SEISMIC ZONING APPLIED TO RISK ASSESSMENT AND LOSS ACCUMULATION PROBLEMS IN EARTHQUAKE INSURANCE

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SUMMARY

Besides the need to calculate a premium that is adequate, i.e. one that will cover the insurer's costs, the insurance of the earthquake risk is marked by one further essential feature: a consideration of the accumulation hazard and the catastrophe potential. The amount of loss to be expected following an earthquake catastrophe determines what strategies are required in terms of underwriting, establishing reserves, and acquiring reinsurance to guarantee a company's solvency even in the event of such a catastrophe occurring. The possible applications of seismic zoning are described, with the emphasis on the significance of microzoning for the problems peculiar to conurbations.

INTRODUCTION

Four years ago, the authors presented their world map of the seismic risk (Ref. 1). The reason for developing this map was the need to gain an impression of the earthquake exposure on a large scale, a need arising out of the everyday work of companies and organizations active on a worldwide scale. The map was designed first and foremost for use when rating insurance risks, but it soon found its way beyond the insurance field into areas primarily concerned with planning such as engineering offices and national and international authorities.

It is obvious that the large-scale picture given by a world map is not sufficient for such projects as designing large industrial plants. And in the field of insurance, too, there are aspects that make a detailed assessment of the exposure necessary. These aspects may be attributed to the worldwide increase in the concentration of populations and to the resulting concentration of material values in conurbations such as San Francisco Bay, Los Angeles, Mexico City, Tokyo, and Manila. This trend will lead to the number of cities with over a million inhabitants doubling from 200 to 400 by the year 2000, and the number of cities with over 10 million inhabitants rising from 10 to 25. Although the exposure is not affected by this, the probability of catastrophic losses is continuously growing.

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THE INSURANCE OF THE EARTHQUAKE RISK

Underwriting problems

The insurance of earthquakes and other natural hazards presents the insurer with two basic problems:

1. Rating that is commensurate with the risk: here the aim is to calculate a premium that covers the insurer's costs on a long-term basis. This affects earthquake insurance in just the same way as any other traditional class of insurance, such as fire insurance.
2. Accumulation loss: this refers to the loss suffered by an insurer as the result of a natural disaster. It has a much greater influence on the insurance of natural hazards than on the traditional classes, because practically any event will affect a multitude of risks and because major disasters generate the greatest burdens an insurer may ever expect.

Contrary to common belief, there are narrow limits to the use of technical and scientific methods for rating earthquake risks, at least as far as the individual insurer is concerned. There are two reasons for this, reasons which seem to be contradictory. On the one hand, the tariff may be subject to a binding supervising authority directive. On the other hand, where there are no requirements made on premium structures, the need to be competitive frequently takes precedence over technical considerations. The best opportunity to introduce such technical considerations is when a new tariff is being designed, and this is first and foremost the responsibility of supervisory authorities.

The aspect of accumulation, however, is a matter for which each company itself is fully responsible. The scale of the liabilities that might be involved requires underwriting, reserving and reinsurance strategies that will guarantee the solvency of the insurer even in the event of extreme catastrophe losses. Well-grounded considerations of the probable magnitude and effects of potential earthquakes are essential. Among the main duties of seismologists and earthquake engineers is to provide the necessary information in a comprehensible and usable form.

Seismic zoning and insurance

In its publication "Guatemala'76" - Earthquakes of the Caribbean Plate" (Ref. 2), the Munich Reinsurance Company presented a zoning system which may be seen as a comprehensive approach to the complex of problems under discussion. Within this system there are three types of zone:

- the exposure zone,
- the loss accumulation zone, and
- the accumulation assessment zone.

The original concept made a strict differentiation between the exposure zone on the one hand and the loss accumulation and accumulation assessment zones on the other.

- Dividing a country into exposure zones (Ref. 2) means a purely scientific description of the different degrees of exposure and is for the sole purpose of rating. The grading of the exposure at present incorporated in the tariff manuals used in some countries is based on quite diverse criteria. As a result, it is often impossible to make a sound conversion into a premium that is technically adequate. In 'Guatemala'76', therefore, the Munich Reinsurance Company suggested a procedure with the purpose of standardizing the criteria, thus making it possible to calculate premiums on a technically sound basis. The reference parameter used in this procedure is the intensity (Mercalli) to be expected once in 50 years given average subsoil conditions, ranging from intensity $\leqslant$ V (zone 0) to intensity $\geqslant$ X (zone 4).

This system was applied worldwide in the "World Map of Natural Hazards" (Ref. 3). The exposure maps that have been produced on a probability basis since this concept was presented have shown that the criterium of "intensity X once in 50 years" is not fulfilled anywhere on this earth, even in areas of high seismicity. It is therefore planned to revise this zoning so that 5 zones are maintained while former zone 4 with intensity X is withdrawn. Zone 1, which at present contains intensities VI and VII, is to be broken down into two zones to compensate for this.

In contrast to this method of zoning, the division of a country into accumulation assessment and loss accumulation zones is meant to take into account the catastrophe aspect in the insurance of natural hazards.

- The division of a country into accumulation assessment zones (Ref. 2) is for practical reasons based on existing administrative units such as provinces or postal areas. Accumulation assessment means determining the geographical distribution of the values insured in one country. For this purpose, the assessment zones must be uniform all over the market, i.e. the same zones must be used by all the companies. Otherwise there is no guarantee that the reinsurers, who are heavily involved in the cover of catastrophe hazards, will also be able to assess and monitor efficiently their liabilities emanating from all parts of the market.

- The loss accumulation zone covers the area affected by the earthquake that represents the greatest loss burden for each individual insurer. As the companies will have different regional concentrations of liability and different insurance portfolios, they will also use different loss accumulation zones as a basis for their deliberations on company policy. This applies not only to the location of the accumulation event, which is selected on the basis of the distribution of liabilities and of course the seismotectonic situation, but also to its intensity. As the degree to which the companies are willing to carry risks varies, so too will the probability of occurrence and the related earthquake intensity used as a basis for the decision. It may also be necessary to examine a number of alternatives to assess the largest loss accumulation.

The loss accumulation is calculated on the basis of the intensity decreasing as the distance from the selected epicentre increases. The corresponding intensity or the expected loss ratio is then allotted to the accumulation assessment zones. This means of course that the size of the assessment zones must be in a sensible relation to the size of the loss accumulation zones, namely in such a way that the loss zone comprises a patchwork of assessment zones.

Accumulation assessment zones as described above are now used in nearly all Latin American countries and in the majority of countries in the Middle East, the Far East, and Europe where earthquake insurance is of any significance.

THE APPLICATION OF SEISMIC ZONING IN EARTHQUAKE INSURANCE

Macrozoning

The zoning system described above was conceived with the primary aim of covering a country entirely. Probability exposure maps were therefore used for exposure zoning and rating. Details may be found in Ref. 1-4.

Microzoning

As indicated earlier, past years have shown with increasing clarity that earthquake insurance is faced with major problems in the great conurbations. In many countries 50% or even considerably more of the values insured against earthquakes are concentrated in or around the capital cities.

How heavy fluctuations in the amount of damage can be in even small areas was shown by the 1957 quake in Mexico City (Ref. 5) and the Caracas quake of 1967, demonstrating at quite an early stage the necessity of applying seismic microzoning in such areas.

The aim of microzoning is to go beyond a region's average exposure and to assess the small-scale variations in the seismic forces and hence the loss expectancy. The following factors may be mentioned in this connection:

- the various types of subsoil (ranging from quite loose young sediments or even man-made fills to solid rock) and their thicknesses,
- the topography of the surface and of the crystalline basement,
- the location of the area in relation to the earthquake focus threatening it (distance and direction),
- the typical focal mechanisms,
- the exposure to landslides, subsidence, liquefaction, and tsunami.

The application of microzoning in calculating premiums, based on the example of Mexico City

An empirical analysis of the losses caused by the earthquake that hit the Valle de Mexico on July 28, 1957, produced a distinct correlation with the subsoil conditions within the city area (Ref. 5).

There are two main zones. The first is Zone C (=Zona Compresible) covering the historical centre of the city and a major part of the business district. The subsoil consists of the hardly compacted deposits of the Lago di Texcoco, which was drained after the Spanish conquest, with a thickness of between 40 and 200 m. The subsoil of the second zone, Zone 2, consists of solid sedimentary or volcanic rock, spreading from the western parts of the city to the surrounding Estado de Mexico. These two zones are connected by the transition Zone T (= Zona de Transición).

If we consider that 60% - 70% of the total insured earthquake liabilities in the country are concentrated in and around the capital, we become aware of how important these circumstances are for the calculation of the premium theoretically required to cover costs. This calculation may be easily carried out in the case of Mexico for two reasons:

Firstly, the loss distribution resulting from the 1957 quake has since proved, on the strength of various subsequent quakes of slight local intensity, to have been typical.

Secondly, the epicentre distribution of these recent quakes is largely representative for the position of the source zones which can cause damage in Mexico City. It is therefore possible to draw well-founded conclusions on the long-term loss expectancy, at least for events of slight local intensity, which have a strong influence on the overall picture of seismicity in the Valle de Mexico.

The following calculation shows the effect of the subsoil conditions on the premium calculation for the Valle de Mexico (Zones C, T, and 2). The calculation of the return periods is based on the historical catalogue going back to 1460 (Ref. 6) but these intensity readings were examined critically using Ref. 7 and the experience gathered from quakes in recent years. The average loss ratios adopted for intensities VI and VII were derived from the figures of the 1957 quake and after that in Mexico City itself, while the quakes in Caracas (1967), Managua (1972), and Guatemala (1976) served as the basis for the higher intensities.

This produces the following basic data for the calculation:

Intensity (Mercalli)	VI (=5.5 - 6.4)	VII (=6.5-7.4)	VIII (7.5-8.4)	IX (≥8.5)
Return period	6	19	51	164 years
Annual frequency	0,165	0,052	0,016	0,007
Loss ratio	1	5	15	30%

The average annual loss ratio derived from these figures is (0,165 x 1 + 0,052 x 5 + 0,016 x 15 + 0,007 x 30)% = 8.75‰ . As the catalogue of data used states the highest intensities observed, of course, this ratio will only have any significance for Zone C where the subsoil conditions are very unfavourable. If a reasonably accurate idea of the amount of losses to be expected in the long term in the Valle de Mexico is desired, therefore, it will be necessary to reduce the intensities for the other zones. Assuming a reduction of one degree for Zone T and of two degrees for Zone 2, and given the liability distribution at present applicable for the individual zones, the overall annual loss ratio is 4.05‰. The coinsurance rate of 25% for earthquake cover in Mexico and the 2% deductible bring this rate down again by in fact about 50%, while on the other hand underwriting surcharges (administrative costs, loading for fluctuations) must also be taken into consideration. The resulting figure is well above the premium presently charged in the Valle de Mexico.

Such a simple application of microzoning is only possible in isolated cases. As experience shows, the number of factors that have a decisive influence can be reduced to just one in Mexico: the subsoil conditions. Where the seismotectonic conditions are more complicated and there are several source zones of different nature, such a procedure would have to be dismissed as an unreliable oversimplification.

In the example above, average figures are produced for the entire portfolio, while the premium that is adequate for the individual risk depends not only on the exposure but also on the type of risk involved, the constructional features and the height of the building. A key role is played by the resonance frequency of the building itself, which should therefore be considered when microzoning maps are being constructed (see Ref. 8 for example).

Even if each risk is treated separately, it is not possible to consider all the constructional factors and the influences mentioned in connection with microzoning in anything but an approximate way in the process of rating - and even then the margin of error is considerable.

The use of microzoning in the treatment of the accumulation problem

The possible ways of applying microzoning techniques to the problem of accumulation may be demonstrated also using Mexico as an example. The principle of dividing up a country into accumulation assessment zones has already been described. In Mexico, the states are used as assessment zones. However, in some cases two or more states are amalgamated to form one zone. As the majority of liability is concentrated in the Valle de Mexico, the amount of loss accumulation depends largely on the intensity of the quake in this zone, whereas the amount in accumulation assessment zones with a low proportion of liability contributes little to the overall loss. With a view to producing the most accurate calculation possible of the loss accumulation that is to be expected, the Zone "Distrito Federal" has been split up further into Zones C, T, and 2, corresponding to the differing subsoil conditions. These zones can now be incorporated into the calculation of the loss with their own loss ratios depending on the intensities there. This means that, by using the same loss ratio and intensity differences as in the rating example, the overall loss ratio in the Valle de Mexico is decreased by 45% compared with Zone C.

This kind of methodical approach makes sense where a high concentration of liability coincides with small-scale intensity variations. Of particular significance in this connection is the rapid growth in the number of high-rise buildings in conurbations, as they are endangered by the long waves of relatively distant earthquakes. Even if the insurer can base the calculation of his loss accumulation on events observed in the past, there is a limit to how far the loss profile can be projected because of the change in the construction methods. The only solution in such cases is provided by theoretical considerations to which seismic microzoning can make a considerable contribution. As well-defined events are the basis for this procedure, an adequate degree of reliability in the statement is guaranteed. In addition it is also possible to include those aspects of microzoning which extend beyond the simple production of maps showing the subsoil conditions but which are frequently just as significant for the explanation of loss patterns. In the case of the 1967 Caracas earthquake, for instance, it was possible to approximate the distribution of the losses even better using one certain model of the bedrock relief apart from the obvious correlation with areas where the sediments filling the valleys had a certain thickness. This model suggests a focussing of the seismic wave energy in such a manner that the areas with the heaviest losses were located in the focus of the waves reflected by the bedrock (Ref. 9).

THE DEVELOPMENT OF THE ZONING CONCEPT

In all those countries like Mexico where there is a high concentration of values in conurbations and varying subsoil conditions, the principle of the most uniform division of a country for accumulation assessment is replaced by an appropriately detailed division of the conurbations. This method is not impaired by there being large areas of the country that are less significant in terms of liability gathered together to form in some cases one single accumulation assessment zone.

The example of Mexico shows quite clearly that going from a large-scale, nationwide method to a small-scale study of conurbations may lead to an overlapping of exposure zones and accumulation zones, zones which were strictly separate in the original concept. Exposure Zones C, T, and 2 in the Distrito Federal and Zones R and 3 in Acapulco are incorporated in the accumulation reporting system as accumulation assessment zones.

CONCLUSIONS

The development attained so far in the process of seismic microzoning make this method an obvious one to apply to problems of eartquake insurance, above all for calculating loss accumulation, as long as the scenario method is used, i.e. the study is based on well-defined, single events.

An application in the field of rating is also possible if one certain seismic focus has a decisive effect on the exposure of an area.

This was demonstrated in the example of the Valle de Mexico. Although there are smaller seismic foci within the valley or not far from it, the overall exposure profile is dominated by relatively distant quakes in the Benioff zone between the North American Plate and the Cocos Plate. These quakes are the cause of the frequently observed accumulation of damage to multi-storey buildings in Zone C.

On the other hand, complex seismotectonic conditions with several source zones at varying distances and possibly with varying quake mechanisms cannot, at least for the present, be used as a reliable basis for rating. It is true that the available zoning methods make it possible to determine the contribution made by individual source zones to the overall exposure, but more data would be required for a quantitative statement on the change in the subsoil influence in conjunction with the distance of the focus and magnitude of the quake. As far as rating is concerned, then, it is hardly attainable even for the expert to take into account such factors as liquefaction, which will not arise in every quake, of course, and even then in varying degrees, or the fact that soft sediments, which are generally regarded as being "unfavourable", can have a positive effect in relation to high-frequency waves. This is, of course, much more feasible where individual objects are concerned than in the case of overall risk considerations such as those required to calculate nationwide tariffs.

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