Blind prediction experiments at Ashigara Valley, Japan

Kazuyoshi Kudo
Earthquake Research Institute, University of Tokyo, Japan

Yoshihiro Sawada
Central Research Institute of Electric Power Industry, Chiba, Japan

ABSTRACT: The international experiment at Ashigara Valley, Japan, on the effects of surface geology on seismic motion is summarized by focussing geotechnical measurements at the test site, distributed data, analyses of the submitted prediction results, and discussions at the International Symposium, held in Odawara, Japan, in March, 1992.

1. INTRODUCTION

The Japanese National Working Group on Effects of Surface Geology (JNWG-ESG) proposed that Ashigara Valley be an international test site. It was approved at the meeting of IASPEI/IAEE Joint Working Group in Istanbul, in 1989 (Kudo et al., 1992). The principal reasons Ashigara Valley was nominated as a test site are:

* Seismologists have anticipated that a large earthquake (M-7) is likely to occur in the vicinity of Ashigara Valley in the near future (e.g., Ishibashi, 1988).

* Ashigara Valley has soft and thick sedimentary layers, and also rock outcrops are found in the surrounding mountains. Therefore, two- or three-dimensional (2- or 3-D) geological effects on seismic wave propagation are expected.

* A high-quality accelerograph array had been installed in Ashigara Valley by the Earthquake Research Institute, University of Tokyo, when the IASPEI/IAEE JWG-ESG was established in 1987.

Prior to the international experiment at Ashigara Valley, a blind prediction experiment was conducted in 1989 (Japanese Working Group on ESG, 1989). The experiment was initially planned as training exercise in organizing the international blind prediction experiment. As a result of this experiment to include the whole Ashigara Valley in the international experiment was not advisable, because the available geotechnical data would be limited if the whole area were included. The JNWG-ESG, therefore, revised the plan by restricting the area for the international test site to within the Kuno district, located at southwest margin of Ashigara Valley. The

JNWG-ESG made precise geotechnical measurements in this area and deployed a simple extended array by using high-quality accelerographs in cooperation with the observation network of the Earthquake Research Institute. Strong motion observation sites at KR1, KS1, and KS2 are located on an outcrop of rock (Andesite, older Hakone somma), on young volcanic sediments (Kanto loam) and on back marsh (alluvial), respectively. At KS2, two borehole seismometers were installed at a depth of 30 m (KD1) and 97.6 m (KD2).

The prediction test in the Ashigara Valley experiment was conducted as follows: all available geotechnical data, including raw data, the standard geotechnical model, and the weak and strong motion records at KR1, were distributed to predictors worldwide. The predictors were then requested to predict the ground motion at sediment sites.

As a first step, the submitted prediction results were statistically analyzed to understand the gross features of the prediction test. Details of the experiments are discussed in the following sections.

2. SITE CHARACTERIZATION

Ashigara Valley is located 80 km southwest of Tokyo, and faces Sagami Bay. The valley is surrounded by the Hakone Volcanoes to the west, Tanzawa mountains to the north and Oiso hills to the east (Fig.1). The valley has soft clay, sand, and gravel which are deposits from the Sakawa and other small rivers. The international test site, the Kuno district, is located at the southwest margin of Ashigara Valley, and forms a small valley or a fan extending eastward about 3 km with a 1 km width. Geology in the test area, as shown in Fig.2, is very complex
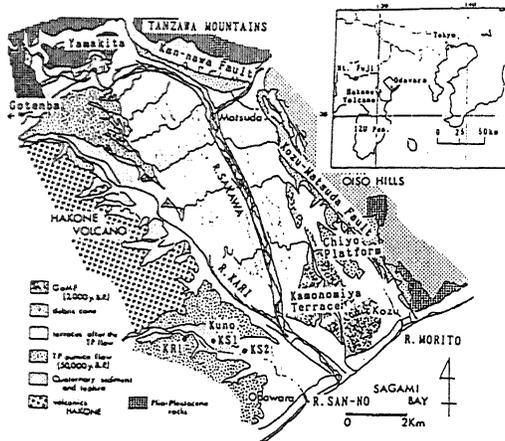
Fig.1 Location and geological map of Ashigara valley.

compared with Turkey Flat test site.

Several kinds of geotechnical measurements were conducted to characterize the test area, i.e., seismic refraction survey across the southern part of Ashigara Valley, down hole seismological/geophysical measurements at the strong motion observation sites, compilation of existing geological borehole data, shallow seismic reflection survey, deep seismic reflection survey and laboratory dynamic soil tests. Based on these geotechnical data, the subcommittee for the geotechnical survey of Ashigara Valley determined the quasi-3D "standard geotechnical model" of the test site, as shown in Fig. 3. The standard geotechnical models (JNWG-ESG, 1991; Sawada, 1992) were made by averaging the geotechnical data, and therefore, the thicknesses or velocities of surface layers do not necessarily coincide with those of the logging data at the strong motion observation

Fig.2 Surface geology at the blind prediction test site in the Kuno district.

age	geology or geography	mark
Holocene	flood plain, back marsh	Ⓐ
	natural levee, debris cone	N b
	Kamonomiya Terrace (Alluvial Terrace)	A t - 3
late Pleistocene	Younger loam (equivalent to Musashino, Tachikava loam formation)	T p m
	Younger Hakone Pumice Flow (coverd by Younger loam in many cases)	H p
middle Pleistocene	Older Hakone Somma Pyroclastic materials	O s - 2

sites. Predictors could use their own "preferred model" based on the raw geotechnical data provided by JNWG-ESG (1991).

Extensive measurements of microtremors at the test area had been conducted, and the results of the analyses were included in the data book (JNWG-ESG, 1991) distributed to the predictors (Seo, 1992).

3. STRONG AND WEAK MOTION PREDICTION TEST

a. Ground motion data

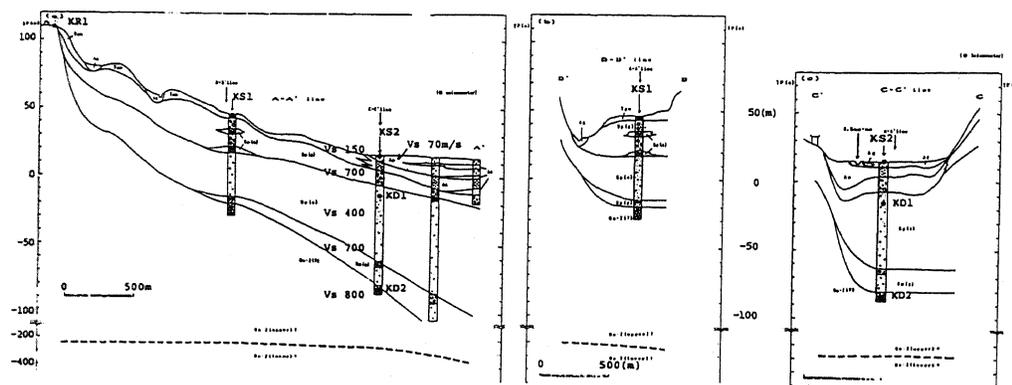Strong motion records from the mainshock (M=5.1) and weak motion data from the foreshock

Fig.3 Geotechnical standard model for profile A–A'(a), east–west cross–section and for the profiles B–B'(b) and C–C'(c), north–south cross–section.

(M=2.9) were used in the blind prediction test (JNWG-ESG, 1991; Kudo, 1992). The earthquakes occurred approximately 8 km southwest from the test area at a depth of 15 km on August 5, in 1990. For the strong motion prediction test, predictors were provided with strong motion records observed at KR1 only, and were requested to predict the ground motions at KS1, KS2, and KD2. And for the weak motion test, foreshock records at both KR1 and KS1 were also provided, and predictions at KS2 and KD2 were requested. Both given and prediction–required ground motions are shown in Figs. 4 and 5.

b. Methods used for the prediction.

Forty–four individuals and groups submitted the blind predictions. The methods used for the prediction are divided into two groups: wave propagation methods (42 participants) and the others (one statistical prediction method and one spectral ratio method using microtremor data). The wave propagation methods are classified into four subcategories: 1-D approaches (28 participants), 2-D modeling (13), hybrid methods of 1-D and 2-D modelings (4) and a 3-D approach (1). It is quite remarkable that predictors of more than half used 1-D transfer matrix method involving nonlinear effects by an equivalent–linear approach (SHAKE). Most predictors used KR1 records as an input seismic motion to sediment sites, and ten individuals or groups deconvolved the KR1 motion for the incident waves to the sediment sites. Four predictors took the effects of seismic source effects into consideration. Details are found in Sasatani (1992).

c. Statistical results of submitted predictions.

Predictors were requested to submit Fourier amplitude spectral ratios, pseudo–velocity response spectra of 5% damping, acceleration and velocity time–histories, and peak values of acceleration and velocity. Figure 6 summarizes the number, quartile, mean, and standard deviation statistics for peak accelerations and velocities. Figure 7 shows comparison between observations and the quartiles of predicted response spectra for strong motion using the standard geotechnical model. Midorikawa (1992) summarized the results by statistical analyses as follows:

* Deviation of submitted predictions is considerably large: Q3 minus Q1 variation (middle 50%) is 30 to 50% for peak value predictions, and on the order of 100% for spectral predictions. The variations are substantially larger than those for the Turkey Flat test.

* Predictions at KD2 (downhole) give a fairly good agreement with the observations, but those at KS1 and KS2 have considerable errors. Predictions by the preferred geotechnical model gave better agreement with the observations than those by the standard model.
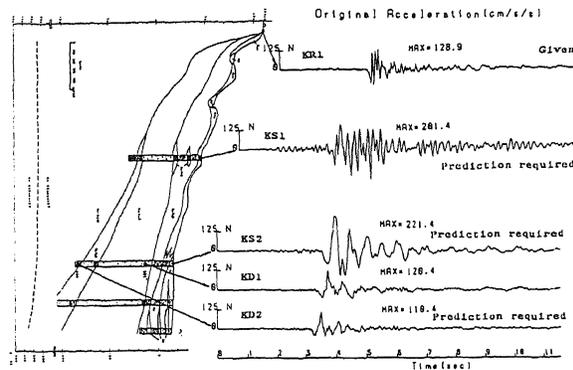
* No significant difference is found in the

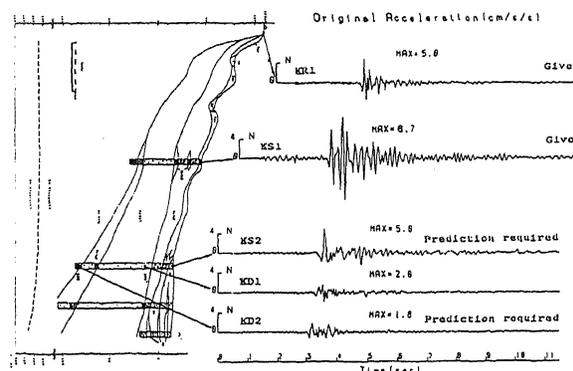Fig.4 Given and prediction–required strong motion records.

Fig.5 Given and prediction–required weak motion records.

comparison of predicted spectral ratios of KS2/KR1 by 1-D modeling to those by a 2-D/3-D method.

* Results that included nonlinear effects in the strong motion prediction are consistent with observations.

4. DISCUSSION AND CONCLUDING REMARKS

The International Symposium on the Effects of Surface Geology on seismic motion was held in Odawara, in late March of 1992. The Symposium included the summary of the Turkey Flat experiments and general technical issues, however, it focused on discussion of the prediction results and related problems in the Ashigara Valley experiments. As Shibuya (1992) summarized, the discussions at the Symposium pointed out four prominent problem.

1) The first question arises from the wide scattering of the prediction results. This question is particularly addressed to the scattering of the results by 1-D methods. Nevertheless, the standard geotechnical model, that is the common model, were used in their predictions. To totally understand the reasons behind such scattering, a detail review of each individual prediction would be required.
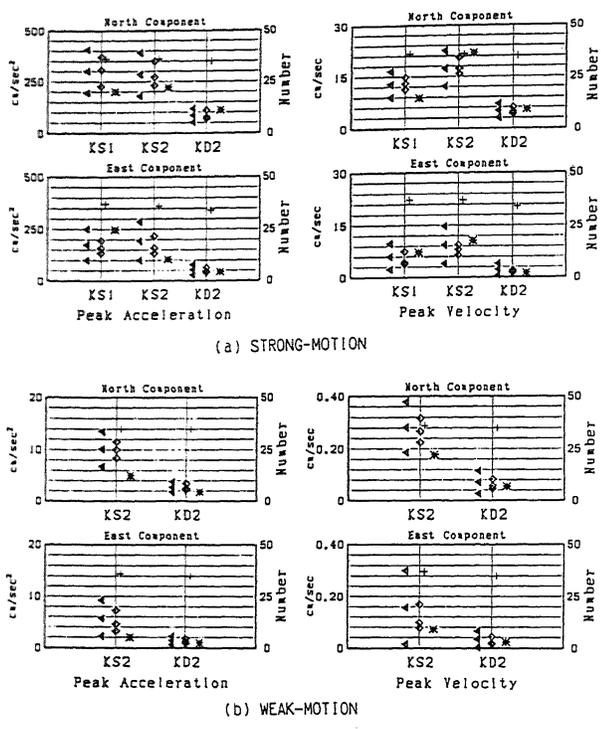
Fig.6 Peak value statistics for the standard geotechnical model predictions (after Midorikawa, 1992).

Fig.7 Response spectra quartiles for the strong motion predicted using the standard geotechnical model (after Midorikawa, 1992).

2) The second question focuses to the input motion to the sediment sites. The records at only one rock site (KR1) and very limited data on geology and topography at the site were distributed to the predictors. This caused difficulties among the predictors in deconvolution for the KR1 data. In a preliminary analysis of the available data, including the others which were not used in the blind prediction test, Kudo and Wang (1992) showed the average spectral ratio of KS2/KR1 is equivalent to that of KS2/KD2 (Fig.8). The wide scattering found in the ratio of KS2/KR1 compared with that of KS2/KD2, may suggest effects of propagation path and/or source radiation, rather than those of topography or geology at KR1. Figure 9 shows the average and the standard deviation of spectral ratio of KS2/KR1 for mostly weak motion data. The predicted results within the standard deviation (roughly 20% respect to the average) can be considered "exact solution".

3) The test site shows a geological and topographical 3-D structure, however, no significant difference was found in the prediction results between 1-D and 2-D/3-D methods (Midorikawa, 1992). Possible reasons, as indicated by Shibuya (1992), are a nearly vertical incidence of waves to the
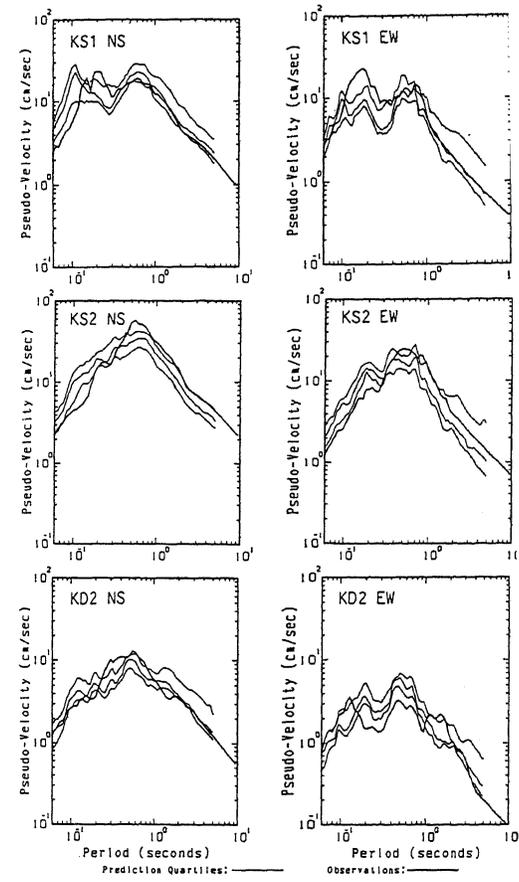
test site and very high impedance ratios between the surface and bedrock layer. Insufficiency of the evaluation by comparison of peak acceleration and/or response spectra is also pointed out. Kudo and Wang (1992), however, suggested 2-D or 3-D effects by showing the difference in spectral ratios of KS2/KD2 for two horizontal components (Fig. 9). The evaluation of the results by 2-D and 3-D modeling is still unsolved, and a precise investigation will be required.

4) Nonlinearity in the strong motion record was also a matter of discussion in the Ashigara Valley experiment. Midorikawa (1992) suggested the nonlinearity in the strong motion data at sediment sites and the coincidence with the observations for the case of the predictions that included the nonlinear effect. Differences of peak frequencies were found in spectral ratios of KS2/KR1 for weak and strong motions. The nonlinearity is very plausible from the shift of peak frequency tending to a low value and the decrease of amplitudes, as found in the spectral ratios
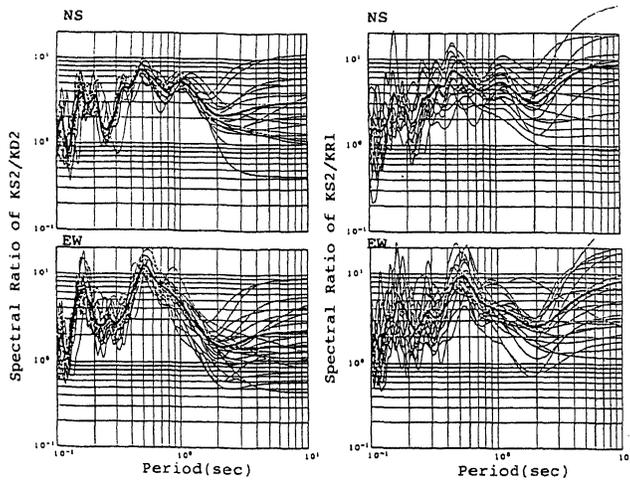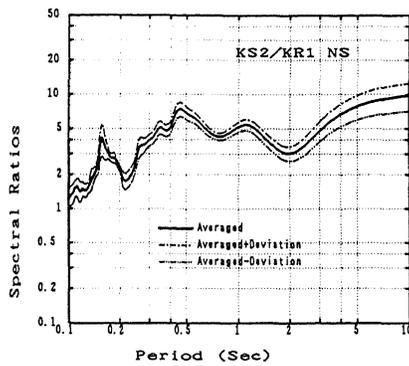
6970

Fig.8 Spectral Ratios of KS2/KD2 and KS2/KR1.

Fig.9 Average and standard deviation
   of the spectral ratio of KS2/ KR1.

Fig.10 Comparison of spectral ratios KS2/KD1 and
   KS2/KD2 for the series of events used in the
   blind prediction test.

of KS2/KD2 and KS2/KD1 for weak and strong motions (Fig.10). Satoh et al. (1992) concluded the existence of nonlinearity   at the major part of the strong motion at a short duration.

Mr. Z. Wang was very helpful for preparing this manuscript.

References

Ishibashi, K., 1988, Kanagawaken–Seibu Jisin to Jisin Yoti I, II (West Kanagawa Earthquake and Earthquake Prediction, Kagaku, 58, 537–547, 771–780. in Japanese

Japanese Working Group on ESG, 1989, Proceedings of National Symposium on the Effects of Surface Geology on Seismic Motion.

Japanese National Working Group on ESG, 1991, Ashigara Valley Blind Prediction Test.

Kudo, K., 1992, Earthquake Motions: Given and Blinded Data, Proceedings of the International Symposium on the Effects of Surface Geology on Seismic Motion, Odawara, Japan, Vol 2, 53–60.

Kudo, K., K. Irikura and H. Kawase, 1992, Effects of Surface Geology on Seismic Motion: Introduction to the Special
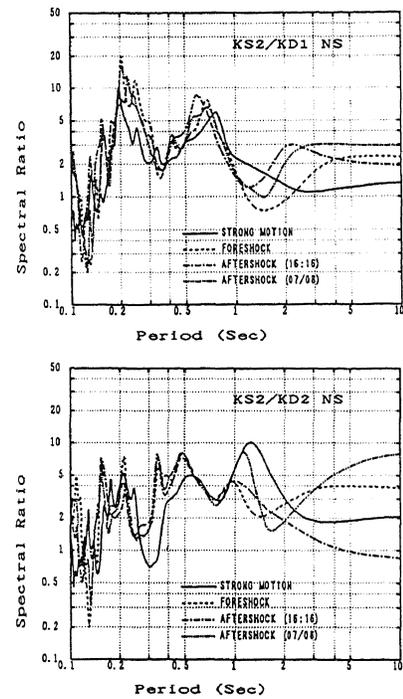
Issue, J. Phys. Earth, 40, 1–4.

Kudo, K. and Z. Wang, 1992, A Preliminary Analysis of Strong Motion Records in Ashigara Valley Test Site, Proceedings of the International Symposium on the Effects of Surface Geology on Seismic Motion, Odawara, Japan, Vol 2, 15–18.

Midorikawa, S., 1992, A Statistical Analysis of Submitted Predictions for the Ashigara Valley Blind Prediction Test, Proceedings of the International Symposium on the Effects of Surface Geology on Seismic Motion, Odawara, Japan, Vol 2, 65–77.

Sasatani, T., 1992, Methodology of Response Analyses Used for the Ashigara Valley Blind Predictions, Proceedings of the International Symposium on the Effects of Surface Geology on Seismic Motion, Odawara, Japan, Vol 2, 61–64.

Satoh, T., T. Sato and H. Kawase, 1992, Local Site Effects on Weak and Strong ground Motions at the, Ashigara Valley, Japan,International Symposium on Earthquake Disaster Prevention, CENAPRED,18–21, 1992.

Sawada, Y., 1992, Geotechnical Data, Proceedings of the International Symposium on the Effects of, Surface Geology on Seismic Motion, Odawara, Japan, Vol 2, 29–42.

Seo, K., 1992, A Joint Work for Measurements of Microtremors in the Ashigara Valley, Proceedings of the International Symposium on the Effects of Surface Geology on Seismic Motion, Odawara, Japan, Vol 2, 43–52.

Shibuya, J., 1992, Summary and Concluding Remarks of the Panel Discussions on the Ashigara Valley Blind Prediction, Proceedings of the International Symposium on the Effects of Surface Geology on Seismic Motion, Odawara, Japan, Vol 3, 43–45.