Domestic insured losses and the Newcastle earthquake

R. J. Blong
School of Earth Sciences, Macquarie University, Sydney NSW 2109

Introduction

What have we learnt from the Newcastle earthquake? Numerous scientific and engineering studies have been published. Particular emphasis has focused on earthquake characteristics, on damage, on soil foundation conditions and on the importance of site microzonation (for example, Melchers, 1990; McCue et al., 1990; O'Keefe, 1991; Mehan, 1992; Melchers & Page, 1992). Relevant aspects of the Standards Australia (SAA) code have been modified. A number of studies have been initiated by insurers and other organisations examining the possible consequences of future earthquakes in or near Australian capital cities.

The present study is also concerned with modelling the consequences of future earthquakes but the emphasis is on the paucity of available data. As the study from which the present comments are drawn was undertaken for a reinsurance broker, the major concern here is matters relevant to the insurance industry. Three aspects are considered - expected earthquake occurrences, estimates of Modified Mercalli intensities, and anticipated damage ratios.

Expected earthquake occurrences

The probabilities of occurrence of earthquakes of specific magnitudes have been examined recently by Gaull et al. (1990), in a paper written mostly before the Newcastle earthquake, with a few comments added in the immediate aftermath. Thus, the authors leave it open as to whether the maximum earthquake magnitude in zones with relatively short histories (anywhere in Australia) should be half a magnitude unit greater than the largest historic earthquake or whether a maximum magnitude for background seismicity in Australia should be M 7.0 or even M 7.5.

The difficulties of dealing with the inadequate data provided by our short history is highlighted by recent European efforts to reach agreement on likely return periods for specific events (for example, de Crook et al., 1989).

The insurance industry, probably not by design, has adopted a more pragmatic approach based on the concept of Probable Maximum Loss (PML). No return periods are specified (so far as I am aware) for a PML event, but repeated questioning of a number of insurers has produced a few estimates in the range 200-1000 years. The emphasis in this concept is not on a somewhat nebulous return period but on the maximum insured loss that might be reasonably anticipated in a relatively long time period.

Estimates of Modified Mercalli intensities

While the approach of many insurers sidesteps the magnitude-frequency question the problem isn't resolved, as it is necessary to use a "design" earthquake to model the expected consequences. Although consequences in a seismological sense can be estimated using peak ground accelerations, shear wave velocities or Modified Mercalli intensities, the latter is the only practicable alternative for most parts of Australia given the absence of other information.

The importance of ground conditions has been recognised in the aftermath of the Newcastle earthquake and in the revised SAA code. The sorts of information required about ground conditions include:

- presence of unconsolidated/poorly consolidated sediments including landfill;
- the thickness and heterogeneity of soft sediments;
- the likelihood of slope failures;
- the possibility of topographic amplification of ground shaking;
- the thickness of weathered *in situ* soil mantles;
- areas of potential liquefaction;
- areas of potential subsidence.

The order of importance of these variables might change depending on the magnitude of the anticipated earthquake, distance from the epicentre, the types of adjacent rocks or sediments and the nature of the contacts between them, and the direction of arrival of the earthquake waves.

With all of these points in mind, the significant question becomes Where do we get the information from? The traditional emphasis in geological mapping in this country has been on hard rocks. While Sydney and Melbourne have been well served by recent texts on engineering geology (Peck et al., 1992), there are no adequate maps. Melbourne was last mapped at a scale of 1:63 360 (inch to the mile) in the 1960s and the engineering geology section of the State Survey has recently all but disbanded. In NSW, coastal deposits have been quite well mapped but there are few divisions in other parts of the Quaternary record. Map units tend to provide broad lithologic divisions or age ranges rather than a focus on many of the items listed above. In most cases maps tell us little about heterogeneity and nothing about thicknesses of sedimentary units.

Other maps provide limited additional useful information. In the Sydney area NSW Conservation and Land Management maps (1:100 000) of soil landscapes focus on the top metre or two but provide some data on soil variability, character and depth to the water table. CSIRO Terrain maps (1:250 000 in Sydney - Finlayson, 1982) seem to have limited value for earthquake microzonation.

The most useful data for microzonation purposes are the files of government agencies and private consulting companies. Although data from the latter are generally unavailable it is worth noting that a proportion of this information has been collected at public expense. Organisation of government agency files in NSW ranges from excellent computer databases to largely unlocatable!

A standardised database on soil and sediment characteristics would be a useful addition to government files in most states. Why couldn't it be mandatory for borehole logs and test results to be sent to a central repository after some suitable interval? While Conservation and Land Management in NSW maintain a soils database, more information on sediments is required and engineering classification tests and geotechnical data need to be reported. Such databases would prove useful not only for earthquake studies but also for soil erosion, building foundations, shrink-swell phenomena and Quaternary geology and geomorphology.

In the absence of such databases, it is necessary to construct maps of soil conditions using incomplete data. For the reports on which this study is based, five soil zones were constructed based on soil landscape data, Quaternary geology, and borehole data gleaned from government agencies. Each of the zones was then assigned an expected Modified Mercalli intensity based on the assumption that, for example, the maximum Modified Mercalli intensity in an M 5.6 earthquake (the same as Newcastle) would be MM VIII. This assumption is also in accord with intensities calculated using functions provided by Gaull et al. (1990). Intensities expected in the other soil zones were assigned on the assumption that intensities experienced on soft rocks and consolidated dry alluvium are about 1 MM scale interval higher, and intensities on landfills, reclaimed ground and soft alluvium with the water table near the surface are 2-3 MM intensity scale units higher than on hard rocks.

These assumptions are virtually identical to those used in a number of studies in the US and elsewhere (see, for example, Ziony, 1985; Steinbrugge et al., 1987; Tiedemann, 1990).

While such an approach may be described as `crude', any other approach requires similar assumptions, even intuitive leaps. However, problems hardly end with selection of Modified Mercalli intensities for a `design' earthquake. The Modified Mercalli intensity-scale was developed 50 years ago. Building styles and codes have changed. The scale is not linear and confuses the consequences of ground shaking and ground failure at intensities above MM IX (Reitherman, 1984). Nonetheless, it is the index of building damage produced by earthquakes most widely used today.

Anticipated damage ratios

Damage ratios which relate Modified Mercalli intensities to building types and loss ratios are relatively common (see Figure). Rarely is the scatter around such curves illustrated or discussed. However, Tiedemann (1984) suggests that scatter might be considerable, with one standard deviation meaning a factor of two or more in mean damage ratio. Because building codes and construction styles vary from area to area and country to country comparison of curves is difficult. Furthermore, the `damage ratio' may be expressed as a mean damage ratio, a percentage building cost, a percentage of the replacement value or some similar (often unspecified) measure. On top of these difficulties is the subjectivity involved in applying the Modified Mercalli intensity scale to a group of damaged buildings (as noted in the aftermath of the Newcastle earthquake).

Numerous factors influence damage to structures other than the properties of incident earthquake waves. These include (in no particular order):

- construction material
- connections and fastenings
- height
- age of structure
- code
- workmanship
- maintenance
- symmetry
- orientation

With these problems in mind, it is not surprising that curves that purport to show damage ratios for the one construction type show considerable scatter. Figure 2 illustrates four curves for brick construction. Even neglecting the scatter around the curves, average percentage loss at MM VIII varies from 15 to more than 50%. As shown on Figure 3, the range for wooden frame and/or timber construction is much less, but still considerable. It is noteworthy that, for all curves shown in Figures 1 to 3, average percentage losses are not shown for MM intensities less than MM VI. In Figure 4 the brick and timber construction curves shown on Figures 2 and 3 are themselves averaged. The `average' curve shown on this figure is an arithmetic average of the averaged brick and timber curves.

At the present time only preliminary efforts have been made to devise similar intensity-damage curves based on Newcastle 1989 data. For the present study a map of five soil zones was prepared for the Newcastle data using the procedure described earlier.

Average zone values for each of 24 postcodes were estimated and expected Modified Mercalli intensities were assigned. No attempt has been made yet to check these expected intensities against those reported - in any case intensity maps (e.g. Melchers, 1990) appear to be available for only some of the 24 postcodes.

Data provided by a group of insurers were used to estimate average percentage losses for each construction type for each postcode. Most insurers group brick and brick veneer construction together and there are a few other relatively minor problems with the data as a result of definitions, boundaries of postcodes, and completeness of data. The average percentage loss value has been calculated for each construction type for each postcode by dividing the average payment for earthquake damage by the total sum insured. Thus, the ratio averages damage across both damaged and undamaged buildings in the postcode. Contents losses have been excluded from consideration. Average percentage losses and expected Modified Mercalli intensities for each postcode and construction type have then been plotted and curves fitted to the not inconsiderable scatter in the data. It is assumed, though it cannot be demonstrated, that the methods used here are similar to those in overseas studies using insured loss data.

The curves shown in Figure 5 are based on a considerable proportion of the total insured losses in the 24 postcodes. The curve for `other' construction, includes steel buildings and some others not readily classified but is based on only about 100 structures that are probably quite diverse in character and construction type. The `brick' curve includes both brick and brick veneer construction. The `total' curve is a weighted average of the data used in construction of the other curves.

Figure 6 compares the Newcastle `brick' curve with the average brick curve for overseas data shown in Figure 4. Two important differences are immediately noticeable. Firstly, the Newcastle curve is much less steep than the average brick curve derived from overseas data. The Newcastle data suggest an average percentage loss at Modified Mercalli intensity VIII of about 15% whereas the average of data from overseas suggests a value nearly double this. Secondly, extrapolation of the available Newcastle data suggests that average percentage losses are substantially above zero (perhaps 3%) at MM V.

These two differences make comparison interesting. Whilst the methodology used has a number of difficulties, it is likely that similar problems characterise overseas data. If as suggested at the time, MM intensities in Newcastle were overestimated, and the Newcastle curve is shifted to the left, the differences in damage levels at low MM intensities would increase. Similarly, if Newcastle construction and maintenance standards were as poor as commonly claimed, it is surprising that the average percentage losses at MM VII and VIII are so much less than the overseas average percentage losses.

Figure 7 facilitates comparison of the Newcastle and average overseas curves for timber dwelling losses. Here the Newcastle curve lies substantially above the overseas average curve though the gap appears to narrow substantially at MM VIII. Again, extrapolation of the Newcastle data suggests that losses at MM V are substantially above zero. Shifting the Newcastle curve to the right might improve correspondence between the curves but this is the opposite sense to that required to improve the match in the brick curves. The preliminary conclusion appears to be that losses for timber homes in Newcastle are substantially above those recorded in most international studies even though the latter presumably often include timber-framed brick houses which should inflate loss values.

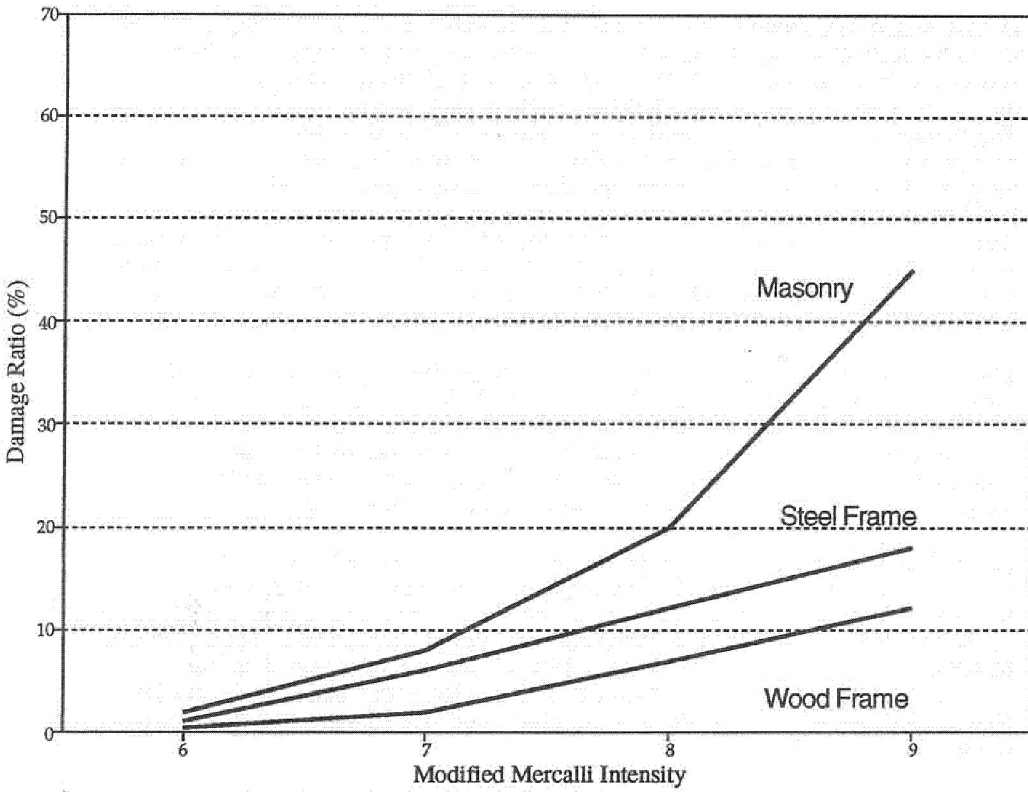

Figure 1. Damage ratios (%) for masonry, steel frame and wood frame construction (after French and Isaacson, 1984).

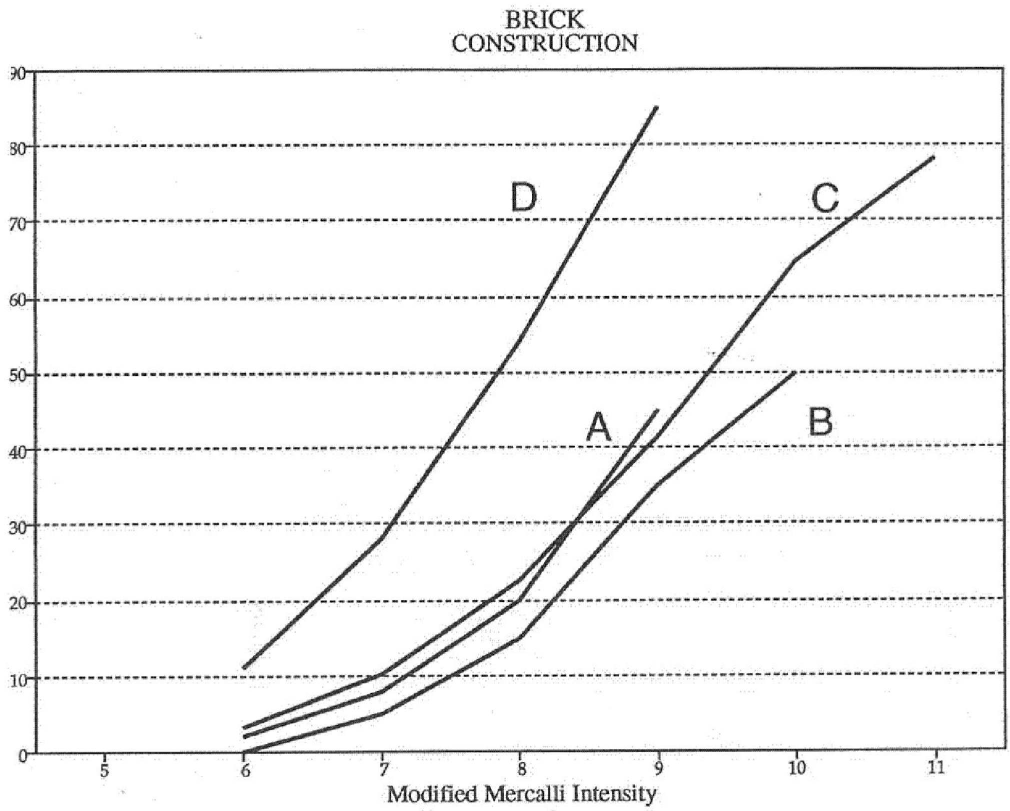

Figure 2. Four curves indicating relationships between average % loss and Modified Mercalli intensity for brick construction:
Curve A after French and Isaacson, 1984
Curve B after Page et al., 1975
Curve C after ATC, 1985
Curve D after Tiedemann, 1990

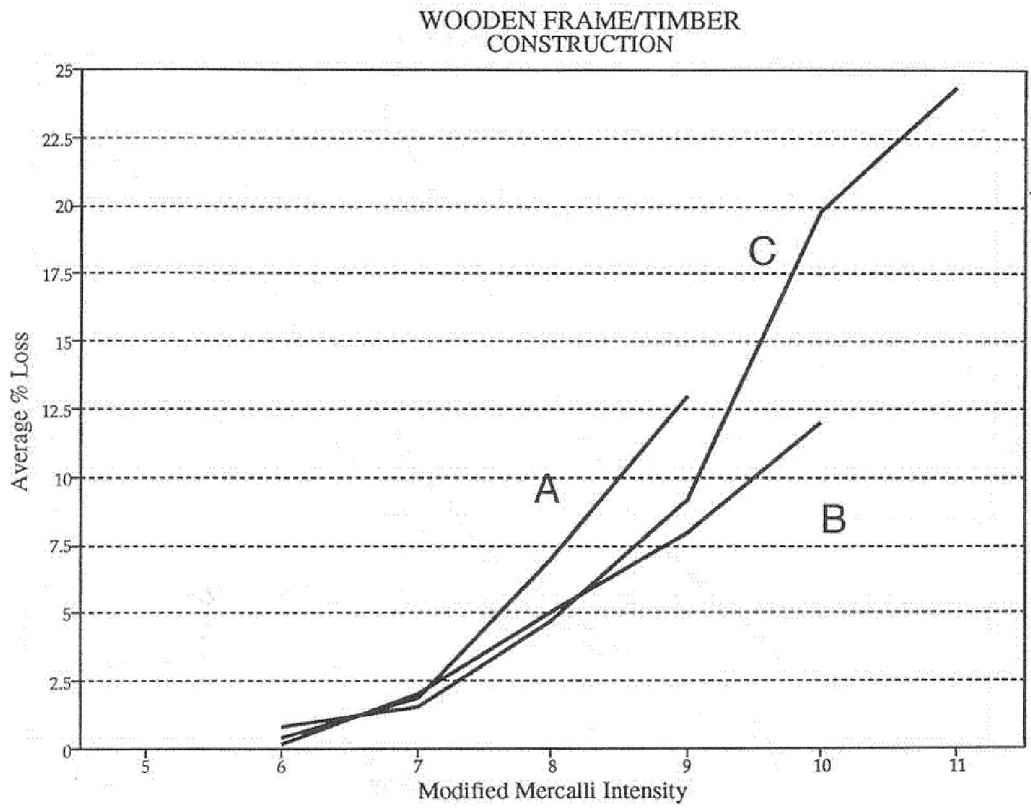

Figure 3. Three curves indicating relationships between average % loss and Modified Mercalli intensity for wooden frame/timber construction:
Curve A after French and Isaacson, 1984
Curve B after Page et al., 1985
Curve C after ATC, 1985

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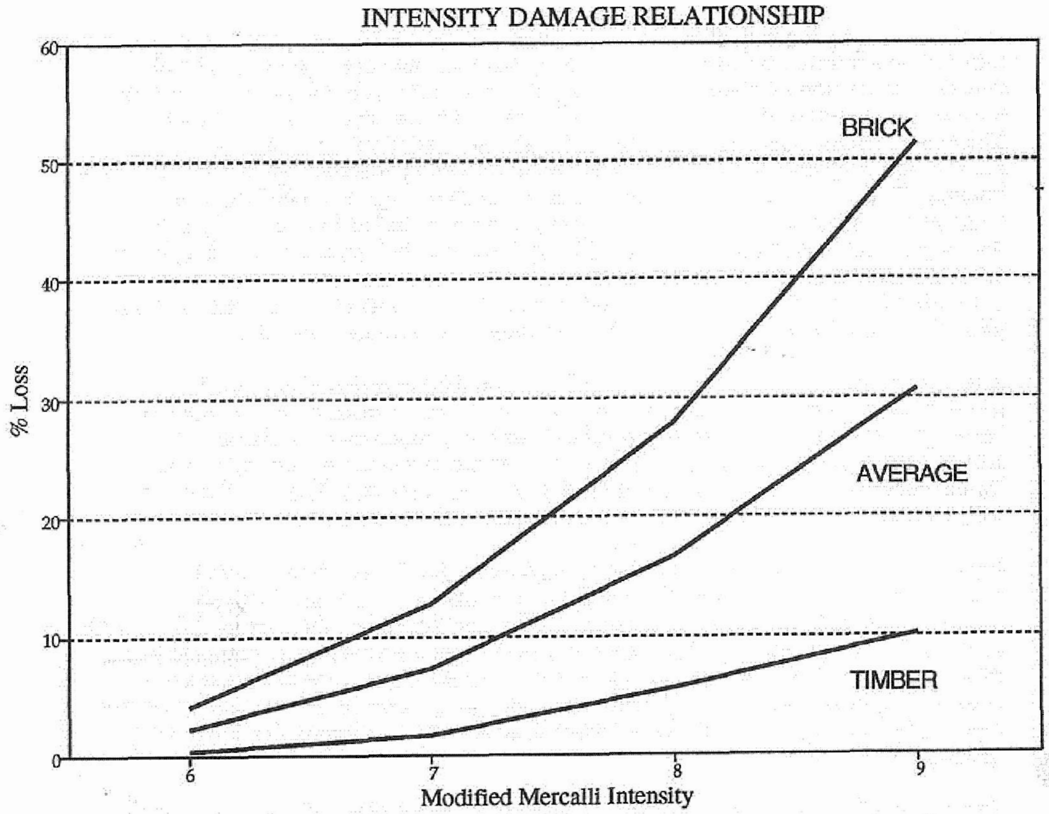

Figure 4. Average % loss curves for brick and timber construction.

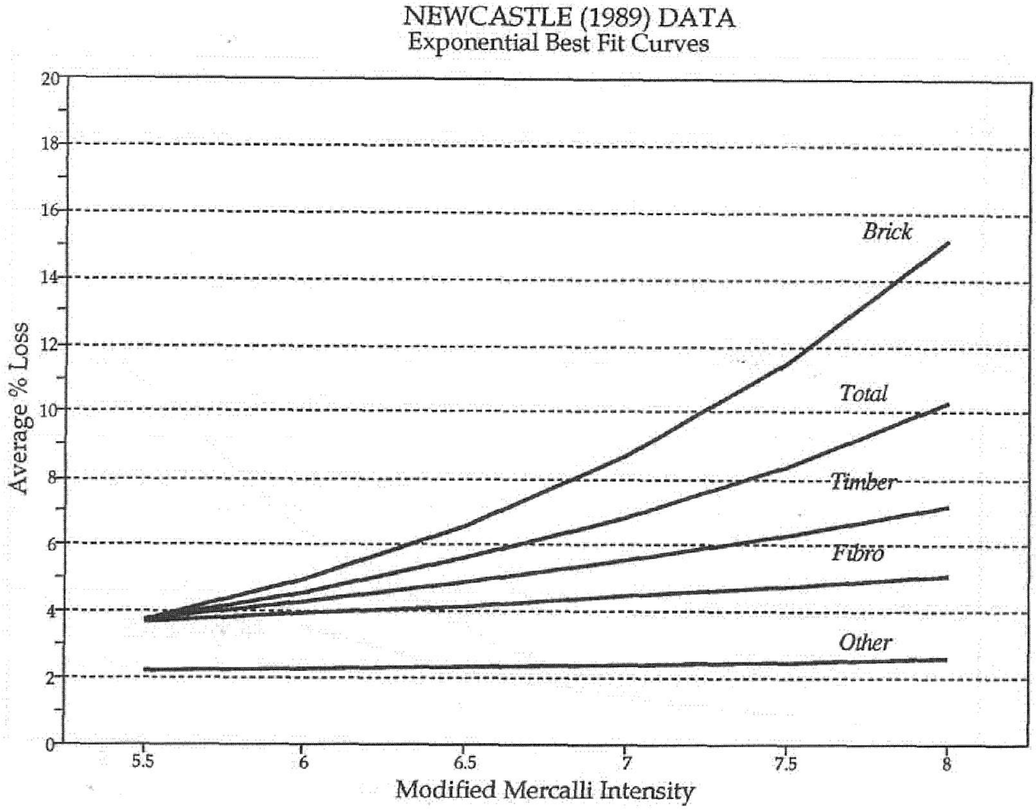

Figure 5. Best-fit curves for four domestic construction types based on losses experienced by a number of insurers in the Newcastle (1989) earthquake. Data from 24 postcodes have been used.

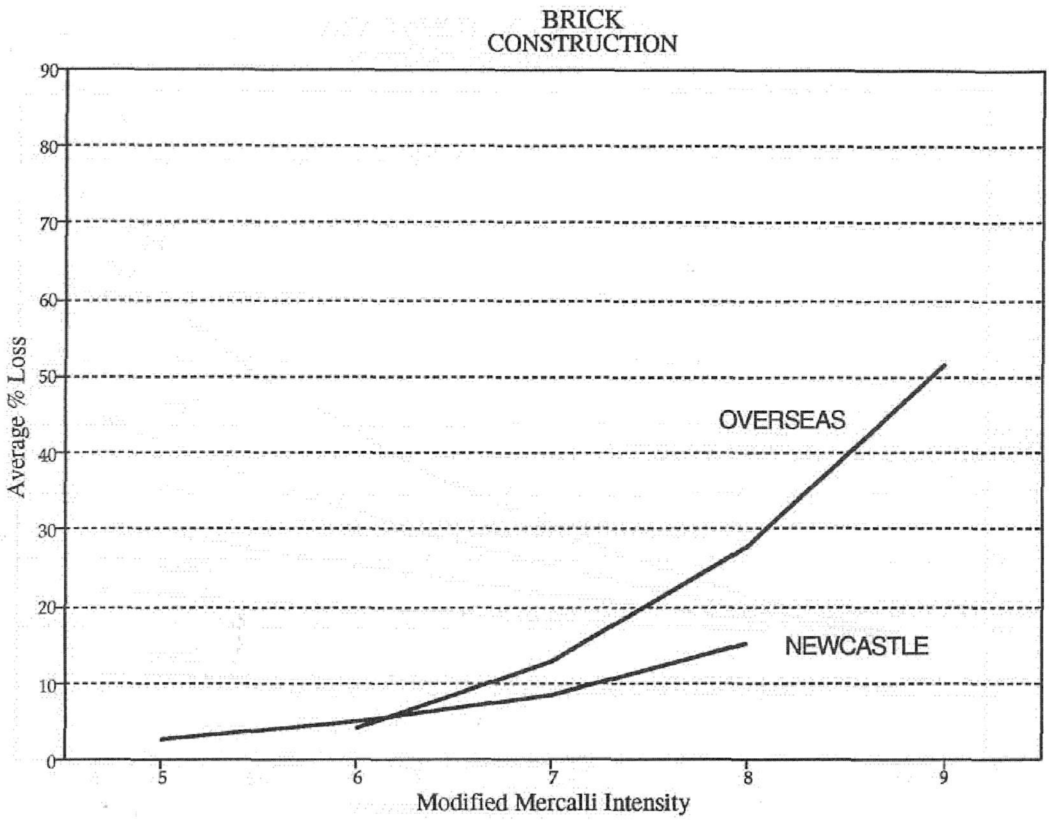

Figure 6 Comparison of average % loss-Modified Mercalli intensity curves for Newcastle and overseas data - brick construction.

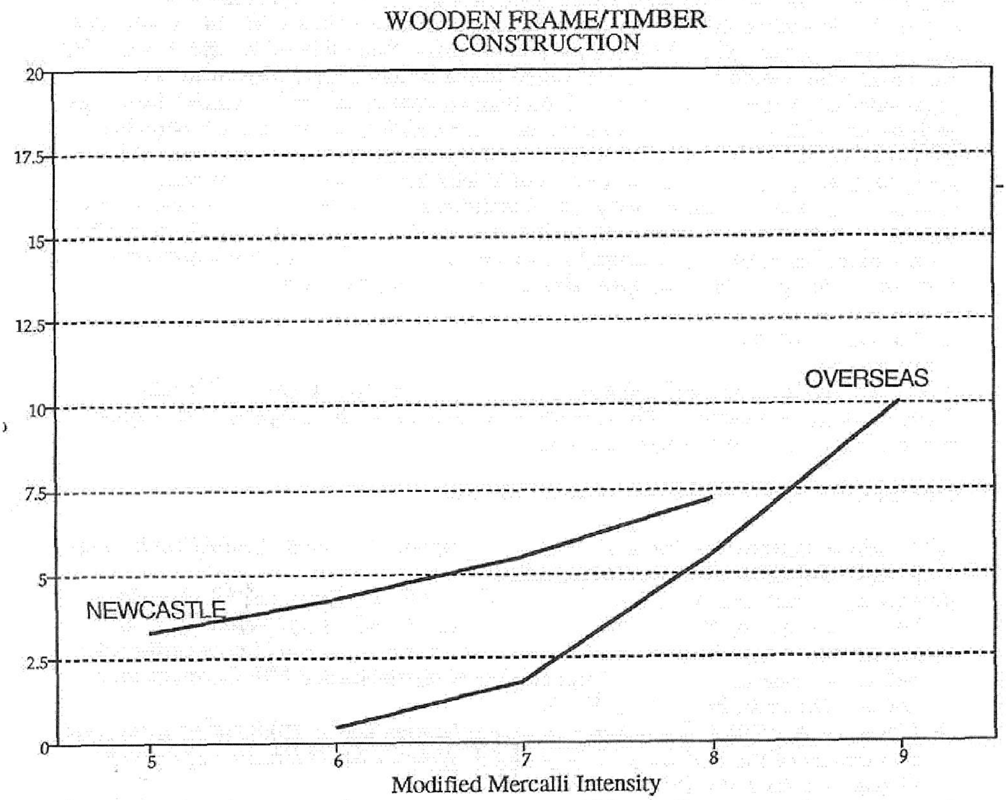

Figure 7 Comparison of average % loss-Modified Mercalli intensity curves for Newcastle and overseas data - wooden frame/timber construction.

Conclusions

It is difficult to draw substantial conclusions from this preliminary study. However, it is clear that very different estimates of earthquake losses for residential construction can be produced depending on which loss curves are used. Obviously, better data are required. It would be helpful if insurers collected separate statistics for brick and brick veneer construction. Most insurers don't computerise data on building age. If such data were available, would our models of future losses be any better? Most insurers aggregate policy data by postcodes. Postcodes containing several thousand dwellings each in urban areas are thus the smallest units for which loss statistics are available. This also means that the smallest unit for which ground conditions can be sensibly analysed is the postcode, usually an area of at least several square kilometres. Obviously, ground conditions vary significantly in many postcodes in Australian cities though there is often no simple way to demonstrate this using readily available public information. Better data are required if a deeper understanding of the relationships between building damage and ground conditions is to be achieved.

Acknowledgments

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References

ATC (1985) Earthquake Damage Evaluation Data for California. *Applied Technology Council Report* ATC-13, 492 pp.

de Crook, T., Schenk, V., Barbano, M.S., Colombo, F., Egozcue, J.J., García-Fernández, M., Kottnauer, P., Leydecker, G., Mantlík, F., Schenková, Z. & Zonno, G. (1989) Seismic hazard computations for regions with low earthquake activity - a case study for the Belgium, The Netherlands and NW Germany area. *Natural Hazards*, 2(3 & 4), 229-236.

Finlayson, A.A. (1982) Terrain analysis, classification and an engineering geological assessment of the Sydney area, New South Wales. *CSIRO Division of Applied Geomechanics Tech. Paper*, 32.

French, S.P. & Isaacson, M.S. (1984) Applying earthquake risk analysis techniques to land use planning. *American Planning Association Journal*, 509-522.

Gaull, B.A., Michael-Leiba, M.O. & Rynn, J.M.W. (1990) Probabilistic earthquake risk maps of Australia. *Australian Journal of Earth Sciences*, 37, 169-187.

McCue, K., Wesson, V., Gibson, G. (1990) The Newcastle, New South Wales, earthquake of 28 December 1989. *BMR Journal of Australian Geology & Geophysics*, 11, 559-567.

Mehan, D. (1992) Damage to homes following the Newcastle earthquake - don't blame it all on clay soils. *26th Newcastle Symposium on Advances in the Study of the Sydney Basin, 3-5 April 1992*, 119-125.

Melchers, R.E., Editor (1990) Newcastle earthquake study. *IEAust.*, 155 pp.

Melchers, R.E. & Page, A.W. (1992) The Newcastle earthquake. *Proc. Institution of Civil Engineers, Structures and Buildings*, 94, 143-156.

O'Kane, P.G. (1991) Newcastle earthquake surveys. *33rd Australian Surveyors Congress, April 1991*, Paper 26, 1-19.

O'Keefe, (1991)

Page, R.A., Blume, J.A. & Joyner, W.B. (1975) Earthquake shaking and damage to buildings. *Science*, 189, 601-608.

Peck, W.A., Neilson, J.L., Olds, R.J., & Seddon, K.D., Editors (1992) Engineering Geology of Melbourne, Balkema, Rotterdam.

Pells, P.J.N., Editor (1985) Engineering geology of the Sydney Region, Balkema, Rotterdam.

Reitherman, R.(1984) Seismic damage to unreinforced masonry buildings. *Report in Case Studies of the Earthquake Performance of Unreinforced Masonry Buildings, US National Science Foundation,* NSF 8218-6, 27 pp.

Steinbrugge, K.V., Bennett, J.H., Lagorio, H.J., Davis, J.F., Borchardt, G. & Toppozada, T.R. (1987) Earthquake planning scenario for a magnitude 7.5 earthquake on the Hayward Fault in the San Francisco Bay area. *California Department of Conservation, Division of Mines and Geology Special Publication* 78.

Tiedemann, H. (1984) Quantification of factors contributing to earthquake damage in buildings. *Earthquake geology,* 20, 169-179.

Tiedemann, H.(1990) Newcastle: The Writing on the Wall. *Swiss Reinsurance Company, Zurich,* 85 pp.

Ziony, J.I., Editor) (1985) Evaluating earthquake hazards in the Los Angeles Region - an earth-science perspective. *United States Geological Survey Professional Paper,* 1360.