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A Proposal of Instrumental MMI Scale Evaluated from California Earthquake records

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1. Introduction

In the absence of strong-motion recordings, the intensity scales provide useful information on the regional distribution of earthquake effects, and it has been used in most cases as scaling parameter for seismic hazard studies. The concept of intensity and intensity scales are considered a classification of the severity of the ground-motion on the basis of observed effects in the stricken area. Since new JMA seismic intensity can be used objectively in early damage assessment, just after a big damaging earthquake, a new method to estimate MM intensity for the California significant earthquakes is proposed (Shabestari & Yamazaki, 1998), and the linear relationship between the reported MMI (Wood & Neumann, 1931) and the calculated JMA seismic intensity is obtained.

2. New Seismic Intensity

In this study by getting ideas from the new JMA seismic intensity scale, a proposal of new scale is introduced using selected time history data set from the Northridge, the Loma Prieta, and the Whittier Narrows earthquakes. Since October 1996 the JMA intensity scale has been revised and large number of seismometers measuring the intensity which are calculated from three-component strong motion records, have been deployed throughout Japan (JMA, 1996). First, the Fourier transform is applied for the selected time window for three-component acceleration time histories. Then a band-pass filter is applied in the frequency domain. After taking the inverse Fourier transform, the effect of the duration (τ) was considered for a vectorial composition of the three-components that is made in the time domain. Considering an acceleration value a_0 having total duration τ satisfying $\tau(a_0) \geq 0.3$ sec, the JMA seismic intensity I_{JMA} is obtained by Eq. (1) as a real (continuous) number.

$$I_{JMA} = 2.0 \log a_0 + 0.94 \quad (1)$$

3. Application of New Seismic Intensity

The new seismic intensity model has been applied for the three California damaging earthquakes, the 1 October 1987 Whittier earthquake ($M_s=5.9$), the 17 October 1989 Loma Prieta earthquake ($M_s=7.1$), and the 17 January 1994 Northridge earthquake ($M_s=6.8$). All data are selected from the three volume CD-ROM records of National Oceanic and Atmospheric Administration (NOAA) of the United States Department of Commerce, National Geophysical Data Center (NGDC), and California Strong Motion Instrumentation Program (CSMIP). To avoid high frequency and instrumental response effects from the records, the corrected time histories are selected. Also to increase the number of data, free field and basement records are included. Figure 1 shows the relations between the calculated JMA seismic intensity (I_{JMA}^*) and the reported Modified Mercalli intensity (I_{MM}) which are taken from the Northridge earthquake (EQE, 1995), the Loma Prieta earthquake (1989), and the Whittier earthquake (1987) reports. Applying linear regression among the three California earthquakes, a new relation between the calculated JMA seismic intensity I_{JMA}^* and the reported Modified Mercalli intensity I_{MM} (Eq. 2) is calculated (Fig. 1d). The proposal of the new seismic intensity (I_{MM}^*), by combining Eqs. 1 and 2 is derived for the three significant California earthquakes as

$$I_{MM} = 1.85 I_{JMA}^* - 2.04 \quad (\sigma=0.315) \quad (2)$$

$$I_{MM}^* = 3.70 \log(a_0) - 0.30 \quad (3)$$

As shown in Fig. 1a, the largest JMA seismic intensity (I_{JMA}^*) is 6.4, which is recorded at the California Santa Monica City Hall ground station during the Northridge earthquake with the PGA_L value of 866.0 cm/s^2 and the epicentral distance of 23 km. The next large value of the I_{JMA}^* is 6.3 for the same earthquake which are recorded at two stations, the Sylmar County Hospital with the PGA_L value of 826.8 cm/s^2 with the epicentral distance of 16 km and the Newhall La County Fire station with the PGA_L value of 578.2 cm/s^2 and epicentral distance of 20 km. Using the relation between the I_{JMA}^* and the I_{MM} by Eq. (2), the new seismic intensity (I_{MM}^*) is derived for the largest I_{MM}^* as 9.8, and for the next larger I_{MM}^* as 9.6. The minimum value of the I_{MM}^* is 4.8 which is obtained from the San Bern Array, County SVCS Bl. station during the same earthquake with the epicentral distance of 114 km. From Fig. 1b, for the 1989 Loma Prieta earthquake, the largest JMA seismic intensity (I_{JMA}^*) is 5.9 which is recorded at the California Corralitos-Eureka Canyon station, with the PGA_L value of 617.7 cm/s^2 . Using Eq. (2), the new seismic intensity (I_{MM}^*) is derived for the largest I_{MM}^* as 8.9 during the Loma Prieta earthquake. For the 1987 Whittier

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earthquake the largest JMA seismic intensity (I_{JMA}^*) is 5.7 which is recorded at the California Whittier, 7215 Bright avenue basement station, with the PGA_L value of 606.7 cm/s^2 (Fig. 1c). Using Eq. (2), the new seismic intensity (I_{MM}^*) is derived for the largest I_{MM}^* as 8.5, for the same earthquake.

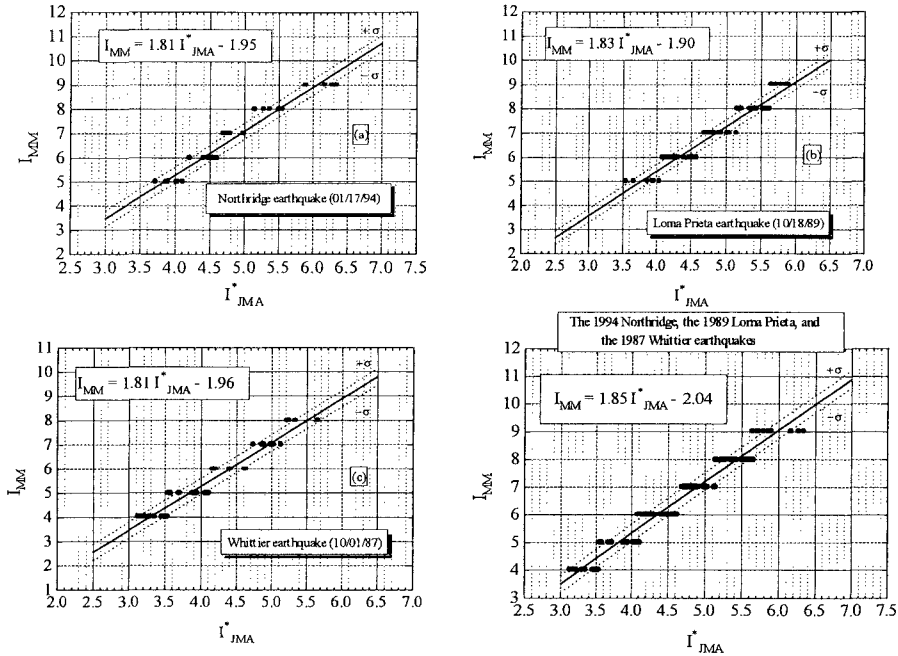


Fig. 1 Relationship between I_{JMA}^* and I_{MM} , for the three significant California earthquakes (a, b, c), and linear relation between I_{JMA}^* and I_{MM} , using the 1994 Northridge earthquake, the 1989 Loma Prieta earthquake, and the 1987 Whittier earthquake (lower right).

4. Results and discussions

As shown in Fig. 1 the relation between the reported MM intensity and the JMA calculated seismic intensity was obtained, fitting a linear regression curve. To derive such a relationship the problem is the accuracy of the MM intensity values which are based on the observations throughout a community having an area of several square kilometers, and in general, are not straightforward to associate with the strong-motion values such as new JMA seismic intensity, PGA , etc. The new seismic intensity (I_{MM}^*) for the California earthquakes was introduced by combining equations 1 and 2.

5. Conclusions

By getting ideas from the JMA seismic intensity algorithm, the method to estimate Modified Mercalli intensity from the acceleration records was proposed. The JMA seismic intensity I_{JMA}^* was obtained for the some California earthquakes, using the free field and basement records which supported by NGDC, USGS and CSMIP. The relation between the reported MM intensity I_{MM} and the calculated JMA intensity I_{JMA}^* was derived. By using the obtained relation the new seismic intensity I_{MM}^* was proposed. The accuracy of the new calculated seismic intensity and the proposed relation of I_{MM}^* should be examined by employing other significant earthquake records.

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