Near-source Attenuation Characteristics of the October 6, 2000 Tottori-ken Seibu Earthquake

Khosrow T. SHABESTARI[1] and Fumio YAMAZAKI[2]

[1] Ph.D., Earthquake Disaster Mitigation Research Center, NIED
(2465-1 Miki, Hyogo, 673-0433, Japan)

[2] Dr. of Eng., Institute of Industrial Science, The University of Tokyo
(4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan)

Attenuation relationships for the ground motion parameters such as Peak Ground Acceleration (*PGA*), Peak Ground Velocity (*PGV*), Spectrum Intensity (*SI*), and instrumental JMA seismic intensity (I_{JMA}) in the October 6, 2000 Tottori-ken Seibu earthquake, are derived considering a near-source saturation effect. The mean predicted attenuation of the *PGA*, *SI*, and I_{JMA} are almost characterized by constant values at a shortest distance of 1 km to the fault extension, while in case of the *PGV*, this is not observed. At the source region the *PGA*, *SI*, and I_{JMA} are predicted as 1000 cm/s^2, 100 cm/s, and 6+ in the JMA scale, respectively. The obtained attenuation relationships are compared with the existing attenuation relationships.

Key Words: The 2000 *Tottori-ken Seibu earthquake, Attenuation relation, Near-source effect, Ground motion indices.*

1. INTRODUCTION

At 13:30 local time, October 6, 2000 a JMA magnitude 7.3 (M_W=6.6) earthquake struck the western Japan. The epicentre was located at 35.275^{0}N and 133.35^{0}E western Tottori prefecture. The source process of this event was characterized by a left-lateral rupture propagation. The main rupture started 2.5 s after the initial break with a length of 20 km and width of 10 km. The upper edge of the final fault plane with a strike, dip, and slip of 150^0, 87^0, and 1^0, respectively (almost vertical), lies 1 km beneath the ground surface[1)].

The 2000 Tottori-ken Seibu earthquake, which caused slight to moderate damage to structures and lifelines, provided reliable strong ground motion records especially for the near-fault data. In this study in order to investigate the strong motion characteristics of the Tottori-ken Seibu earthquake, the Japan Meteorological Agency (JMA) instrumental seismic intensity (I_{JMA}), as well as other ground motion parameters such as spectrum intensity (*SI*), peak ground acceleration (*PGA*), and peak ground velocity (*PGV*) are calculated for five hundred fifteen (515) free-field acceleration records of K-NET and KiK-NET. The shortest distances from the each recording station to the fault extension were calculated using the source rupture process by Yagi and Kikuchi[1)]. Then the attenuation relationships of the ground motion parameters for this earthquake are developed considering a near-source saturation effect.

2. NEAR FAULT STRONG MOTION

From the distribution of the *PGA* versus *PGV* at the Hino K-NET (TTRH02) station, the maximum *PGA* and *PGV* values in the horizontal component reach to more than 900 cm/s^2 and 100 cm/s respectively (Fig. 1). In order to demonstrate the directivity characteristics of near-fault strong motion, the resultant velocity time histories of two horizontal components on the horizontal plane between 0^0-360^0 are calculated (Fig. 2). The Yonago (TTR008) station with a 6.5 km shortest distance from the upper edge of the fault plane shows a clear forward rapture directivity effect[2)] in the direction perpendicular to the fault. On the contrary, the Hino (TTRH02) and the Nichinan (TTR009) stations registered a maximum resultant velocity in the direction parallel to the fault strike. This might be explained by the radiation pattern[2)]. Figure 3 shows the frequency contents for those near-fault records, the velocity response spectra with 0.05 damping for the two horizontal components and the maximal velocity direction were calculated. The cumulative effects of seismic radiation from the fault[3)] can be observed at Hino (TTRH02), Kohfu (TTR007), Yonago (TTR008), Nichinan (TTR009), and Nita (SMNH02) stations in the maximal velocity direction (Fig. 2) and at the periods longer than 0.6 s in the velocity response spectra of the three components and the maximum velocity direction (Fig. 3).

The *PGA*, and *PGV* of the larger of the two horizontal components were selected from the data

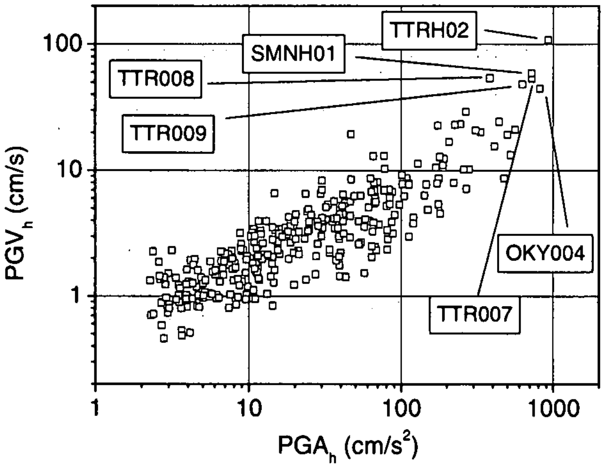

Fig. 1 The relation between PGV and PGA larger of two horizontal components for the October 6, 2000 Tottori-ken Seibu earthquake.

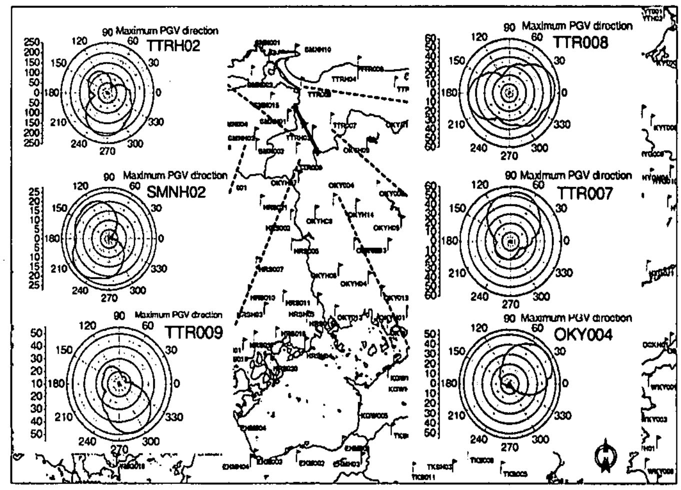

Fig. 2 Locations of (flags) the near-fault stations, (star) the epicenter, (solid line) the surface projection of the fault. The rotated maximal velocity direction for near-fault stations.

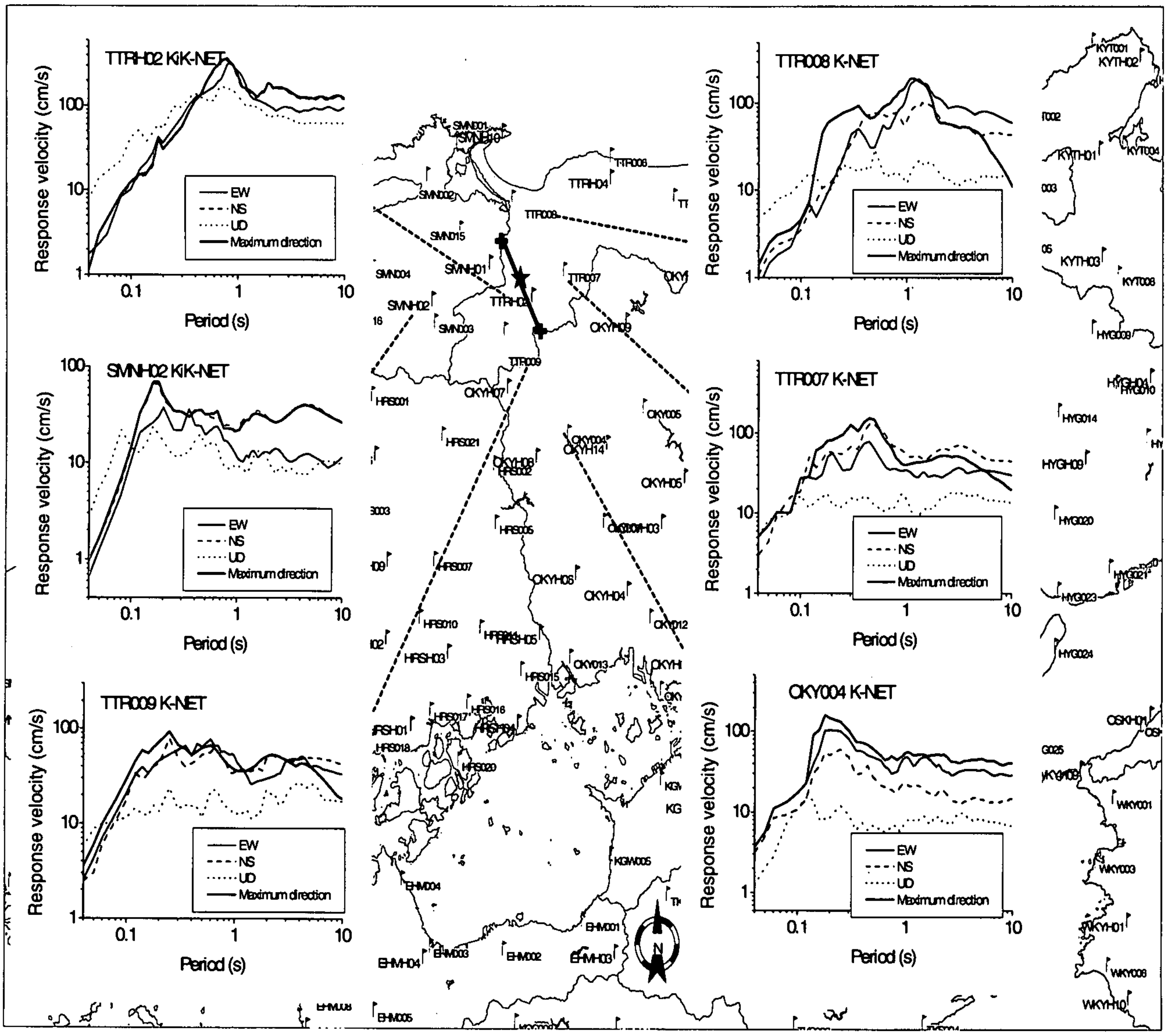

Fig. 3 Distributions of the velocity response spectra of the three components and the maximum velocity direction with 0.05 damping for the near-fault stations in the 2000 Tottori-ken Seibu earthquake.

set. Records with *PGA* less than 1.0 cm/s^2 in vectoral composition of the two horizontal components were omitted. The instrumental JMA seismic intensity scale, which was revised by JMA in October 1996[4] and Spectrum Intensity[5] were calculated for 515 three-component acceleration records.

3. ATTENUATION MODEL

The attenuation model considering the near-source saturation effect for the strong ground motion indices in the October 6, 2000 Tottori-ken Seibu earthquake is given by

$$Y = b_0 + b_1 r + b_2 \log_{10}(r + d) + \varepsilon \qquad (1)$$

in which Y is $\log_{10}PGA$, $\log_{10}PGV$, $\log_{10}SI$, or the I_{JMA}, r is the shortest distance to the fault rupture, b_i's are the regression coefficients to be determined, d is the near-source saturation effect in kilometer, and ε represents the error term. The terms $b_1 r$ and $b_2\log_{10}(r+d)$ represent anelastic attenuation and geometric spreading, respectively. The coefficient b_2 is constrained as −1.89[6] for the intensity and as −1.0 for the *PGA*, *PGV*, and *SI*. The near-source saturation term (d) is applied only for the geometric spreading term. This is because in the near-source, anelastic attenuation is negligible compared with geometric spreading. Since the near-source data used in this study is from a single earthquake, the saturation effect term (d) assumed to be constant. A non-linear least square analysis for the 2000 Tottori-ken Seibu earthquake were performed to estimate the d. This was done by iteratively finding d in which the sum of squares of errors are minimized. The error term is defined as the difference between the predicted ground motion parameters by Eq. (1) for a trial value of d and the corresponding recorded ground motion indices.

4. RESULTS AND DISCUSSIONS

The results of regression analysis for the ground motion parameters in the October 6, 2000 Tottori-ken Seibu earthquake are given in Table 1. Figure 4 shows the predicted *PGA*, *PGV*, *SI*, and I_{JMA} by the attenuation relationships in this earthquake. Since the Tottori-ken Seibu earthquake provides a useful strong ground motion data set especially near the fault region, the near-source saturation effect (d) has been taken into account. However, since the near-field data in this study is limited to only one event it is not possible to adjust whether the records support magnitude-independence. The near-source attenuation characteristics of *PGA* has been studied by many researchers[7),8),9)]. Campbell proposed the attenuation relationship considering the distance and the magnitude saturation terms using data from the United State supplemented by worldwide data[8]. Fukushima and Tanaka[9] used 28 Japanese earthquakes and 15 worldwide events. They constrained the near-field attenuation model assuming the peak ground acceleration near the fault rupture is magnitude-independent. Figure 4a compares the predicted *PGA* obtained by this study with the Fukushima and Tanaka[9] result and the proposed attenuation relationship by Shabestari and Yamazaki[10].

Table 1 Obtained regression coefficients for all indices

	b_0	b_1	b_2	d (km)	ε
PGA	4.130	-0.00315	-1.00	9.6	0.250
PGV	2.703	-0.00037	-1.00	2.1	0.232
SI	2.800	-0.00146	-1.00	6.1	0.278
I_{JMA}	7.842	-0.00402	-1.89	5.6	0.535

The main reason for the differences on the d term obtained in this study and other studies[8,9] is referred to as the earthquake-to-earthquake component of the variability[11]. The mean attenuation curves for *PGA*, *PGV*, and I_{JMA} obtained by Shabestari and Yamazaki[10] fit the recorded and calculated ground motion data for the intermediate to the far-field distances (Figs. 4a, 4b, and 4d). This is not true for the near-source distances (less than 10 km) since we[10] did not consider a near-source saturation effect into our relation. From Fig. 4 it can be seen that the mean predicted attenuation of *PGA*, *SI*, and I_{JMA} in the Tottori-ken Seibu earthquake almost characterized by constant values at a shortest distance of 1 km to the fault extension. However, in case of the *PGV* this is not observed. At the source region *PGA*, *SI*, and I_{JMA} are predicted as 1000 cm/s^2, 100 cm/s, and 6+ in the JMA scale, respectively. Although the mean resulting attenuation curves almost fit the data in the near fault rupture regions, still the scatterings of ground motion parameters due to local site conditions as well as the directivity effect are observed. Thus, the fit will be improved if the recorded data are corrected for site effect[10].

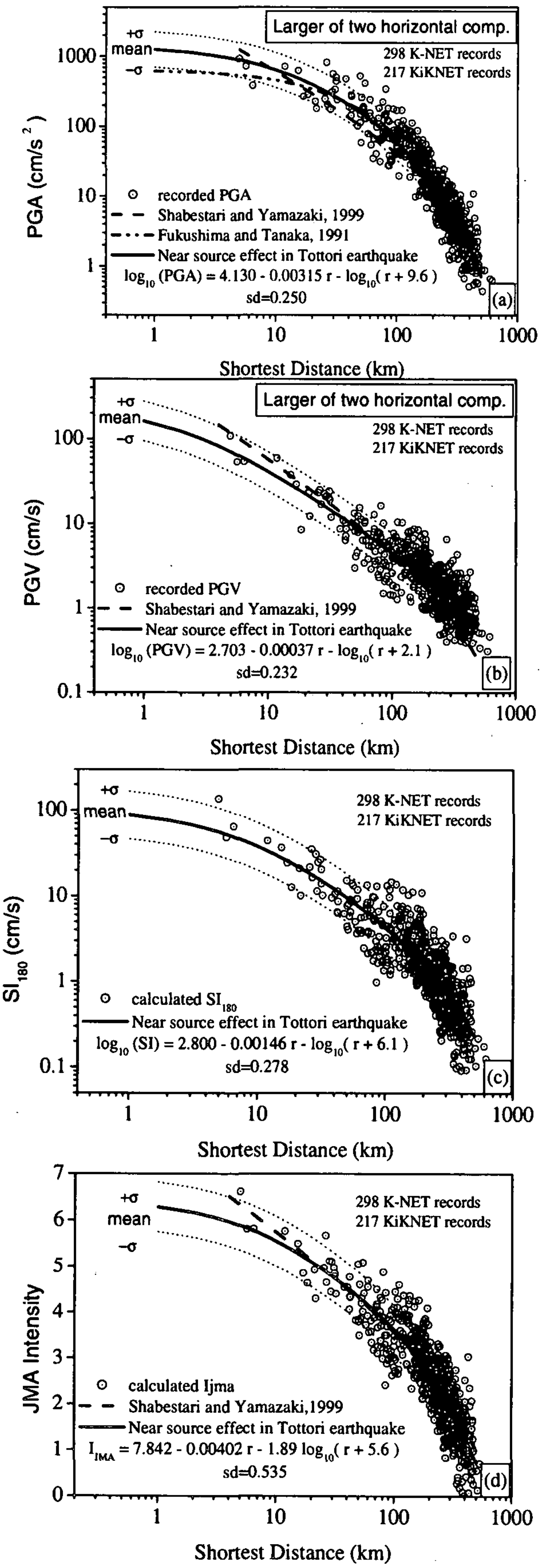

Fig. 4 Predicted (a) *PGA*, (b) *PGV*, (c) *SI*, and (d) I_{JMA} by the attenuation relationship in the October 6, 2000 Tottori-ken Seibu earthquake.

5. CONCLUSIONS

Near-source ground motion characteristics of the October 6, 2000 Tottori-ken Seibu earthquake were demonstrated using free-field acceleration records of K-NET and KiK-NET. The directivity and the local site effects have been observed from the maximum velocity direction and frequency contents of the near-fault records. Since there are significant numbers of the near-fault data registered during this earthquake, attenuation relationships for the ground motion parameters were developed considering the near-source saturation effect. The distance adjustment term (*d*), applied for only the geometric spreading term, was assumed to be a constant. At a shortest distance of 1 km to the fault extension the mean resulting attenuation curves for the *PGA*, *SI*, and I_{JMA} were found to be the constant values in the source region.

REFERENCES

1. Yagi, Y. and Kikuchi, M.: Source rupture process of the Tottori-ken Seibu earthquake of Oct. 6, 2000, http://wwweic.eri.u-tokyo.ac.jp/yuji/tottori/, 2000.
2. Somerville, P., Smith, N.F., Graves, R.W., and Abrahamson, N.A.: Modification of empirical strong ground motion attenuation relations to include the amplitude and duration effects of rupture directivity, *Seismological Research Letters*, 68 (1), 199-222, 1997.
3. Somerville, P.: Characterized of near fault ground motions, *U.S.-Japan Workshop: Effects of Near-Field Earthquake Shaking*, PEER and ATC, 2000.
4. JMA: Note on the JMA seismic intensity, Gyosei, 1996 (in Japanese).
5. Katayama, T., Sato, N., and Saito, K.: SI-sensor for the identification of destructive earthquake ground motion, *Proc. of the 9th World Conference on Earthquake Engineering*, VII, pp. 667-672, 1988.
6. Tong, H. and Yamazaki, F.: Relationship between ground motion indices and new JMA seismic intensity, *Seisan-kenkyu*, Vol.48, No.11, 1996 (in Japanese).
7. Kamiyama, M., O'Rourke, M.J., and Flores-Berrones, R.: A semi-empirical model of strong ground motion peaks with appropriate comparisons to the 1989 Loma Prieta, the 1985 Michoacan and the 1971 San Fernando earthquakes, *Japan Soc. Civil Eng, Jour. Struct. Mech. Earthquake Eng.*, Vol.10, No.4, 29-39, 1994.
8. Campbell, K.W.: Near-source attenuation of peak horizontal acceleration, *BSSA*, Vol.71, No.6, 2039-2070, 1981.
9. Fukushima, Y. and Tanaka, T.: A new attenuation relation for peak horizontal acceleration of strong earthquake ground motion in Japan, *Shimizu Tech. Res. Bull.* Vol.10, 1-11, 1991.
10. Shabestari, T.K. and Yamazaki, F.: Attenuation relation of strong ground motion indices using K-NET records, *The 25th JSCE Earthquake Engineering Symposium*, Vol.1, 137-140, 1999.
11. Boore, D. M. and Joyner, W. B.: The empirical prediction of ground motion, *Bull. of the Seism. Soc. Am.* 72, No. 6, S43-S60, 1982.