Development of Regional Earthquake Early Warning System with Structural Health Monitoring Function and Real-Time Ground Motion Prediction Using Front-Site Waveform Data

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This paper presents firstly, the development of an integrated regional earthquake early warning (EEW) system having on-line structural health monitoring (SHM) function, in Miyagi prefecture, Japan. The system makes it possible to provide more accurate, reliable and immediate earthquake information for society by combining the national (JMA/NIED) EEW system, based on advanced real-time communication technology. Secondary, this paper presents an advanced methodology based on Artificial Neural Network (ANN) for forward forecasting of ground motion parameters, not only PGA, PGV, but also Spectral information before S-wave arrival using initial part of P-waveform at a front site.

Fig.1 shows the developed EEW/SHM system. The authors have so far installed the earthquake observation system at a building of the Tohoku University in Sendai, Miyagi Prefecture, Japan. The building in Sendai is a 9-story SRC building completed in 1969, experienced 1978 Miyagi-ken Oki earthquake and retrofit work was performed in 2000. The strong motion observation has been performed for about 40 years. On the other hand, the same system has been installed at a building in Oshika, the earthquake front site for the approaching Miyagi-ken Oki earthquake. The building is a 3 story RC building used as local government branch office. It is noted that Oshika is on the way of earthquake propagation path and located 60km distance from Sendai. The data from the front-site and the on-site are processed by the analysis system which was installed at the analysis center of Disaster Control Research Center, Tohoku University. The real-time earthquake information from JMA is also received at the analysis center. The regional EEWS combined with the National EEWS comprises the data transmission circumstance connecting the earthquake observation system with the structural health monitoring function and enables to predict the high accurate ground motion characteristics using the front-site waveform data.

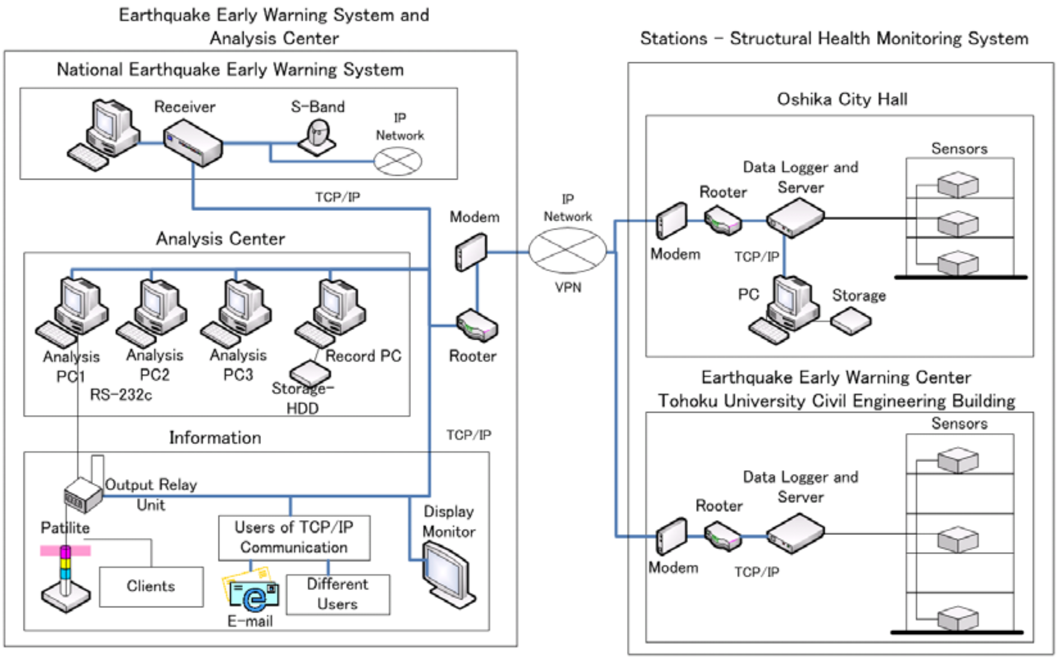

Fig. 1 The developed EEW/SHM system

The authors have investigated the real-time ground motion prediction method using the front-site waveform information. Fig.2 shows the conception of the method using ANN. The accuracy of the method has been verified using the K-NET data for 39 earthquakes which occurred in the Miyagi Oki area (refer to Fig.3).

Fig.4 shows the necessary information to construct the ANN structure for the peak ground motion, PGA and PGV. The earthquake observation data for 35 earthquakes among the 39 earthquakes, as well as the positional-information and site repartition information, were used as training data to construct the ANN structure. The approximated initial 5.5 seconds P waveform information and PGA at the Oshika site (MYG011) of K-NET were used as the front-site waveform data. The data set for the remaining 4 earthquakes was used as the test data in the blind prediction of PGA and PGV at the 4 sites, namely, Sendai (MYG013), Taiwa (MYG009), Shiogama (MYG012), and Ishinomaki (MYG010). Fig. 5 shows the comparison of the results in the peak ground motion prediction for (a) PGA and (b) PGV. The results by the proposed method are compared to those calculated by the conventional attenuation formula (Si &Midorikawa,1999). It is found that the remarkable improvement of the accuracy in the peak ground motion prediction is done by the proposed method.

Similarly, the Fourier Spectra at the 4 sites were predicted using the ANN structure as shown in Fig.6. The results are shown in Fig.7. The predicted values are compared with the observed values. In this figure, the results for the training data and for the test data are shown by the figure. It is found that the spectral prediction has high accuracy.

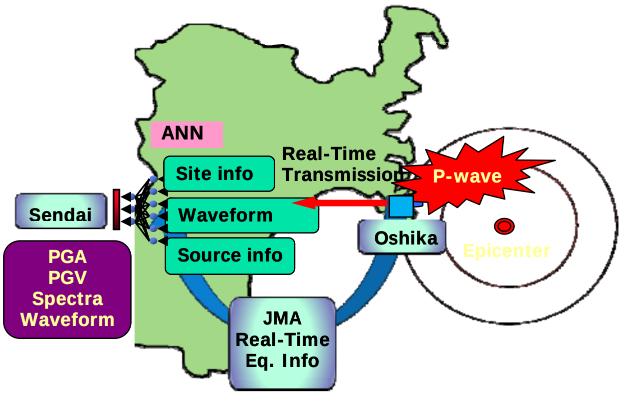

Fig.2 Conception of the accurate real-time ground motion prediction based on the regional EEWS combined with the real-time earthquake information form JMA

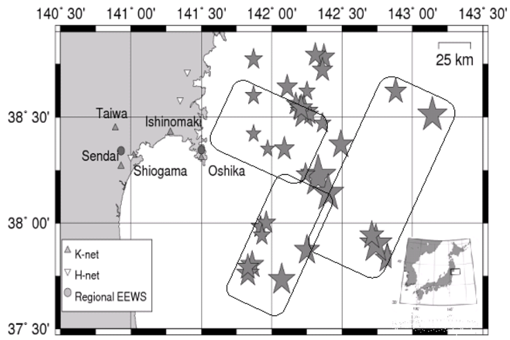

Fig.3 Epicenter distribution of the 39 earthquakes occurred in Miyagi Oki area used in the study

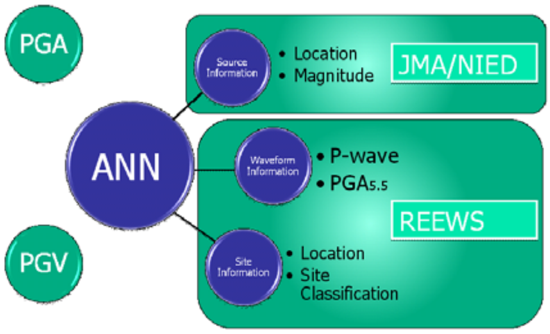

Fig.4 Information for ANN construction in the peak ground motion prediction

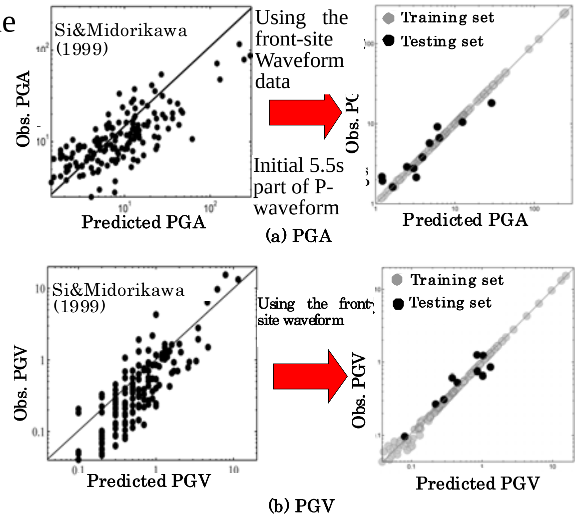

Fig.5 Comparison of the results in the peak ground motion prediction

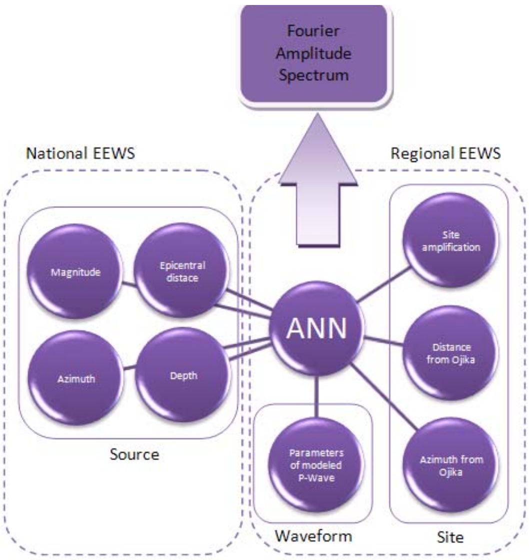

Fig.6 Information for ANN construction in the spectral ground motion prediction

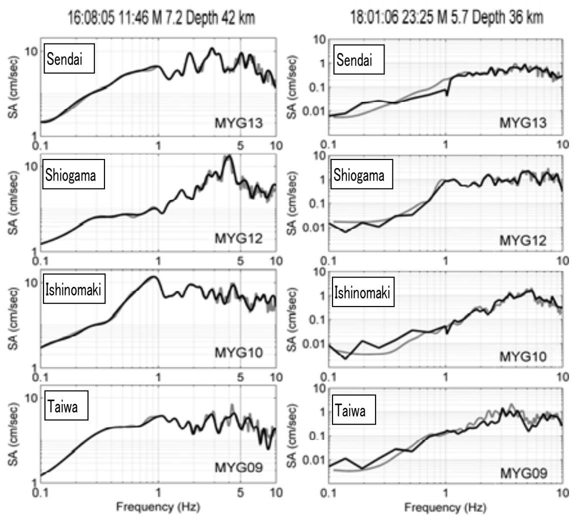

Fig.7 Comparison of the predicted and the observed Fourier spectra (left: Training data, right: Testing data)