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Relationship Between Peak Ground Acceleration and Modified Mercalli Intensity

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1. Introduction

The most important intensity scales which are used since middle of last century are Rossi-Forrel scale (RF) from 1883, the Modified-Mercalli scale (MMI, 1931), the Medvedev-Sponheuer-Karnik scale (MSK) in its versions from 1963, 1981, 1992, and JMA intensity scale (1951). In the absence of any strong-motion recording sites, 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. Development of the intensity scale can be seen in the consideration of early damage assessment program. In this study the Modified Mercalli Intensity and the peak ground acceleration (PGA) are collected for the most significant California earthquakes. Then the relationship between MMI and PGA are proposed.

2. Modified Mercalli Intensity Scale

A basis for the Modified Mercalli Intensity was introduced by Mercalli in 1902 with ten levels. This was increased to twelve grades by Cancani who tried to express these grades in term of acceleration. In the 1923, Sieberg published an elaboration of the Mercalli scale with Cancani' scheme. The Mercalli scale was advanced by Wood and Neumann (1931) which was improved by Richter in 1958. In the United State, MMI is used (Wood and Nuemann, 1931) and U. S. Geological Survey (USGS) is responsible for collecting earthquake intensity data, using a questionnaire and also they send field investigation to the destructive earthquakes to analyze the resulting damage. The graphic comparison of the four important intensity scales such as the Rossi-Forrel, the Japan Meteorological Agency, (the standard seismic intensity in Japan), and the Medvedev-Sponheuer-Karnik, are shown in Fig. 1.

Scale	Degree of Intensity											
MSK-64	1	2	3	4	5	6	7	8	9	10	11	12
MM	1	2	3	4	5	6	7	8	9	10	11	12
RF	1	2	3	4	5	6	7	8	9	10		
JMA (old)	1		2		3		4		5	6	7	

Fig. 1 Comparison of different macroseismic scales (after Grunthal, 1994)

3. Correlation between PGA and MMI

In this study the three major California earthquakes such as the 1971 San Fernando (M=6.5 in local magnitude scale), the 1989 Loma Prieta (M=7.1 in local magnitude scale) and the Northridge (M=6.8 in surface magnitude scale) are selected from the National Geophysical Data Center, NGDC and USGS data base. To make a correlation between the PGA and MMI the free field data are collected, and also the larger of the PGA value of the two horizontal components are used. Using the mean of the PGA values with respect to the MMI, the linear relationship were calculated for each given earthquake. The linear relationships for the San Fernando, Loma Prieta and Northrigde earthquakes are given by following equations. Figure 2 graphically shows the correlation of PGA and MMI.

$$\text{Log } (PGA)_L = 0.27\ I_{MM} + 0.48 \qquad \text{for San Fernando event} \qquad (1)$$

$$\text{Log } (PGA)_L = 0.13\ I_{MM} + 1.33 \qquad \text{for Loma Prieta event} \qquad (2)$$

$$\text{Log } (PGA)_L = 0.15\ I_{MM} + 1.07 \qquad \text{for Northridge event} \qquad (3)$$

Also Gutenberg and Richter (1942), proposed the relationship between the average of the horizontal PGA and MMI by Eq. (4). Neumann (1954), proposed the relation which are valid for the average epicentral distances up to 25 kilometers by Eq. (5). Hershberger (1956) derived another relation by Eq. (6). Kawasumi (1951) proposed correlated PGA in cm/sec^2 which recorded by JMA and the JMA intensity, by Eq. (7).

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$Log(PGA)_A = 0.33\ I_{MM} - 0.5$ Gutenberg and Richter (1942) (4)

$Log(PGA)_A = 0.308\ I_{MM} - 0.04$ Neumann (1954) (5)

$Log(PGA)_A = 0.43\ I_{MM} - 0.9$ Hershberger (1956) (6)

$Log(PGA)_A = 0.5\ I_{JMA} - 0.35$ Kawasumi (1951) (7)

4. Results and discussions

Figure (2) compares graphically three selected relations with this study results. It can be seen that the slopes of the Northridge, the Loma Prieta, and the San Fernando events are smaller than other relationships. Choosing the average value of the PGA or the larger value of the PGA from of the two horizontal components, makes an important action to represent the characteristics of the data base, (Ansary and Yamazaki, 1995). Also instead of using mean value of the PGA, it is possible to use iterative regression analysis results, to derive a relationship. MM intensities are not straightforward to associate with the strong-motion values, because the MM intensities generally are based on the observations throughout a community having an area of many square kilometers. Hence, it is useful if new method to calculate MMI using an algorithm like obtaining JMA intensity is developed

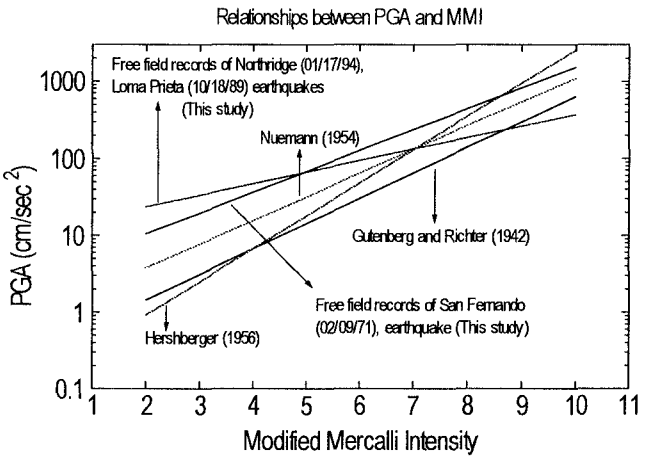

Fig. (2) Graphic representation of selected PGA and MMI correlation

5. Conclusions

The correlation between the PGA and MMI was derived, for the three large California events, using the free field records (corrected) which supported by NGDC and USGS. The slope of our relation is smaller than other relation. Since the MM intensities value is not directly associated with strong-motion PGA value which obtain from one point, therefore using iterative regression analysis for the large California earthquakes is recommended. Recently we are working on this issue and the result will be used as an input to the proposal new seismic intensity model for the California region.

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