Relationship Between JMA Intensity and Strong Motion Parameters

The University of Tokyo, Institute of Industrial Science, Student Member Kazi Rezaul Karim
The University of Tokyo, Institute of Industrial Science, Member Fumio Yamazaki

Introduction: The JMA (Japan Meteorological Agency) seismic intensity (I_{JMA}) has been used as a measure of strong shaking for many years in Japan.[1)] Other strong motion indices, e.g., Peak Ground Acceleration (PGA), Peak Ground Velocity (PGV), and Spectrum Intensity (SI), etc., are also used to describe the severity of an earthquake. Hence, it is important to know the relationship between the JMA seismic intensity and strong motion indices (e.g., PGA, PGV, and SI). In this study, a strong motion data set was used, which consists of eight hundred and seventy nine (879) three-components acceleration records selected from thirteen (13) major earthquake events that occurred in Japan, the United States, and Taiwan. The JMA seismic intensity and other ground motion indices were calculated using the selected data set. The relationships between the JMA seismic intensity and PGA, PGV, and SI were then derived performing a two-stage linear regression analysis.

Earthquake data: The strong motion data set used in this study consists of eight hundred and seventy nine (879) three-components acceleration records selected from thirteen (13) major earthquake events that occurred mostly in Japan, two in the United States, and one in Taiwan, and the magnitude for the selected events ranges from 5.1 to 8.1. The data set of the strong motion records is limited to

1. Acceleration records only from free-field sites were selected
2. Only the non-liquefied records were included in the data set
3. Acceleration records with a PGA greater than or equal to 10 cm/s^2 in one of the horizontal components were included in the data set
4. The acceleration records include both far-field and near-field ones
5. In case of closely located stations, only one record was selected and others were omitted

Estimation of JMA seismic intensity: The JMA seismic intensity is calculated using the selected data set and the linear relationships between the JMA seismic intensity and ground motion indices are derived performing a two-stage linear regression analysis.[2)] The linear relationships derived in this study as:

$$I_{JMA} = -0.79+0.20{*}M+1.81{*}\log_{10}PGA_R \quad (\sigma = 0.292,\ R^2=0.942) \quad (1)$$
$$I_{JMA} = 3.38-0.14{*}M+1.82{*}\log_{10}PGV_R \quad (\sigma = 0.344,\ R^2=0.937) \quad (2)$$
$$I_{JMA} = 2.65-0.04{*}M+1.92{*}\log_{10}SI \quad (\sigma = 0.158,\ R^2=0.982) \quad (3)$$

The relationships are also derived using other parameters, such as, the product of two ground motion indices or the combination of two ground motion indices. In this case, the relationships are derived as:

$$I_{JMA} = 1.31+0.01{*}M+0.98{*}\log_{10}PGA_R{*}PGV_R \quad (\sigma = 0.203,\ R^2=0.975) \quad (4)$$
$$I_{JMA} = 0.87+0.07{*}M+0.98{*}\log_{10}PGA_R{*}SI \quad (\sigma = 0.125,\ R^2=0.987) \quad (5)$$
$$I_{JMA} = 1.59+0.02{*}M+1.38{*}\log_{10}SI+0.59{*}\log_{10}PGA_R \quad (\sigma = 0.104,\ R^2=0.991) \quad (6)$$
$$I_{JMA} = 1.25+0.01{*}M+0.95{*}\log_{10}PGV_R+1.00{*}\log_{10}PGA_R \quad (\sigma = 0.202,\ R^2=0.975) \quad (7)$$

where I_{JMA} is the JMA intensity, M is the magnitude, PGA_R and PGV_R are the resultant of the two horizontal components, and SI is the maximum of SI calculated from 0 to 180 degree in the horizontal plane with one-degree interval. For a comparison with other studies, the relationships from Equations (1) to (7) are normalized for a magnitude of 7, and the new relationships take into the following forms:

$$I_{JMA} = 0.62+1.81{*}\log_{10}PGA_R \quad (8)$$
$$I_{JMA} = 2.43+1.82{*}\log_{10}PGV_R \quad (9)$$
$$I_{JMA} = 2.39+1.92{*}\log_{10}SI \quad (10)$$
$$I_{JMA} = 1.38+0.98{*}\log_{10}PGA_R{*}PGV_R \quad (11)$$
$$I_{JMA} = 1.36+0.98{*}\log_{10}PGA_R{*}SI \quad (12)$$
$$I_{JMA} = 1.74+1.38{*}\log_{10}SI+0.59{*}\log_{10}PGA_R \quad (13)$$
$$I_{JMA} = 1.31+0.95{*}\log_{10}PGV_R+1.00{*}\log_{10}PGA_R \quad (14)$$

Comparison of the results with other studies: The relationships (normalized for a magnitude of 7) of JMA intensity and ground motion indices obtained for the 879 non-liquefied records in this study are shown in **Figure 1**. It should be noted that the linear relationships obtained by Tong and Yamazaki[3)] were based on the larger of the two horizontal components of the acceleration records (PGA_L, PGV_L, SI_L). To compare the results with this study,

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Contact Address: 4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan. Tel: 03-5452-6390, Fax: 03-5452-6389

the relationships obtained by Tong and Yamazaki[3)] were converted from larger to resultant of the two horizontal components using the mean ratio of larger/resultant obtained in this study. **Figure 2** shows only the comparison of the relationships between JMA seismic intensity and *SI*, which are obtained in this study with the ones obtained by Tong and Yamazaki.[3)] One can see that the relationships between the JMA intensity and *SI* obtained in the both studies are very similar. It was also observed that the relationship between JMA intensity and PGA_R obtained in this study is very similar comparing to the one obtained by Tong and Yamazaki,[3)] however, some difference was observed with respect to PGV_R. The relationship between JMA intensity and PGV_R obtained in this study shows a little bit higher intensity value up to a PGV_R level of around 10 cm/s comparing to the one obtained by Tong and Yamazaki,[3)] and it shows a lower intensity value beyond that level. This difference comes might be due to the difference of the data sets and method of analysis. The data set used by Tong and Yamazaki[3)] is well distributed and contains smaller values of intensity. On the other hand, the data set used in this study is well distributed, however, the range of JMA intensity is between 1.52 and 6.55. In case of multiple ground motion indices, very good agreement was observed with the one obtained by Tong and Yamazaki,[3)] particularly, with respect to the combination of PGA_R and *SI*.

Conclusions: The JMA seismic intensity was calculated using 879 three-components non-liquefied records. The relationships between JMA intensity and other ground motion indices, i.e., *PGA*, *PGV*, and *SI*, were obtained performing a two-stage linear regression analysis. The major findings are as follows:

1. The relationship between the JMA seismic intensity and strong motion parameters obtained in this study showed a very similarity with the ones obtained by Tong and Yamazaki with respect to both *PGA* and *SI*, however, some difference was observed with respect to *PGV*. In case of multiple ground motion parameters, very good agreement was observed between the relationships obtained in this study comparing to the one obtained by Tong and Yamazaki
2. Comparing the correlation between the JMA intensity with all strong motion parameters, it follows as: (a) the JMA intensity shows the highest correlation with the parameter such as the combination of *PGA* and *SI*, (b) it shows the second highest correlation with the parameter such as the product of *PGA* and *SI*, and (c) it shows the next higher correlation with *SI*.

Based on the above findings, it can be concluded that for estimating the JMA seismic intensity from strong motion parameters, the choice of multiple ground motion parameters would be better than single ground motion parameter. The obtained relationships may be useful for the disaster management agencies in Japan and deployment of new SI-sensors, which monitor both *SI* and *PGA*.

References

1) Japan Meteorological Agency (JMA) Report, 1996. Note on the JMA Seismic Intensity. *Gyosei* (in Japanese).

2) Boore, D.M. and W.B. Joyner, 1982. The Empirical Prediction of Ground Motion. *Bulletin of the Seismological Society of America*, **72**(6), S43-S60.

3) Tong, H. and F. Yamazaki, 1996. Relationship Between Ground Motion Indices and New JMA Seismic Intensity. *Seisan-Kenkyu*, Institute of Industrial Science, the University of Tokyo, **48**(11), 65-68 (in Japanese).

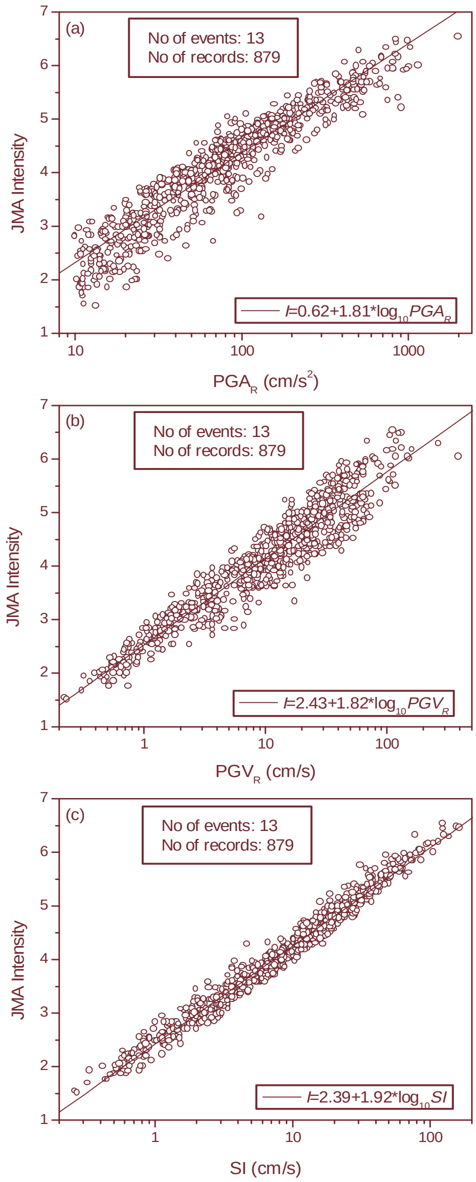

Fig. 1 Relationship between the JMA seismic intensity and ground motion indices

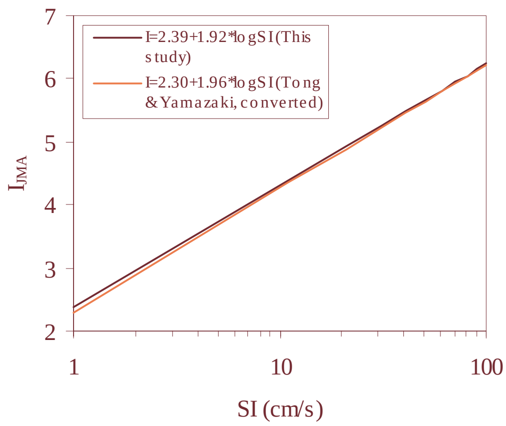

Fig. 2 Comparison of the relationship obtained in this study with other study[3)]