Earthquake damage functions for Australian houses and the probable maximum loss for an insurance portfolio

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Abstract

There are, to date, few accelerometers in major Australian population centres. Microzonation of the earthquake hazard has therefore been based on poorly calibrated models of the likely site amplification.

The proportion of homeowner (building) insurance claims (i.e., the claim frequency) in each postcode area in the Sydney region resulting from the December 1989 Newcastle earthquake, for a large portfolio, provides a method of "calibrating" the earthquake hazard throughout the region.

The Newcastle earthquake has also enabled damage vs intensity relationships to be derived for household buildings and their contents, based on the first sufficiently large sample of insurance claims in Australia. The results are markedly different to damage ratio functions derived elsewhere, e.g., New Zealand.

Some results are presented from these two studies. These have important implications for the estimation of earthquake Probable Maximum Losses for insurers' property potfolios.

Catastrophe insurance

Insurers need to hold reinsurance for both their large individual risks and for their aggregate loss potential. The reinsurance of the accumulated risk of loss from a single insured peril is called *Catastrophe Excess of Loss* (`Cat.', or `XL') reinsurance.

An insurer typically retains the aggregate loss up to a threshold based on the insurer's reserves, premium income, geographical spread of risks, and the requirements of the Insurance and Superannuation Commissioner. Each insurer purchases Catastrophe reinsurance for larger aggregate losses, up to the insurer's estimate of the *Probable Maximum Loss* for any of the insured perils. Windstorm (tropical cyclone) potential losses determine the PML for locations in northern Australia. Hail and windstorms had produced the largest as well as the most frequent claims in recent years by property insurers against their Catastrophe reinsurance policies, prior to the Newcastle earthquake. The potential for a massive loss if a major earthquake were to occur near Sydney, Adelaide or Perth was generally recognised, although estimates of the PML, for a given portfolio, were based on arbitrary factors of uncertain lineage (often asserted to be the opinion of an expert, in London, Munich, Zurich or a university, usually unnamed; see, for example, Staveley, 1986). The potential for a major earthquake loss at Melbourne was generally not accepted.

These factors were settled by each insurer and its lead Catastrophe reinsurer over drinks at renewal time. The reinsurers favoured higher risk factors than the direct underwriters, since this has the effect of requiring a higher PML. The price of Catastrophe cover depended on the phase of the *insurance cycle*, in which capacity diminishes from time to time and the market rates harden; this, in turn, usually attracts new capital to the insurance markets. It is commonly asserted that reinsurers aim to recover their losses from catastrophes, either in Australia or overseas, within a few years.

The world Catastrophe market is presently in a very tight phase. There is insufficient capacity for insurers perceived by the market to have high risk. It is not possible for

some insurers to place the top layers of the Catastrophe covers which they desire; there is an unusual congruence of views amongst insurers and specialist Catastrophe reinsurers and reinsurance brokers that more scientific methods of assessing the PML for a portfolio (and for each insured peril) should be utilised, if only to ration the scarce market capacity more efficiently.

Damage ratio and claim ratio

The *damage ratio* is the direct cost of damage from a particular event divided by the aggregate value of the assets at risk in a defined area. The damage ratio is typically reported for a particular type of construction, such as `brick dwellings' or `low-rise commercial'.

The aggregate claims paid by all insurers will differ from the aggregate economic loss because:

1. not all property is insured, or insured for full value, even though it is a condition of most insurance policies that the property will be insured for at least 80% of the appropriate sum;

2. insurance claims are subject to a deductible;

3. some insurance policies pay an indemnity value (depreciated value) rather than the cost of repairing or replacing damaged contents (`new for old').

The *claims ratio* for a particular insurance portfolio and event, such as the *Newcastle* earthquake, is the ratio of the claims payable to the aggregate sum insured within a defined area, possibly differentiated by wall material, building age, or other coded data from the insurance proposals. (Note that data extracted from insurance files must be carefully checked, since it is based on information provided by clients, who frequently give incorrect information, even for such items as their postcode or suburb! Claims estimates also need to be reviewed, since earthquake claims are often reopened or take considerable time to finalise.)

Earthquake claims ratio for Australian dwellings

Prior to the Newcastle (December 1989) earthquake, very few dwellings in Australia had been damaged by earthquake.

Estimates of the potential damage to dwellings for a hypothetical major earthquake near a capital city have generally, therefore, been based on relationships between damage and intensity derived in either the United States or New Zealand.

Adelaide (1954) earthquake

The most damaging earthquake prior to that at Newcastle in 1989 was that at Adelaide on 1 March 1954. About 30,000 dwellings (out of a total of about 135,000) sustained damage: McCue, 1975; Selby, 1979. The total value of claims paid by insurers `*...exceeded four million pounds*'" (Kerr-Grant, 1956). (Other sources state that the insured damage totalled $6M: Selby 1979; Staveley 1986).

The Adelaide earthquake, with a local magnitude assessed at ML 5.3 (Greenhalgh et al., 1986), produced intensities of MM VI or greater over an area of about 600 km^2 Two small areas, totalling about 100 km^2, experienced MM VII south of Adelaide. A very small area, near Darlington on the southern outskirts of Adelaide, sustained MM VIII damage. Most of the urban area experienced an intensity of only MM V.

No damage ratio has been sighted for the *Adelaide* earthquake. Nor was any attempt made at the time (at least in the published reports) to deduce a relationship between damage ratio and intensity. Data from the Adelaide earthquake was used by the Australian Government Actuary, along with Californian data, to derive crude damage ratio and insurance premium estimates as part of the investigations of a national natural hazards scheme for Australia in the mid-1970s: Technical Committee, 1978.

Most of the dwellings in Adelaide at the time of the 1954 earthquake were of brick or stone construction and many were vulnerable to damage for an earthquake producing intensities greater than MM VI (Kerr-Grant, 1956). Some damage was, according to Kerr-Grant, due to pre-existing defects in masonry due, for example, to soil movement in moisture-sensitive soils.

About 22% of the dwellings in the Adelaide Statistical District made an insurance claim (30,000 claims; 134 103 occupied dwellings). Assuming that the bulk of the damage was to the buildings rather than to their contents and that most buildings were insured, the Damage Ratio was about 0.8% ($6M; 135 000 dwellings with an average insurable value of about $5,000).

Much of the damage was incurred *outside* the MM VI isoseismal. If it is assumed that 75% of the damage and 50% of the claims relate to dwellings within the MM VI isoseismal, the Damage Ratio for dwellings with an intensity of MM VI or more was about 6%.

Other Australian earthquakes

As noted above, very few dwellings in Australia have suffered earthquake damage, other than those damaged at Adelaide in 1954 and in the Newcastle region in 1989. The following discussion illustrates how few dwellings had been damaged and how difficult it was to develop intensity-damage relationships.

The Office of the Australian Government Actuary (Technical Committee, 1978) considered damage data for the Meckering (1968), Robertson (1961) and Picton (1973) earthquakes, as well as the Adelaide (1954) event. The report noted that there were only 85 dwellings damaged by the 1968 earthquake in Meckering township, and, quoting Botta (1974), stated that there were 7706 insurance claims totalling $1.34M, including claims from areas between the epicentre and Perth, where intensities of up to MM VI were experienced.

Denham (1976) noted that damage resulting from the Picton (1973) earthquake was mainly confined to older buildings, as would be expected from the intensities, which were generally MM V or less (the magnitude of the earthquake was ML 5.3). Insurance claims totalled only $0.196M, or an average of $464 for the 423 claims. (This estimate may include damage to a glass works at Wollongong as well as claims paid for damage to dwellings under householder policies of insurance.)

Rynn et al. (1987) provide data on insurance claims relating to earthquake damage from northern NSW and Queensland. There were so few claims that it is not possible to derive even an estimate of the likely proportion of policies which will have a claim, for a given earthquake intensity in Queensland, from the data presented. Given that many older dwellings in Queensland are of timber construction, it is likely that the claims frequency for a major earthquake in Queensland would be much lower than for a similar earthquake magnitude elsewhere in Australia. The damage ratio is also likely to be quite modest.

Claims ratio and claims frequency for a householder insurance portfolio, Newcastle earthquake

An insurer with a large portfolio of domestic dwellings in NSW has provided the author with claims data for both the Newcastle and Sydney metropolitan areas.

Claims data for insured dwellings, rather than for insured commercial and industrial property, were examined for several reasons. Firstly, the proportion of dwellings in the Newcastle area which were severely damaged was much higher than for commercial and industrial property. Secondly, the stock of insured dwellings is less heterogeneous than for the commercial and industrial portfolio. The latter are insured under Fire or ISR policies; ISR policies include coverage for business interruption losses, which are highly variable and dependent on factors specific to the particular business. Finally, the Probable Maximum Loss for many insurers' property portfolios is largely determined by the estimate of the probable maximum loss for the insured dwellings; better techniques are needed to improve these estimates, by relating the claim ratio to the felt intensity.

Building damage and contents damage claims data from this major insurer's householder portfolio have been analysed by postcode and also by wall material. Several thousand claims were available for analysis. Maps of the claims frequency and claims ratio were prepared for this client (using *MapInfo* software), but are not presented here for reasons of client confidentiality.

The mean frequency and severity of *building* and *contents* claims for this insurer's dwellings in the Newcastle area (postcode areas 2280 to 2307) were as follows:

Item	*Building policies*	*Contents policies*
Av. claim frequency *(No. of claims/No. of policies)*	55%	11%
Claim ratio *(Aggregate cost of claims/ Aggregate Sum Insured*	5.5%	0.3%
Mean claim *(Aggregate cost of claims/No. of claims*	$9 000	$600
Median claim amount	$2 500	-

For claims relating to the structure of dwellings, the claim ratio and claim frequency were found to be highly correlated with the building age for those with brick or fibro walls, but not for timber dwellings. (The concentration of older brick dwellings in those suburbs which have the poorest soils may be a confounding factor in the interpretation of this result.)

In common with several other investigations into the cause of severe damage in some suburbs distant from the apparent epicentre of the earthquake but not in adjacent areas, a strong correlation was found between the claim ratio (mapped at postcode scale) and the surface geology.

Claims ratio as a function of modified Mercalli intensity

Relationships have been developed between the claim ratio and the modified Mercalli intensity, for brick dwellings and for those with other wall materials. This is shown in Figure 1. Also shown on that figure is the damage-intensity relationship derived by Dowrick and Rhoades (1991) from analysis of data from the *Edgecumbe* earthquake in the Bay of Plenty region of New Zealand in March 1987.

Most houses in the area affected by the *Edgecumbe* earthquake were of timber construction. The damage ratio for houses in New Zealand has a threshold of MM VII for significant damage, whereas that derived by the author from the *Newcastle* data appears to have a threshold at about MM VI. For intensities of MM VII or more, the damage ratio at Newcastle is about five times greater than in New Zealand. Much higher damage was also sustained in areas outside the MM VI isoseismal, in the Gosford-Wyong, Port Stephens, Maitland-Cessnock and Sydney areas, than was experienced for similar intensities remote from the epicentre of the *Edgecumbe* earthquake.

These features appear to be due to a number of factors. New Zealand dwellings generally have significant earthquake-resistant features, at least up to intensities of MM VII or so, both as a result of progressive tightening of the code provisions and a general awareness of earthquake-resistant design principles in the house construction industry. Brick dwellings are generally of recent construction and have adequate ties and do not use lime mortar.

Probable maximum loss for a more severe earthquake in the Newcastle area

Gaull et al. (1990) consider that the maximum earthquake magnitude feasible in source zone 22 (covering much of NSW and Victoria) is 6.1. This may be compared with the estimated magnitude of 5.6 for the Newcastle December 1989 earthquake. An earthquake with a Magnitude of 6.1 would appear to have an average recurrence interval of about 250 years for the Lachlan Fold Belt, a source zone of about 285 000 square kilometres. The *average* frequency of earthquakes exceeding magnitude 6.0 within about 30 km of the Newcastle CBD (and therefore likely to affect a significant proportion of the portfolio in the Newcastle area) would appear to be very much less than once in 10 000 years. Thus, an earthquake with a magnitude of 6.1 close to Newcastle (or Sydney) is a relatively severe PML event.

An earthquake of magnitude 6.1 in the vicinity of Newcastle would be expected to cause intensities to be about three-quarters of a modified Mercalli intensity unit higher than in the 1989 event. Damage would, therefore, be more severe, and occur over a wider area.

The relationships between intensity and damage ratio, developed in the previous section, have been used to estimate the loss for each of nine zones. Separate estimates of the loss have been made for the portfolios of brick dwellings and those with other wall materials in the Newcastle area.

In summary, claims under building policies for a portfolio of insured dwellings in the Newcastle area (Insurance Council of Australia risk accumulation zone 46) might experience a claims ratio of 6.8%, say 7%. The estimated claim ratio may be uncertain by plus or minus 25%. Allowance has been made in this figure for damage in adjacent risk accumulation zones, including the Sydney area, but the claim ratio has been expressed as a proportion of the aggregate sums insured in the Newcastle area, i.e., Zone 46 only.

Although there would be considerable spillover of damage from the Newcastle region for such an earthquake, the estimated claim ratio for this Zone is a guide to the PML for a severe earthquake in another area of NSW, such as Sydney.

For contents claims, the loss in the vicinity of the earthquake would be about $2.5M, or about $4800 per million dollars SI (0.48%).

Claims frequency in the Sydney region

A considerable number of claims were received by insurers in respect of dwellings in the Gosford-Wyong area as well as from the Sydney region. While few of these claims were for significant amounts and some may have been fraudulent, the spatial pattern of the claims is of considerable interest.

There is a paucity of seismometers in Australian urban areas. The claims frequency for each postcode area in the Sydney region for the *Newcastle* earthquake provides useful information about the potential claims frequency and claims ratio for a severe earthquake closer to Sydney.

The claims frequency in the Sydney area integrates the effects of soil conditions and the age, wall material and condition of the insured buildings in each postcode area. A higher than average claim frequency for a particular postcode area suggests that it is vulnerable to severe earthquake damage.

A statistical analysis has ben carried out of the claims frequency for the portfolio of a major insurer for each of the 235 postcode areas in the region bounded by Heathcote, Ingleburn, Katoomba, Windsor and Wyong. The average claim frequency for the area south of the Hawkesbury River was one claim per 260 policies. The claims frequency was mapped. A map was also prepared of the significance level for the test of the homogeneity of the claims frequency. (The latter map is somewhat different from the former because there are different numbers of policies in force in each postcode area.)

The principal features of the map of standardised claim numbers are as follows:

- claim frequencies well above the average in an area bounded by Homebush, Vaucluse, and Maroubra;
- claim frequencies also well above average in the Manly-Fairlight, Belmore, Revesby and Sylvania areas;
- claim frequencies above average in the area around Botany Bay and Port Hacking;
- a broad area of below-average claims frequency, west and south of Parramatta and north of the Harbour.

Although there are high claim frequencies for some suburbs with a preponderance of old buildings (such as Redfern and Newtown), the claims frequency is low for suburbs such as Glebe, Ultimo, Balmain, Annandale and Rozelle. The age of buildings does not appear to be the dominant factor in the spatial pattern of the claims frequency.

The marked difference between the claim frequencies for localities within 10 km of the coast north of the Harbour and for such localities south of the Harbour suggests that soil (or landscape) factors are the predominant variables affecting the claims frequency.

Postcode areas with either an unexpectedly low or unexpectedly large number of claims were identified, where the claims frequency was significantly different from the average frequency of claims of 3.87 claims per 1000 policies for areas south of the Hawkesbury River.

Ten postcode areas had *fewer* claims than expected, at the 5 percent level of significance, if claims had no geographic pattern. Those postcode areas were:

Lane Cove, Toongabbie, Seven Hills, Fairfield, Cabramatta, Liverpool, Bossley Park, Penrith, St Marys, and Blaxland.

For several of the above postcode areas (Seven Hills, Fairfield and Cabramatta), the high proportion of timber dwellings appears to have contributed to the below-average claims frequency.

There were *more* claims than expected from 23 postcode areas. (This represents 11% of the 212 postcode areas south of the Hawkesbury River. A binomial distribution of claim numbers was assumed, with a 5 % level of significance.) These 23 postcode areas were:

Redfern, Eastlakes, Bellevue Hill, Waverley, Bondi Beach, Edgecliff, Vaucluse, Kingsford, Kensington, Coogee, Maroubra, Newtown, Camperdown, Lindfield, Fairlight, Manly, Palm Beach, Ashfield, Strathfield, Enfield, Belmore, Hurstville, and Sylvania.

Several of these postcode areas are contiguous, and share Quaternary surface geology. Another significant feature of these postcode areas is that they generally have a higher proportion of brick dwellings insured than the average for the portfolio. The high claims frequency for the Ourimbah, Berkeley Vale, Bateau Bay and Gorokan areas is related to their proximity to the earthquake epicentre as well as to their surface geology.

More surprising is the unexpectedly low claims frequency for Woy Woy and Umina, where the claims frequency was 5.2 per 1000 policies. Although these areas are underlaid by Quaternary sediments and have a water table at shallow depth (factors which might be expected to cause a high claims frequency), the high proportion of timber dwellings appears to account for the relatively low claims frequency.

The claims frequency was also above average, even if not statistically significant at the five percent level, in other areas underlaid by Quaternary sediments, such as Randwick, Matraville, Brighton-Le-Sands, Caringbah and Cronulla.

Little, if anything, can be inferred from the pattern of contents claims.

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