ATTENUATION RELATION OF STRONG GROUND MOTION INDICES USING K-NET RECORDS

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Since May 1996, the National Research Institute for Earth Science and Disaster Prevention (NIED) of the Science and Technology Agency constructed a strong motion network that contains 1000 stations throughout Japan. In this study attenuation relationships considering the station coefficient of each recording site for the strong ground motion indices, such as PGA, PGV, and JMA seismic intensity, were developed using accelerograms of Kyoshin Network (K-NET). The final acceleration records consist of 6,017 three-component sets from 94 earthquakes in the period of May 1996 to December 1998. The obtained attenuation model was examined by recorded data in some large magnitude events.

Key Words: *Attenuation relation, K-NET, PGA, PGV, JMA instrumental intensity.*

1. INTRODUCTION

After the 1994 Northridge earthquake in United State, and the 1995 Hyogoken-Nanbu earthquake in Japan, much attention has been paid to develop real time earthquake disaster mitigation systems[1]. In such systems, the peak ground acceleration (PGA), the peak ground velocity (PGV), or the new instrumental JMA intensity are used as the index representing the ground motion severity.

Since May 1996, the National Research Institute for Earth Science and Disaster Prevention (NIED) of the Science and Technology Agency constructed a strong motion network (K-NET) that contains 1000 stations throughout Japan. The average distance between stations is 25 km, and each station has a three-component strong motion accelerometer, with a wide frequency range that can measure up to 2G. The accelerometers were placed on the free field in a uniform simple structure with a concrete base. For each K-NET station detailed geological and geotechnical bore-hole profiles are available[2].

Considering these situations, attenuation relationships including coefficients of the magnitude, the shortest distance from site to the fault plane, the depth, and the station coefficient of each recording site for the strong ground motion indices, such as PGA, PGV, and the new instrumental JMA intensity (*I*), are developed using data recorded by K-NET.

2. EARTHQUAKE DATA

The acceleration records used in this study consist of 6,017 three-component sets from 94 events, with the JMA magnitude equal or greater than 5.0. These data were recorded by K-NET95-type accelerometers at 823 free field sites from May 1, 1996 to December 31, 1998. The data set includes records for some moderate events, such as the 19 October, and the 3 December 1996 Miyazaki earthquakes (M=6.6 in JMA scale, for the both earthquakes), the 26 March (M=6.3), and the 13 May (M=6.2) 1997 Kagoshima earthquakes which caused slight to moderate damage to structures and lifelines. Since we have near source records for the above mentioned events, and the 25 June 1997 Yamaguchi Prefecture earthquake (M=6.1), and the 3 September 1998 Iwate Prefecture earthquake (M=6.1), the shortest distances to the fault planes were calculated[3),4)]. The earthquakes whose focal depths are greater than 200 km were excluded. Also the earthquakes whose focal depths are zero in the JMA report were assumed as 1.0 km.

3. STRONG MOTION INDICES

The peak ground acceleration (PGA), and the peak ground velocity (PGV) of the larger of the two horizontal components were selected from the current data set. Records with peak ground accelerations (PGA) less than 1.0 cm/s^2 in vectorial composition of the two horizontal components were omitted. The new JMA instrumental intensity scale, which was revised by JMA in October 1996[5] were calculated for 6,017 three-component acceleration records. Figure 1 shows the distribution of JMA magnitude with the shortest distance, depth, and PGA with JMA magnitude for the current data set.

4. ATTENUATION MODEL

The attenuation model for the earthquake strong ground motion indices is given by

$$Y = b_0 + b_1 M + b_2 r + b_3 \log_{10} r + b_4 h + c_i \qquad (1)$$

in which Y is the $\log_{10}$(PGA), the $\log_{10}$(PGV), and the I, for the peak ground acceleration, peak ground velocity, and the new JMA instrumental intensity, respectively. M is the JMA magnitude, r is the shortest distance to the fault rupture, h is the depth, c_i are the coefficients representing local site effect of the ith station. Note that the mean value of all the station coefficients is zero. b_i's are the coefficients to be determined. The term $b_2 r$ represents anelastic attenuation and the term $b_3 \log_{10} r$ represents geometric spreading. In this study b_3 for the intensity is constrained as −1.89 following the Tong and Yamazaki relation[6]. The three-stage iterative partial regression method[7),8)] was used to obtain the attenuation coefficients.

5. RESULTS AND DISCUSSIONS

The results of regression analysis are shown in Table 1. Figure 2 indicates the distribution of the obtained station coefficients for the PGA with the station coefficients for PGV, for the 823 K-NET stations. The weighted means (with the number of records for each station used as weights) are 0.090, 0.047, and 0.036 for the intensity, PGA, and PGV indices. To make a comparison between the result of this study and previous study result of attenuation relation for JMA data set[9] that has shown in Table 1, magnitudes equal and greater than 5 were selected. The obtained attenuation coefficients are also listed in the Table 1.

Figure 3 shows the predicted PGA for depth of 10 km and magnitude 6, 7, and 8, using two JMA data sets. By removing events with magnitudes less than 5, the predicted PGA curves of given magnitudes 7 and 8, become small for the new JMA data set (Fig. 3).

Figure 4 compares the predicted JMA intensity, PGA, and PGV with respect to the shortest distance for depth of 10 km and magnitudes of 5.0 (dot line),

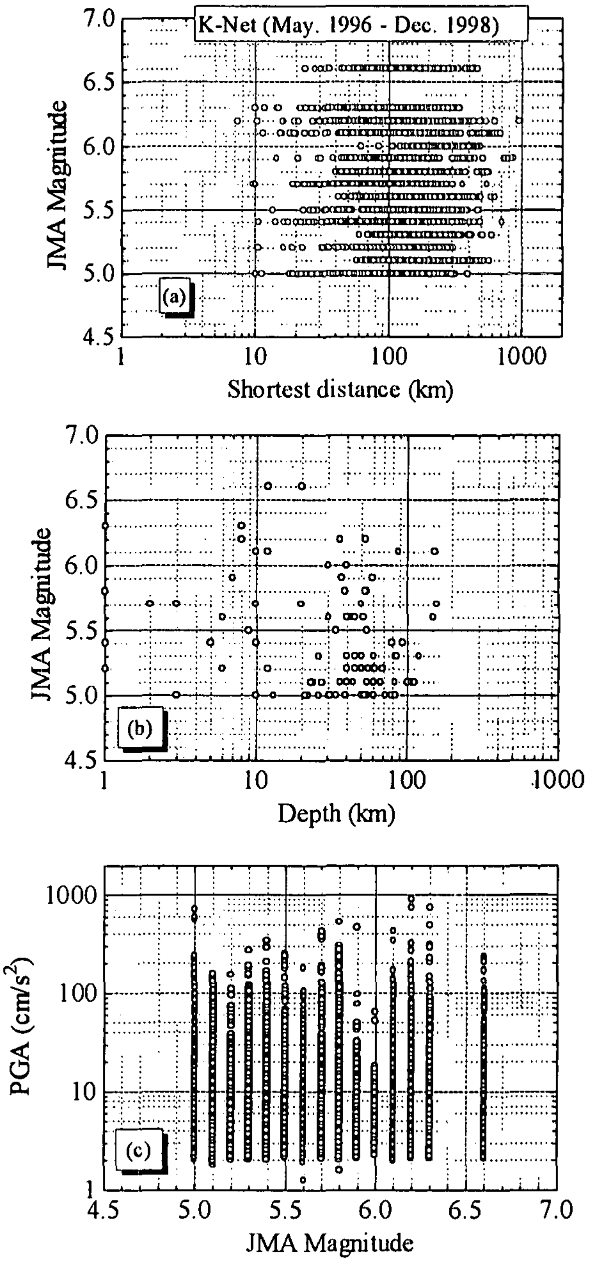

Fig. 1 Distribution of the JMA magnitude with (a) shortest distance, (b) depth, and PGA with (c) JMA magnitude for the current data set.

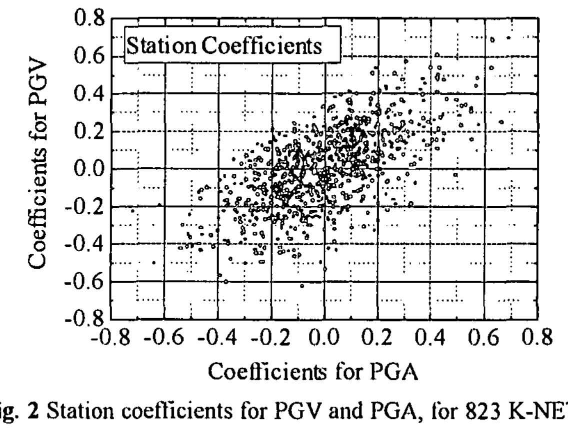

Fig. 2 Station coefficients for PGV and PGA, for 823 K-NET recording stations used in this study.

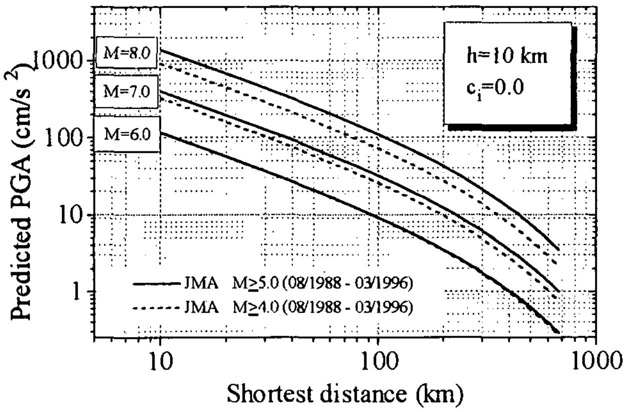

Fig. 3 Predicted PGA using previous JMA data set (solid lines) and new JMA data set (dash lines).

Table 1 Comparison of obtained regression coefficients

	data	b_0	b_1	b_2	b_3	b_4	σ_r	σ_e	σ
JMA seismic intensity	K-NET	1.346	0.855	-0.00313	-1.89	0.00774	0.419	0.334	0.535
	JMA	-0.857	1.184	-0.00251	-1.89	0.00537	0.465	0.282	0.544
	JMA*	-0.087	1.053	-0.00256	-1.89	0.00496	0.459	0.224	0.511
PGA	K-NET	1.185	0.352	-0.00192	-1.00	0.00478	0.224	0.197	0.298
	JMA	-0.191	0.540	-0.00117	-1.00	0.00311	0.250	0.150	0.291
	JMA*	0.345	0.451	-0.00122	-1.00	0.00293	0.248	0.119	0.275
PGV	K-NET	-0.860	0.493	-0.00138	-1.00	0.00344	0.215	0.143	0.258
	JMA	-2.030	0.671	-0.00100	-1.00	0.00197	0.237	0.120	0.265
	JMA*	-1.509	0.581	-0.00104	-1.00	0.00192	0.242	0.104	0.263

* JMA data set (magnitudes equal and greater than 4)[9]
Underlined values are constrained

6.0 (dash line) and 7.0 (solid line), with the results of the JMA data set (symbol lines). From Table 1 for the JMA data set the obtained magnitude coefficient b_1 is larger than for the same coefficient of the K-NET data set. The intercept coefficient b_0 for the JMA data set is smaller than the same coefficient obtained for the K-NET data set. Hence, For the large magnitude events, the predicted curves obtained from JMA data set are higher than those obtained from K-NET data set. The effects of large magnitude distribution in JMA data set might explain this[9].

The predicted intensity, PGA, and PGV for the magnitude 7.0 event are about 5.5, 475 cm/s^2, and 41 cm/s respectively, at the shortest distance of 10 km, using K-NET data set. For the same magnitude and depth values, using the selected JMA data set, the predicted intensity, PGA, and PGV are about 5.6, 408 cm/s^2, and 47 cm/s, respectively. The predicted intensity, PGA and PGV from K-NET data are larger than those from JMA-data as shown in Fig. 4. Due to narrow magnitude distribution in between 5.0 to 6.5 for the current data set of K-Net, the proposed attenuation relations are limited in this range.

Although the current K-NET data set includes some near-source records such as the 1996 Miyazaki earthquakes, and the 1997 Kagoshima earthquakes, the near field effect[10] was not considered in the attenuation model. The proposed attenuation models for the PGA and PGV were examined in Fig. 5 for two large earthquakes in the current data set: the 3 December 1996 Miyazaki earthquake, the 26 March 1997 Kagoshima earthquake. In Fig. 5, the solid line represents the predicted attenuation relation (c_i=0.0), open circles are recorded PGA and PGV values, and plus symbols are adjusted PGA and PGV removing site effects (station coefficients). It is observed that the adjusted PGA and PGV values are much closer to the predicted curves than the recorded ones.

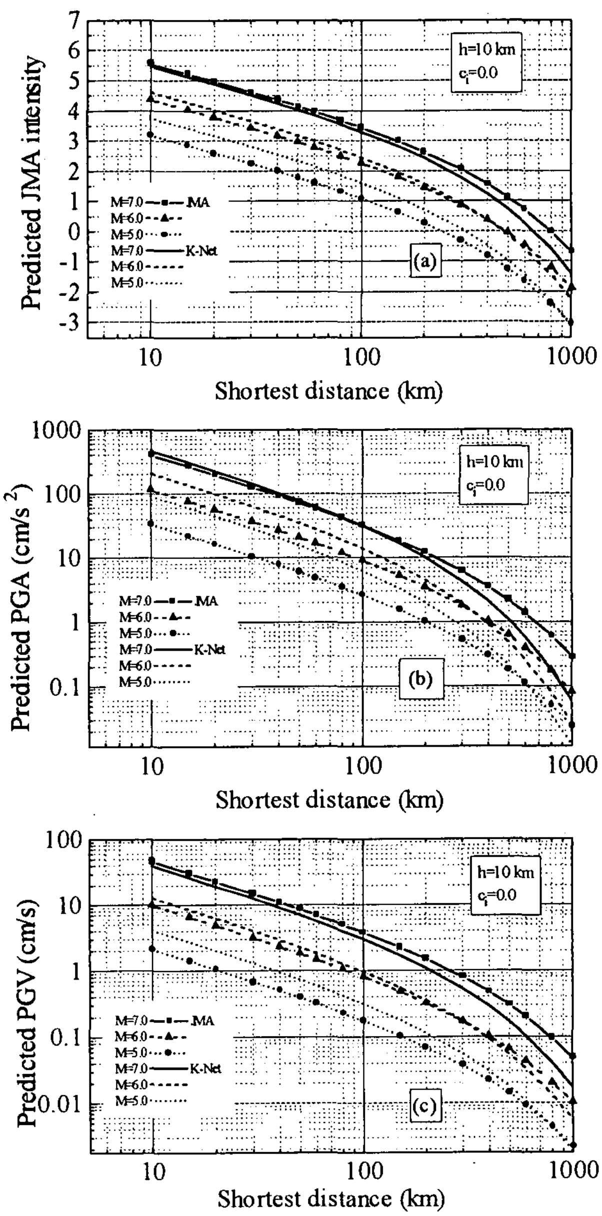

Fig. 4 Predicted (a) JMA intensity, (b) PGA, and (c) PGV for JMA magnitudes of 5.0, 6.0, and 7.0 for depth of 10 km considering mean station coefficient zero for each earthquake ground motion indices.

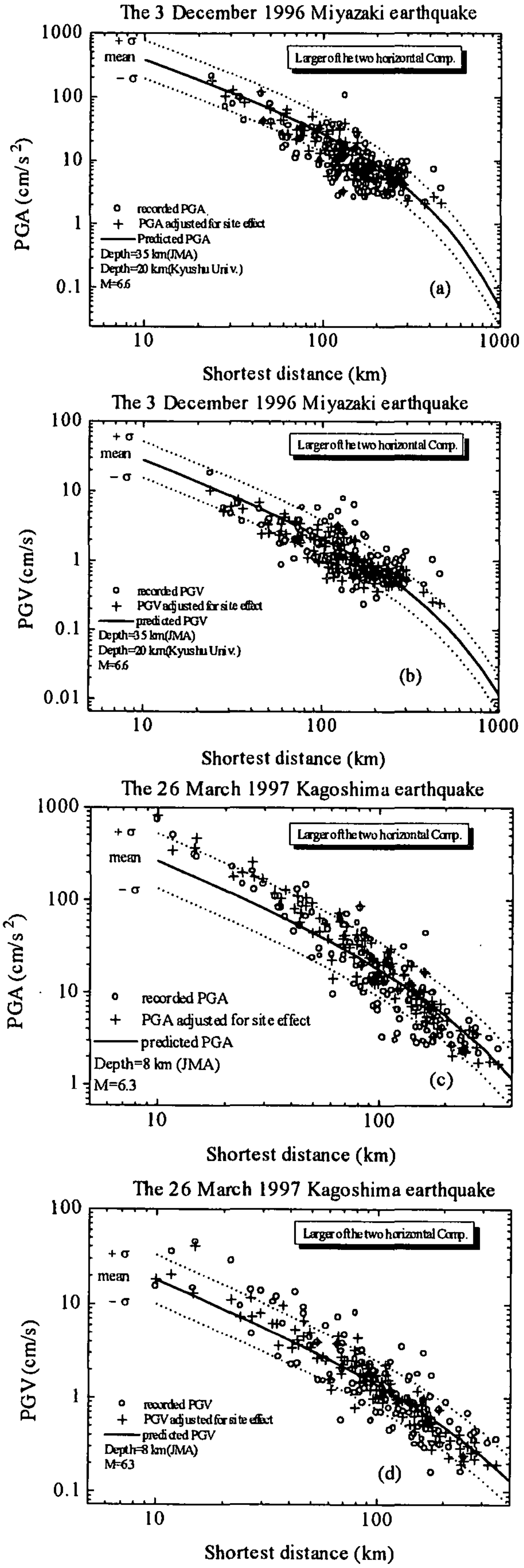

Fig. 5 Predicted PGA and PGV by the attenuation relationship compared with recorded and adjusted PGA and PGV in two large magnitude events.

6. CONCLUSIONS

Attenuation relationships were developed for the new JMA seismic intensity, PGA, and PGV using the 6,017 three-component records from the K-NET95-type accelerometers. The results of attenuation relation of the current compiled K-NET data set were compared with the results of the JMA data set. For the large magnitude earthquakes, the predicted curves of earthquake ground motion indices for the JMA data set are larger than those for the K-NET data set. The effects of large magnitude events in JMA data set might explain this. Hence, the proposed attenuation model using current K-NET data set is valid for the JMA magnitude range in between 5.0 to 6.5. Local site effects are considered by the station coefficients for 823 free field K-NET recording sites. The obtained attenuation model for PGA and PGV were examined by recorded data in two large magnitude events: the 3 December 1996 Miyazaki earthquake, the 26 March 1997 Kagoshima earthquake.

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