EARTHQUAKE ENGINEERING AND INSURANCE: PAST, PRESENT AND FUTURE

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SUMMARY

This paper is focussed on the characteristics of earthquake insurance that have limited its utilisation as an effective disaster management tool, and its inter-relationship with earthquake engineering. The historical development of earthquake insurance is presented, along with the increasing role that earthquake engineering is playing in improving its effectiveness for disaster management. The paper concludes with a look at a future where the increasing integration of risk management will lead to earthquake engineering becoming an integral part of the holistic fuinancial risk mangement of organisations.

INTRODUCTION

Modern disaster management is based on four major areas of activity - preparation, response, recovery and mitigation [Mileti 1999]. Catastrophe insurance is a disaster management tool primarily focussed on recovery. Through it, individuals and organisations can be provided with financial recompense following a loss, enhancing their ability to recover from the loss quickly and with a minimum of trauma. Other tools with which it competes in this respect are government emergency aid, charity, and the insured's own accumulated assets (or self-insurance as it is known in the industry).

Catastrophe insurance reduces the vulnerability of individuals and organisations to disasters, but does not necessarily reduce the scale of losses. This is the role of mitigation activities. For mitigation of earthquake losses the major tool is earthquake engineering. Depending on the policy conditions earthquake insurance can be either an incentive or disincentive to mitigation [Walker 1985]. On the other hand insurability against earthquakes can be dependent on the earthquake engineering design of constructed facilities - whether they be housing, commercial buildings, factories, or infrastructure.

This interdependence between earthquake engineering and insurance has not always been appreciated, and has rarely been exploited. This is largely due to the difficulties associated with integrating knowledge from widely different fields before the age of powerful networked computers. The Information Revolution is changing this. As a consequence there is an increasing integration of earthquake engineering and insurance activities, which has the potential to significantly increase the effectiveness of both tools in the management of major disasters.

This paper looks at the characteristic features of earthquake insurance, how it has developed to the present day, how it is likely to develop in the future, and the role that earthquake engineering is likely to play in this development. It is written from the standpoint of an Australasian earthquake engineer working in the insurance industry.

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GENERAL PROPERTY INSURANCE

Property insurance has its origins in fire insurance, by which it is still commonly known in the commercial area. In the English speaking world it can be traced back to the Great Fire of London in 1666 [Kunreuther 1998]. It is based on the formation of a pool by contributions, known as premiums, from the members of the pool from which those suffering a loss are compensated for it.

Property insurance works best where there is a significant number of randomly occurring independent losses each year to members of the pool that are large in respect of their individual economic circumstances, but in total are small relative to the total insured value covered by the pool. Although there may be considerable variability between individual claims, the annual variability of the total losses will be small as a result of the Central Limit Theorem - or law of large numbers as the insurance industry calls it. Consequently a premium rate can be set which is only a small multiple of the burning rate or average annual loss relative to insured value, ensuring affordability for the insureds.

There are essentially three types of property insurance pools - mutual societies, commercial stock companies, and government schemes that generally incorporate a compulsory element. The earliest English insurance pools formed after the Great Fire of London were mutual societies with the first stock insurance company being the Sun Fire Office formed in 1710 [Gerathewohl 1990]. In Europe the early pools appear to have been more government controlled.

In extending fire insurance to cover other hazards it was recognised that a number of conditions of insurability need to be met including a large demand for cover, a large spread of risks by type and location, random occurrence of risks (free of moral hazard), affordable premiums, and events that are capable of definition (Lester 1980).

Providing certain conditions are met in terms of building construction, these conditions are met by fire losses. However the inclusion of losses from natural hazards created a problem in meeting these conditions that does not appear to have been initially recognised. This is the problem of accumulation of risks subject to loss from a single event. The Great Fire of London was an example of this, but insurability was achieved by fire insurance being conditional on fire spread being restricted by either separation of buildings or providing buildings with a fire resistant outer envelope, as well as a fire brigade being located in close proximity. It is not so easy to limit the number of losses from a single natural hazard event such as an earthquake. In combination with the difficulties of assessing the frequency and magnitude of such losses this raises significant questions about the insurability of such events as an extension of fire insurance.

CATASTROPHE INSURANCE ISSUES

Suppose an insurance pool has 100,000 homes insured with an average value of $100,000. Suppose on average one percent experience a fire each year, and of those that do the average loss per event is $10,000 with a standard deviation of $20,000. This means an average annual total loss from the pool of $10 million with a standard deviation of $630,000. If a premium rate of 0.15% is charged it will create a pool that after allowing for administrative expenses of 25% will have 99.9% probability of being able to meet all losses. If total losses exceeding total premiums were experienced, the probability of recovering it the following year would be extremely high.

Now suppose the same pool is at a similar risk from earthquakes in terms of average annual loss. In this case however, instead of the losses arising from a multitude of relatively small events involving generally one property only, they arise from a few large losses. If all the properties in the pool are from the same locality, then all will be at risk from each event. Suppose the risk of a damaging earthquake occurring in the locality in any year is one percent, and that if it does occur then the average total loss is 10 percent of the total insured value with a standard deviation of 20 percent of the total insured value. In terms of events this has the same characteristics as above for fire, and the average annual risk for an individual house will be the same - ie 0.05%. However a premium rate of 0.15% is unlikely to be adequate.

Suppose the average earthquake occurs. The total loss will be one billion dollars. A premium rate of 0.15% will only produce $15 million in one year. Of course such an event may not occur for a 100 years, but it could occur next year, and the loss could be anything from a hundred million to several billion dollars depending on the earthquake intensity. To accommodate losses of this magnitude reserves are needed, or arrangements made to obtain an equivalent amount of capital, sufficient to meet the expected maximum. If reserves are to be used, for a theoretically sustainable long-term system the accumulation of reserves will need to be at a rate which will at least ensure that in a hundred years it would be able to meet the average total loss from an event. These calculations need to take into account inflation of the value of houses and expansion of the housing stock which effectively reduce the value of reserves relative to total insured value over time, and return on the investment of the reserves which partly overcomes this.

A simulation of the growth of reserves for different premium rates assuming annual inflation of house values of 5%, annual expansion of housing numbers of 2.5%, and annual investment returns of 5% was undertaken It showed that if the premium rate is equal to the 'burning' rate - ie 0.1% - even after 100 years the pool would only be able to meet 40% of the estimated average earthquake loss at that time. To meet the average loss after 100 years would require a premium rate of 0.27%, but this would leave the pool very exposed for the preceding 100years. To ensure the pool could meet an average loss after 20 years would require a premium rate of 0.63%. This does not include administration and taxation expenses, and there is still the problem of paying the losses if an event occurs in the first 20 years, or if it is much greater than the average loss, which is possible. Clearly for this situation a premium of 0.15% would be inadequate.

The problem is reduced significantly if the insured property is more dispersed. Suppose the 100,000 houses are equally divided among five communities sufficiently far apart to be independent in respect of earthquake effects, but having the same earthquake risk as in the previous example. In this case only 20,000 houses will be at risk from each event, but the average time between events will be only 20 years. The theoretical minimum sustainable premium rate in this case, other factors being kept constant, is 0.13%. In reality losses can occur at random, losses may be greater than average, and allowance must be made for providing an extra injection of capital in the event that the loss exceeds the pool reserves. These costs, which can be significant, also need to be included in the actual premium rate in addition to administration and taxation charges. Clearly even in this case a premium rate of 0.15% would be inadequate.

This demonstatrates how insuring for catastrophic events involving large accumulations is quite different from insuring for fire. Insurance pools primarily formed for fire insurance, which includes most normal insurance companies, need protection from the catastrophic events, particularly if they do not have a wide geographic spread of their portfolio. The normal approach is by using reinsurance pools. Reinsurance pools are different from insurance pools in that they generally try to spread their risks over as wide a geographic area as possible - which means that by nature they tend to be international - and they usually only accept a portion, governed by their reserves, of any potential loss from a single event.

Management of catastrophe reinsurance operations, including the determination of premiums, must still take into account all the factors described above, as the average time between very large events is still relatively long. Only one earthquake has occurred this century which if it were to occur today would cause insured losses exceeding US$50 billion. This is the 1906 San Francisco. It has been estimated that if it occurred today the insured losses would be of the order of US$80-100 billion [RMS 1995]. 'Burning' costs have only marginal relevance when dealing with events like this.

EARTHQUAKE INSURANCE

Pre-1980's

Earthquake property insurance can be divided into building damage due to shaking, contents damage due to shaking, building and contents damage due to fire following, and business interruption due to earthquake. It is also normal to distinguish between home insurance and commercial insurance.

As indicated above earthquake property insurance effectively began as an extension of fire insurance, initially probably unwittingly. About two thirds of the estimated US$330 million dollars worth of property damage from the 1906 San Francisco earthquake was covered by insurance [Gerathewohl 1990]. Damage due to shaking was not covered. But most of the building damage was attributed to fire, and fire policies at the time did not exclude fire following earthquake. As a result of the San Francisco earthquake a cautious approach was adopted to earthquake insurance in the United States and other places known to have significant earthquake risks. This led to three different approaches to earthquake insurance as follows:

- Earthquake included as a standard peril within a fire policy;
- Earthquake offered as additional peril either on its own or in connection with a standard fire policy to which special conditions may be attached;
- Earthquake insurance covered by a government based, and often compulsory, scheme.

The inclusion of earthquake as a standard peril within a fire policy was generally restricted to home insurance and to areas where earthquake risk was considered negligible. Australia, where it was introduced in this form in 1927, would be a typical example of this. It was effectively provided as a free universal extension. The 1954 Adelaide earthquake awakened the insurance industry to the earthquake risk, particularly in regard to the need to monitor accumulations [Meek 1956], but does not appear to have had any impact on the provision of earthquake cover. Following the Meckering earthquake in 1968 a deductible of $100 per dwelling was introduced [Staveley 1986], but it was probably not until the possibilities of major catastrophic losses became a concern after Cyclone Tracy devastated Darwin in 1974 that insurers began to include a provision for earthquake losses in their premiums. The need for this was reinforced by the 1989 Newcastle earthquake which produced a major loss for the Australian insurance industry, but although deductibles have increased, earthquake insurance continues to be universally available as a standard peril automatically covered by home insurance policies in Australia.

Offering earthquake insurance as an additional peril in conjunction with a fire policy is the most common way in which earthquake insurance is provided. In this case the cover is provided for an additional premium. This is often for losses due to shaking only as those due to fire following are often still included in the basic fire policy. Although offered since the early part of this century, it does not appear to have been widely utilised until the second half of the century. Reasons for this seem to be that where the risk was recognised the rates were considered too high, and where the risk was considered negligible it was considered a waste of money. With increasing awareness of the earthquake risk, generally as a result of an earthquake causing significant damage, the proportion of fire policies having earthquake attached has increased. In some countries like New Zealand and Australia, almost all property covered by fire policies are now also covered for earthquake, although in Australia this has been a relatively recent phenomenon. In the United States it is not so universally used with reports indicating that even in California before the 1980's less than 10 percent of homeowners took out earthquake insurance, and that in the most vulnerable areas this has only increased to between 30 and 40 percent since then [Mileti, 1999].

The value of catastrophe insurance in the recovery process following major disasters has long been recognised, and in some countries this led to the development of government controlled natural disaster insurance schemes. New Zealand provides a good example of this. Following the 1931 Napier earthquake, New Zealand's largest earthquake disaster to date, the insurance companies only paid out about 10 percent of the estimated total property loss [Eiby 1975]. Most of this was probably for fire losses following earthquake covered under normal fire policies. Significant damage next occurred in the 1942 Masterton earthquake. Again most of the damage appears to have been uninsured despite the availability of earthquake insurance. In the previous year the government had set up a special war damages insurance pool funded by a levy of 0.25 percent of insured value on all fire insurance premiums. The government extended the scheme to cover earthquake, establishing the pool as the Earthquake and War Damage Fund. After the war the levy was reduced to 0.05%. The scheme covered all property for indemnity value and over time was extended to other uninsured natural hazards. In 1993 it was restructured as the Earthquake Commission, the fund renamed as the Natural Disaster Fund, and it was restricted to replacement cover home insurance up to NZ$100,000 for buildings and $20,000 for contents, with the levy remaining unchanged [NZNSEE 1993]. Because no very large earthquake loss has occurred since it began, its reserves have increased over time, being reported as NZ$150 million in 1975, [Eiby 1975], NZ$1.1 billion in 1985 [NZNSEE 1993], NZ$2.0 billion in 1990 [Ibid], and NZ$3.2 billion 1998 [EQC 1998]. This growth has been aided by high returns on investments and favourable foreign exchange transactions in recent years. However even at the present level the Fund would be insufficient to meet the losses from a maximum credible earthquake in the Wellington region.

Where governments have not taken control of earthquake insurance they have generally imposed regulatory measures on the insurance industry. These regulations have a significant impact on the provision of earthquake insurance. In Australia the regulations are primarily intended to ensure solvency in an otherwise deregulated market. The main impact in this case is to ensure that insurance companies provide themselves with adequate financial protection against a major catastrophe such as an earthquake or tropical cyclone. The insurance industry in the United States is much more regulated than in Australia, with a heavy emphasis on consumer protection in the form of control on premiums and policy conditions. This reduces the ability of the insurance companies to take a flexible or innovative approach to catastrophe insurance, and in recent years has led to major problems in the provision of earthquake insurance in California and hurricane insurance in Florida [Kunreuther 1998]. In Japan, earthquake insurance has only been available since the 1950's. It is underwritten by the government and severely regulated [AHGL 1995] with relatively high premiums, including limitations on the amount of cover that can be provided, primarily it seems to protect both the insurance companies and the government from a major event. As a consequence earthquake insurance tends to be regarded as poor value for money and has limited use. This was highlighted following the 1995 Kobe earthquake for which the estimated direct property losses were of the order of $100 billion, of which the insurance industry provided less than $5 billion [AHGL 1995].

Business interruption insurance is generally the subject of a separate insurance policy and has been available for earthquake, or at least for losses from fire following earthquake, since at least the early part of the century. Traditionally business insurance is related to losses arising from damage to the insured's property, which is appropriate for fire but not necessarily for earthquake. The limitations for earthquake were recognised as long ago as the 1940's [Jenkins 1948], but are still often present in policies [Fawcett 1995]. The Kobe earthquake highlighted the large losses that can arise for businesses as a result of interruptions contingent on damage to infrastructure or suppliers delivering essential goods and services to a company on a modern a 'just-in-time' arrangement [AHGL 1995].

With the exception of New Zealand, prior to the 1980's there does not appear to have been a great deal of interaction between the insurance industry and the earthquake engineering community. The insurance industry expected buildings to be properly designed for earthquakes where required by building regulations, but did not get actively involved in the development and promotion of earthquake engineering research and its implementation in codes and standards. In New Zealand the Earthquake and War Damages Commission was very cognisant of the relationship between their exposure and the level of earthquake engineering incorporated in the design of buildings. Their support of earthquake engineering research and development, and its application, has been a major factor in the high level of implementation of modern earthquake engineering expertise in New Zealand over the last 30 years.

Current Situation

Since the 1980's major changes have occurred which are changing the earthquake insurance landscape, and its relationship with earthquake engineering. The primary reason for this is the tools for natural catastrophe loss risk assessment and the design of risk financing programmes which are being made available as a result of the information revolution [Walker 1997a]. Earthquake engineers have played a major role in these developments, particularly those at Stanford University associated with the work of Haresh Shah in the 1980's which led to the formation of Risk Management Solutions Inc, and those undertaking similar developments with Peter Yanev at EQE Limited at roughly the same time.

The earthquake loss simulation models based on the use of geographic information systems (GIS) which arose from these developments represented a radically different approach to earthquake loss risk assessment to that previously used in the insurance industry. The old method relied on estimates of the loss as a percentage of insured value determined on a catastrophe zone basis, which was formalised as the CRESTA Zone method. Extrapolation from past losses was an essential aspect of this approach. But in most zones there was little or no past information of much value due to the long periods between very large earthquakes, even in areas of high seismicity. Consequently most of the estimates were really guesstimates, and the statistical significance of any probabilistic information associated with them was almost nil. Catastrophe loss modelling has changed this. Catastrophe loss simulation models enable past and future earthquakes to be simulated geographically according to the best information on occurrence probabilities, fault characteristics, attenuation characteristics, and soil amplification characteristics, and the damage losses to property to be simulated on an individual basis according to location. This enables very detailed probabilistic information on losses to be obtained.

The output information can be used to provide insurance and reinsurance companies with probabilistic information on their total exposure, or exposure to specific events, for use in designing financial risk protection programmes, including traditional reinsurance programmes. It can also be used to provide probabilistic information on the contribution to the total risk of individual properties, enabling the determination of risk based premiums for individual properties.

Both of these uses have major implications for the provision of earthquake insurance.

The traditional approach to earthquake insurance utilising reinsurance has been developed largely by trial and error over many years. Embodied in it are many empirical and heuristic procedures which have been found to work, but do not necessarily have a strong rational base. Such conditions give rise to a relatively conservative industry resistant to change, and heavily dependent on experience for its long term success. It was from such a situation that the development of models of structural engineering behaviour based on engineering mechanics enabled building designers to break away from traditional forms of construction based on masonry and timber, and design innovative structures in steel and concrete for which there was no precedent.

The development of catastrophe loss simulation models is having the same impact on the catastrophe risk financing area. In conjunction with financial risk models such as dynamic financial analysis (DFA) models, they are being used to design entirely new types of financial risk protection which go well beyond the boundaries of traditional insurance and reinsurance. The generic name for this development, which encompasses the whole field of risk financing, is alternative risk financing [JBDL 1998], and the term risk financing engineering has been used to describe the process. The capital markets through the use of derivatives have become a new source of risk finance as a result, and are effectively replacing Lloyds as the vehicle by which wealthy individuals and non-financial organisations can participate in risk financing.

Until the advent of these tools, the only feasible way of rating premiums for catastrophic risks such as earthquakes for most properties was by a blanket approach. The reason for this was that the cost of individual rating was too high. The new tools in combination with modern electronic communication have changed this. The total losses are estimated by summing the individual losses. The latter can be used to extract data on individual risk as a function of insured value, locality, soil type and building construction that can be placed in a database and readily accessed at point of sale to provide an individualised risk based premium. The use of this approach is only in its early stages, and can be expected to increase as the competitive advantages are recognised. One well known example of it is the California Earthquake Authority, which provides information on its premiums from its web site based on data supplied by the customer on property street address, building type and building value.

The use of risk based premiums does not just provide an insurance company with a way of enhancing its competitiveness through being able to attract good risks by providing more attractive terms and deterring bad risks by high premiums, deductibles or other means. It also makes earthquake insurance not just an important tool for the recovery process of disaster management, but an incentive for disaster mitigation [Walker 1995]. Blanket catastrophe insurance generally operates as a disincentive to mitigation unless closely associated with the enforcement of effective hazard resistant building regulations. New Zealand is a good example of where the latter has worked well, but primarily because building regulations are the responsibility of the national government, which also has a major vested interest in the national earthquake insurance scheme. In a country like the United States where the interdependence between insurance and building regulations is very weak, blanket insurance premiums are a disincentive to mitigation, and can lead to apathy on the part of the community and its political leaders in adopting and enforcing effective mitigation factors. This was probably a significant factor in the large losses experienced in Florida from Hurricane Andrew in 1992.

The Future

The impact of the Information Revolution on risk financing is still in its early stages, and the most dramatic changes are probably still to come.

The biggest foreseeable impact is likely to be an outcome of the current move towards an integrated or holistic approach to the risk management of organisations [Elms 1997]. Historically risks were classified into different types and dealt with at the individual unit level of large organisations. Information technology is enabling all the risks to an organisation to be considered in an integrated manner, and an optimum solution for the organisation in respect of protection determined. Such approaches do not just look at the downside of risk, but also the upside. An earthquake may be bad news to an organisation suffering loss as result, but it may be good news to an organisation providing goods and services required in the event of an earthquake. The significance of the losses may be strongly dependent on economic factors such as interest rates, foreign exchange rates, and the state of the building market at the time. These are other risks, traditionally considered separately, for which the tools are now being developed to consider them all together, and determine the solution which most enhances shareholder value.

To date most of this activity has been in relation to direct financial risks and the use of financial instruments to optimise the management of them. The catastrophe loss simulation models are playing a significant role in this activity, as without their output it would be difficult to include catastrophe risks in the analysis. However the models are still very limited in terms of the total needs of integrated financial risk management. This is because to date they are primarily focussed on the costs of repair and replacement associated with property damage, and to a lesser extent the business interruption costs arising from these. To fully meet the needs of integrated financial risk management they will need to cover contingent losses arising from damage to other facilities, and also the impact of the catastrophe on economic factors such as interest rates, building costs and foreign exchange rates. There will be a role for earthquake engineers in this activity, particularly in modelling the the impacts of infrastructure damage.

However the most exciting opportunities for earthquake engineers in this field will occur when mitigation of damage becomes part of the integrated risk analysis [Walker 1997b]. To date mitigation of earthquake damage has been a separate activity from financial risk management. Engineers design buildings according to criteria established by consensus within the earthquake engineering profession. The damage risk associated with the resulting building then becomes a fixed input into the risk management process. However there is no reason for this to be so. Once minimum levels of performance have been set in relation to life safety, the optimum level of structural performance should be governed by economic cost benefit considerations, which is exactly what integrated risk management is about. Increasing seismic design levels reduces the risk of damage. The optimum level of seismic design will be that which in conjunction with the other risk mitigation actions produces the optimum result in terms of shareholder value.

Currently the closest approach to this is the retrofitting of buildings to improve their resistance to hazards where it is linked to reduction of insurance premiums or removal of onerous insurance conditions. Until now this has been largely undertaken on an individual building basis. An exception was a program instituted in Fiji in 1985 for upgrading existing housing for wind resistance to meet insurance requirements for insurance against damage from tropical cyclones [FBSC 1985]. Recently Standards Australia published a four volume handbook on the structural upgrading of older Australian houses to improve their wind resistance [SA 1999]. This publication provides for three different levels of upgrading, and is intended for use by the insurance industry in conjunction with risk related insurance premiums and conditions. This will enable owners to make their own risk based decision on the appropriate level of structural performance. The more appropriate time for making these decisions is at the design stage, and it is not difficult to imagine a time when determining the appropriate level of resistance based on an integrated risk analysis will be part of the design process. This will require a significant change in focus of earthquake engineering research, with much more emphasis on the economic consequences of various levels of failure than now, and how to control these by design, than now.

CONCLUSIONS

Earthquakes pose difficult problems for the insurance industry, and for emergency managers who look to insurance to make a major contribution to the recovery process. World wide insurance against earthquakes is very variable, with few countries being as fortunate as Australia and New Zealand where it is almost universally available and used.

The major problem is accumulation of damage from a single event. Traditional insurance and reinsurance have severe limitations in providing full cover for large cities at major risk such as Tokyo, Los Angeles and the San Francisco Bay area.

The Kobe earthquake demonstrated that modern earthquake engineering knowledge can mitigate the damage to a level at which it is insurable. Modern developments in earthquake loss simulation are enabling the design of innovative risk financing programmes which do not have the restrictions of traditional insurance. These offer the opportunity for utilising mitigation as part of the process of optimising the risk management of organisations. This will open up new opportunities for earthquake engineering research and practice.

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