unintentionally, less than the actual rebuild cost due to an inaccurate or out-of-date valuation or it may be intentionally less to reduce the cost of the owner’s premium. In most countries, when an underinsured building is damaged, the insurer pays for the damage in proportion to the percentage insured, a practice referred to as ‘averaging’. For example, a hypothetical structure with a rebuild cost of $10m is insured for only $7m, *i.e.* 30% underinsurance. The structure suffers $6m damage from the violent shaking of the February 2011 event, a damage ratio of 60%. In most countries the insurer would “average” the claim and pay $4.2m, *i.e.* 70% of the actual damage since the building is 30% underinsured. In New Zealand insurers typically pay for damage up to the sum insured regardless of the underinsurance. In the current example this is $6m which means an insured loss ratio of 86%. The earthquake-prone building and stricter foundation requirements mean the repair costs are likely to be higher again and costs only ever increase once work starts (*e.g.* if asbestos is found). For the hypothetical building, the insurer and the owner decide that the 86% ratio will probably end up over 100% of the sum insured with the extra cost to fall on whichever party insists on the repairs. Rather than waste more time and money, the structure is declared a total insurance loss and it is pulled down. This situation is frustrating to engineers who see the 60% damage ratio and know the structure can be repaired. Elsewhere in the world the structure might have been repaired because it would be an economic solution. In Canterbury it is simply uneconomic. This is not an ideal situation for any party. Engineers are frustrated, insurers have paid more than they anticipated and the building owner has an empty site and a cheque that will not replace the original structure.

Underinsurance will continue in the future: the insurance market may decide to insist on ‘averaging’ in their claims processing. Insurers are already signalling a move away from open-ended replacement residential policies to policies with specified limits and it is very likely all policy documents will contain more detailed fine print.

5.3 Post-event Loss Amplification

It costs more to fix damage to one building when there is wide-area damage than it does to fix the same damage to the same building when it is the only one damaged. This can be due to simple supply and demand economics (referred to as economic demand surge). It can also be the result of complications from infrastructure impacts and/or actions by local authorities. Loss modellers refer to these types of additional costs as post-event loss amplification.

By contracting Fletcher EQR to manage the Canterbury Home Repair Programme, EQC have taken steps to control economic demand surge in residential construction. The cordon around the Christchurch CBD after the February 2011 event was necessary to ensure public safety. It also increased business interruption claims. The intervention of central government to red-zone very liquefaction-prone properties has decreased Christchurch’s vulnerability to liquefaction in future earthquakes and increased the global reinsurance market’s confidence in providing cover for the city. The zoning has come at a cost to insurers, EQC and the government (and poses questions as to the government’s possible intervention in future disasters).

With so many claims yet to be settled and so much repair work yet to be done, it will be some time before post-event loss amplification from the CES can be estimated accurately.

6 CONCLUSIONS

The scientific, engineering and economic research necessary to understand the CES event losses will take time. Meanwhile, the insurance market is likely to change the way it offers cover and the way it responds to disasters. Treasury is currently reviewing the Earthquake Commission Act (Treasury 2012). Christchurch will be rebuilt with modern structures designed to or above the latest building code.

The CES has been extraordinary in many ways. Loss modellers and the insurance market did not foresee many aspects of the events. While we will all learn from the CES, the next major earthquake loss event in New Zealand, whatever it will be, will probably be very different.

Loss models need to be reviewed. Re/insurers need revised models as soon as possible but the models cannot be updated overnight. It is worth noting that if a loss model had a “perfect” stochastic set, “perfect” ground motion calculations and “perfect” vulnerability functions it would still not have produced an accurate estimate of insured loss unless it knew just how the insurance market had evolved to convert economic losses into insured losses. It seems obvious that while the research is being done, the next step is to ensure that the people building models and the market using them are all working from a consistent set of assumptions which accurately reflect the way the market actually works.

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