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EFFECT OF SITE CONDITIONS ON THE SEISMIC INTENSITY

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ABSTRACT

In this paper a method for correcting the value of the seismic intensity calculated with an attenuation formula in order to include the site soil condition is presented.The proposed method is based on: empirical data obtained from the study of earthquake damages, seismic characteristics of soils and the seismic intensity degree on rock or dense gravel.

The results confirm that the seismic-intensity variation due to soil condition can be calculated with the formula proposed by Medvedev when the local seismic characteristics of soils are introduced in the Medvedev´s formula.

KEYWORDS

Seismic intensity, soil conditions, seismic risk.

INTRODUCTION

When the seismic intensity is the parameter chosen in the seismic zoning maps or is the parameter used for quantifying the seismic effects in studies of seismic risk and in studies of insurance against earthquakes, is very important to evaluate the influence of soil on intensity. That is necesary because the results of field studies of strong earthquakes show clearly the influence of ground types on seismic intensity (Astroza and Monge, 1991).

Barrientos (1980) obtained an attenuation relation of intensity with the information of 73 chilean earthquakes (subduction earthquakes) and theirs respective macroseismical data and 945 Mercalli Modified intensity degree data. The attenuation relationship proposed by Barrientos is:

$$I(r) = 1.3844\ M_s - 3.7355\ \log(r) - 0.0006\ r + 3.8461 \qquad (1)$$

where I(r) is the seismic intensity in a city or place located from the hypocenter of an earthquake of Richter magnitud M_s a distance equal to r.

In this equation no consideration about the local site conditions had been done, so the equation estimates the intensity in a "mean" type of soil. Since most of the data used for the derivation of this formula correspond to chilean cities located on dense gravel deposits, that "mean" soil could be similar to this type of soil.

In order to use this type of attenuation relationship, a method for correcting the value of the seismic intensity considering the site condition of soil is proposed.

METHODOLOGY

The method is based on empirical data obtained from the study of earthquake damages made by the authors in the ten last year and studies of soil characterization in the affected regions, complemented with studies of seismic refraction and gravity for gathering data about the superficial stratums and the depth of the bedrock.

With this information the intensity increment for typical chilean soils is obtained with the relation proposed by Medvedev (1965), between the seismic-intensity increment and the seismic characteristics of soil:

$$n = x_n \log \left(\frac{V_0 \ \rho_0}{V_s \ \rho_s} \right) \qquad (2)$$

where:

n = seismic-intensity increment for the soil under consideration with reference to rock.
v_0, v_s = velocity of propagation of compressive seismic wave in the rock and in the investigated soil.
ρ_0, ρ_s = density of rock and of examined soil.

The intensity on rock I_o is obtained subtracting the increment of intensity on gravel, indicated in the table 1, to the value calculated with Barrientos´s attenuation relation or to the value obtained from the isoseismal map of an earthquake. The increments for quaternary deposits were determined comparing the isoseismals on rock with intensities obtained in 88 cities and villages located in the damaged area of the March 3, 1985 Valparaiso chilean earthquake (Astroza and Monge, 1992).

Table 1. Increment of intensity with respect to rock.

Geologic Unit	Number of data	Increment
Volcanic pumicite ashes	19	1.5 - 2.5
Gravel	32	0.5 - 1.0
Colluvium	28	1.0 - 2.0
Lacustrine deposits	9	2.0 - 2.5

Taking the data given in tables 1 and 2, the values of x_n indicated in the table 3 were obtained with the eq. (2), and the mean value was used

$$x_n = 1.43$$

Table 2. Seismic characteristics of soils (Araneda, 1995).

Soils	v_s (m/sec)	ρ_s (g/cm^3)
Rock	4000	2.65
Gravel	2100 - 2900	2.1 - 2.0
Colluvium	700 - 600	1.9 - 1.8
Lacustrine deposits	200 - 150	1.5

Table 3. Correlation between intensity and seismic characteristics of soils.

Soil	n (mean value)	$\log\left(\frac{v_0\ \rho_0}{v_s\ \rho_s}\right)$	x_n
Gravel	0.75	0.77003 - 0.38087	1.30
Colluvium	1.5	0.99188 - 0.90145	1.58
Lacustrine deposits	2.25	1.67312 - 1.54818	1.40

If a ground consists of several layers with different velocities of P waves and densities, Medvedev proposed to use the mean seismic rigidity ($v_s\rho_s)_{mean}$. This value is determined by the equation

$$(v_s\ \rho_s)_{mean} = \frac{1}{\sum h_j} \sum v_j\ \rho_j\ h_j \tag{3}$$

Finally, the correction of the seismic intensity value due to the effect of soil condition is calculated by the equation

$$delta(I_s) = (I_0 + n) - I(r) \tag{4}$$

APPLICATION TO CITIES OF MAULE REGION, CHILE.

This region extends between parallels 34°40′and 36°15′of south latitude and is a region located on a seismic gap. The main cities in the region are: Curicó, Molina, Talca, San Clemente, Constitución, Linares, Parral, San Javier y Cauquenes.

Considering the historical earthquakes, the maximum intensity in many of these cities corresponds to the 1928 earthquake with a magnitude M_s = 8.0. For this earthquake the isoseimals are showed in the Fig. 1 (Beck et al., 1994).

In order to verify the method proposed in this paper, we compare the value obtained with the eq. (4) with the value obtained subtracting the intensity value calculated with Barrientos′s attenuation relation to the intensity value reported for this earthquake in the indicated cities (Beck et al., 1994). This last delta value is detailed in table 4.

The tables 5a and 5b indicate the delta value obtain with eq. (4). In these tables the rock intensity is calculated with the map of the Fig. 1, reducing by 0.5 or 1.0 the intensities of this map, considering the isoseismals representatives of a soil like a dense gravel. The reductions are calculated according to the values of the table 1.

The n values of the tables 5a and 5b were obtained with the seismic characteristics measured in different places of each city and using the eqs. 2 and 3.

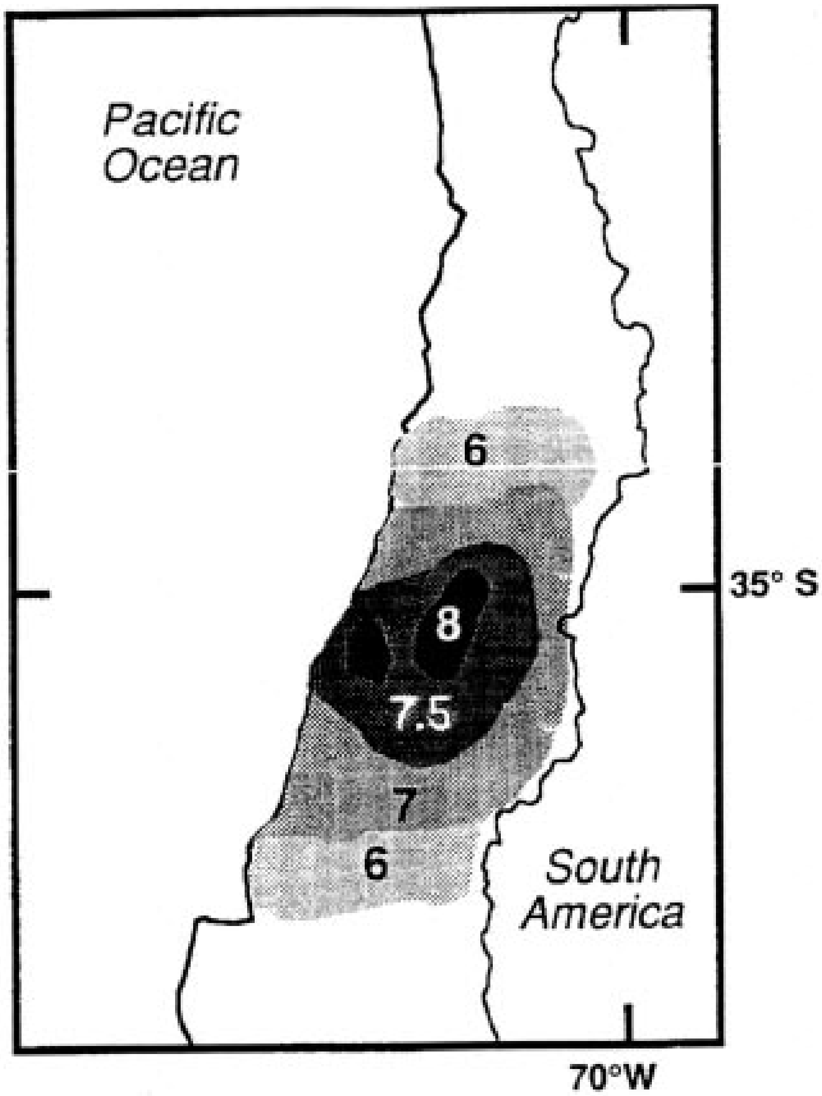

Fig. 1. Isoseismals of the Talca earthquake, December 1928.

Table 4. Delta value considering the intensity values reported for 1928 earthquake, $M_s = 8.0$.

City	r (km)	I(r)	I_{1928}	Delta(I_s)
Curicó	98.7	7.4	8.0	0.60
Molina	98.6	7.4	7.5	0.10
Talca	77.9	7.8	8.5	0.70
San Clemente	95.9	7.5	-	-
Constitución	25.4	9.7	8.5	-1.20
Linares	100.6	7.4	7.5	0.10
Parral	91.3	7.5	7.5	0.00
San Javier	79.0	7.8	7.5	-0.30
Cauquenes	49.2	8.6	7.5	-1.10

Tabla 5a. Delta value, $I_o = (I_{1928})_{gravel}$-0.5.

City	n	I_o	I(r)	Delta(I_o)
Curicó	0.7	7.5	7.4	0.78
Molina	0.6	7.0	7.4	0.18
Talca	0.8	7.5	7.8	0.46
San Clemente	1.1	7.5	7.5	1.10
Constitución	0.8	8.0	9.7	-0.86
Linares	0.7	7.0	7.4	0.27
Parral	0.8	7.0	7.5	0.31
San Javier	0.7	7.0	7.8	-0.13
Cauquenes	0.9	7.0	8.6	-0.74

Tabla 5b. Delta value, $I_o = (I_{1928})_{gravel}$ - 1.0.

City	n	I_o	I(r)	Delta(I_o)
Curicó	0.7	7.0	7.4	0.28
Molina	0.6	6.5	7.4	-0.32
Talca	0.8	7.0	7.8	-0.04
San Clemente	1.1	7.0	7.5	0.60
Constitución	0.8	7.5	9.7	-1.36
Linares	0.7	6.5	7.4	-0.23
Parral	0.8	6.5	7.5	-0.19
San Javier	0.7	6.5	7.8	-0.63
Cauquenes	0.9	6.5	8.6	-1.24

The delta values of table 4 and the mean delta value of the table 5a and 5b are detailed in table 6.

Table 6. Delta values.

City	$Delta(I_o)_{table\ 4}$	Delta(I_o) (mean value)
Curicó	0.60	0.53
Molina	0.10	-0.07
Talca	0.70	0.21
San Clemente	-	0.85
Constitución	-1.20	-1.11
Linares	0.10	0.02
Parral	0.00	0.06
San Javier	-0.30	-0.38
Cauquenes	-1.10	-0.99

CONCLUSION

The comparison of the values of the table 6 shows that the effect of site conditions on the seismic intensity can be calculated with eq. (4). In order to apply the method is necessary to know the isoseismal map on rock for an earthquake and the micro-seismic refraction profiles in the target city or zone.

This method was applied in a seismic risk study developped in the region of Maule,Chile (Morales and Sapaj, 1995). In this study was used the attenuation relation proposed by Barrientos and some of the results were presented in the Fifth International Conference on Seismic Zonation (Monge et al., 1995).

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