SEISMIC RISK AND EARTHQUAKE INSURANCE IN SOUTH AND CENTRAL AMERICA

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ABSTRACT

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A method is developed for the calculation of earthquake insurance coefficients, defined as annual premiums normalized by the value of the insured property, taking account of the extent of damage, time element and building type. The method is applied to the seismic histories of capital areas in South and Central America.

INTRODUCTION

We attempt to provide a reasonable basis for the evaluation of annual premiums for insurance against earthquake damage, considering the extent of damage, the probability of its occurrence, and various building types, but excluding secondary effects (fires, floods, landslides, etc.). Obviously, this field of study requires close cooperation between insurance experts, construction engineers and seismologists. Numerical evaluation of earthquake insurance coefficients is possible when a reliable seismic history of major earthquakes is available. In the present work, the developed method is applied to capital areas in South and Central America, including Santiago, Lima-Callao, Bogotá, Caracas, Managua, Guatemala City and Mexico D.F. Earlier literature on earthquake insurance has mostly dealt with the United States and Canada.

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FUNDAMENTAL CONCEPTS AND RELATIONS

Basic relations

Parameters used, their symbols and definitions, are summarized in Table I. The damage D caused by a particular earthquake is equal to $d \,.\, P$, where d is the damage rate ($0 \leq d \leq 1$). Moreover, D is proportional to the acting force, i.e. mass x acceleration $= m \,.\, a$, hence:

$$D = d \,.\, P \sim m \,.\, a \qquad (1)$$

While P is exclusively a construction-design parameter, d is proportional to the ground acceleration. It follows from (1) that d is equal to the damage normalized by the amount insured.

The annual premium AP is proportional both to the expected damage D and to the damage risk R, i.e.:

$$AP \sim D \,.\, R = d \,.\, P \,.\, R = c \,.\, P \qquad (2)$$

The product $c = d \,.\, R$ is the earthquake insurance coefficient.

Table I
Earthquake insurance parameters

Parameter	Symbol	Definition
Amount insured	P	Value of the property covered by the earthquake insurance.
Earthquake damage	D	Damage to the insured property, expressed in money value, caused by a particular earthquake; equations (1) and (2).
Damage rate	d	Earthquake damage normalized by the amount insured, $0 \leq d \leq 1$; equations (1) and (2).
Annual premium	AP	Equation (2).
Damage risk	$R_j(d)$	Probability of occurrence of a damage rate d for a building of type j; equation (4).
Earthquake risk	$R(I)$	Probability of occurrence of intensity I; equation (5).
Selection risk	$R_{Ij}(d)$	Probability of occurrence of damage rate d for intensity I and building type j.
Earthquake insurance coefficient	c_{jd}	Product of damage rate d and damage risk $R_j(d)$ = annual premium AP normalized by the value of the insured property P; equations (2) and (7).
Mean return period	$T(I)$	Mean time interval (years) between two successive earthquakes of intensity I; equation (6).
Premium period	S	Time interval covered by the insurance agreement. In this paper, S = 1 year.

Damage rate

As stated, the damage rate d is proportional to the ground acceleration. The latter can be estimated from seismic intensities by the following approximate relation:

$$\log a = I/3 - 0.5 \tag{3}$$

Where I = intensity (12-degree scale) and a = corresponding acceleration (cm/sec^2).

Combining (1) and (3), each intensity degree can be related to a certain earthquake damage D. For example, if intensity XII (damage practically total) is ascribed a damage $D = P$, $d = 1$, then intensity XI (approximately half the acceleration of intensity XII) causes a damage $D = 0.5\,P$, i.e. $d = 0.5$, etc. However, this estimation is valid only for a uniform type of building. A detailed classification according to building type can only be made approximately, with the guidance of the definitions of the various intensity degrees. Also, from an engineering point of view, we have to put $d = 1$ if a building needs to be completely rebuilt, even if only partially damaged.

Damage risk

The damage risk $R_j(d)$ is governed by the earthquake risk $R(I)$ and the selection risk $R_{Ij}(d)$:

$$R_j(d) = \Sigma_I \; R(I) \, . \, R_{Ij}(d) \tag{4}$$

The earthquake risk $R(I)$ is calculated by the following equation:

$$R(I) = 1 - \exp\,[-S/T(I)] \tag{5}$$

where S = premium period, assumed constant and equal to one year, and $T(I)$ = mean return period of intensity I, defined as:

$$T(I) = \text{(period of observation):(number of events)} \tag{6}$$

The selection risk $R_{Ij}(d)$ is estimated by applying the MSK (Medvedev-Sponheuer-Kárník) intensity scale. By the detailed and semi-quantitative definitions of the various intensity degrees, this scale permits evaluation of damage rates and selection risks. Four levels of selection risk are used: 5%, 50%, 75% and 100%.

Earthquake insurance coefficient

The earthquake insurance coefficient c_{jd} for a certain building type j and a certain damage rate d is obtained from the following equation, cf. equation (2):

$$c_{jd} = d \, . \, R_j(d) = d \, . \, \Sigma_I \; R(I) \, . \, R_{Ij}(d) \tag{7}$$

with the summation extended over all intensity degrees where the assigned value of d is present.

APPLICATION TO SOUTH AND CENTRAL AMERICA

The method developed in the former chapter has been applied to a number of capitals in South and Central America. The restriction to capital areas stems from the fact that only these are of insurance interest in this part of the world.

Seismic history

The significant parameters mentioned above, i.e. damage

Table II
Mean return periods T(I) and earthquake risks R(I)

Area	Intensity 12-deg. scale	Period of observa-tion	Number of events	T(I) years	R(I)
Mexico	VI	1665-1973	75	4.11	0.216
D.F.	⩾ VI	,,	121	2.55	0.323
	VII	1460-1973	51	10.1	0.094
	⩾ VII	,,	66	7.77	0.121
	VIII	,,	14	36.6	0.027
	⩾ VIII	,,	15	34.2	0.029
	IX	,,	1	~ 513	~ 0.002
Bogotá	VII	1625-1967	5	68.4	0.015
	⩾ VII	,,	7	48.9	0.020
	VIII	,,	2	~ 171	~ 0.006
Santiago	VII	1822-1971	5	29.8	0.033
	⩾ VII	,,	7	21.3	0.042
	VIII+	,,	–	100	0.01
Lima-Callao	VII	1932-1974	3	14	0.069
	⩾ VII	,,	6	7	0.133
	VIII	,,	3	14	0.069
Caracas	⩾ VIII	1812-1967	3	51.7	0.019
Managua	⩾ VIII	1885-1972	4	21.8	0.045

Table III
Insurance coefficients c_{jd}
for various damage rates d and building types

Damage rate d	Area	Building type[1]) a	c
0.05	Mexico D.F.	0.01425	0.00400
	Bogotá	0.00105	0.00060
	Lima-Callao	0.00690	0.00432
0.1	Mexico D.F.	0.02075	0.00197
	Bogotá	0.00173	0.00038
	Lima-Callao	0.01208	0.00380
0.2	Mexico D.F.	0.01601	0.00047
	Bogotá	0.00240	0.00006
	Lima-Callao	0.01725	0.00069
0.5	Mexico D.F.	0.00985	0.00005
	Bogotá	0.00188	
	Lima-Callao	0.01898	
1	Mexico D.F.	0.00235	
	Bogotá	0.00030	
	Lima-Callao	0.00345	

[1]) a = buildings in field-stone, rural structures, adobe houses, clay houses.
c = reinforced buildings, well-built wooden structures.

rate and damage risk, can be estimated from any sufficiently well known seismic history. Estimation of intensities from magnitudes M by some conversion formula $I = f(M)$ has been considered but was abandoned, because numerous unknown factors influence such a relation to a very great extent. Instead, our calculations are exclusively based upon reported intensities, obtained by thorough searching in catalogues, bulletins, isoseismal maps, reports and papers, as well as by personal communications.

Available information has been catalogued for Santiago for the years 1575-1971 (12 earthquakes), Lima-Callao 1555-1974 (19), Bogotá 1625-1967 (8), Caracas 1641-1967 (6), Managua 1881-1972 (14), Guatemala City 1862-1976 (8), and for Mexico D.F. for the years 1460-1973 (129 earthquakes). In order to assess earthquake risk, other information besides the seismic history may also be of significance, especially structural features, location in relation to active fault systems, as well as ground structure. These factors have been summarized by us, but are not further used.

Earthquake risk and insurance coefficients

Our estimated mean return periods $T(I)$ and earthquake risks $R(I)$ are summarized in Table II. Examples of our calculated insurance coefficients are given in Table III.

For given damage rates d and given building types j, we have calculated for each investigated locality the corresponding earthquake insurance coefficients c_{jd}. Then, the annual premium is found from $AP = c_{jd} \cdot P$, where P is the money value of the insured property. It has to be emphasized that the insurance coefficients only take account of seismic effects. Therefore, the significance of the given c_{jd} is relative rather than absolute. They give an estimate of the relative insurance needed for different areas, for different buildings and for different damage rates. Among the areas investigated, the most expensive earthquake insurance is found in Lima-Callao, Managua and Mexico D.F., while the lowest premiums are expected in Bogotá.

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REFERENCE

Kulhánek, O. & M. Båth 1976 Earthquake insurance coefficients with application to some South-Central American capitals - Seismol. Inst. Uppsala Rept. 8-76: 57 pp.