Investigation of Source, Path and Deep Local Site Effects for Evaluation of Broadband Strong Ground Motions

Background

It is necessary to precisely predict the seismic ground motions at the specified evaluation point for advanced seismic design of energy facilities such as nuclear power plants. Since the characteristic period is different according to the target structure, the evaluation of the strong motion in the period range from about 0.1 to 10 seconds is required. The quantitative modeling techniques of seismic source, wave propagating path from source to site, and deep subsurface structure beneath the evaluation site are important to overcome such issues.

Objectives

The purpose of this study is to reveal the detailed source, path, and local site effect of the past earthquakes for the development of broadband strong-motion prediction method, along with the investigation of deep velocity profile particularly for the estimation of the long-period motions.

Principal Results

1. Spatio-temporal rupture process during the large destructive earthquake using the inversion technique

Since the spatial distributions of slip and stress drop on the seismic fault affect the strong ground motions observed particularly in the near-source area, it is important to examine such detailed source rupture process for the evaluation of strong ground motion from inland crustal earthquakes. In this study the source inversion technique is applied to the strong-motion records from the 2007 Niigata-ken Chuetsu-Oki earthquake of M 6.8, and the distribution of asperities, which are areas of relatively large slips, is specified (Fig.1 and 2).

2. Separation analysis of source and path effect from the strong-motion records for the intra-plate earthquakes

It has been difficult to determine the source parameters of intra-plate earthquakes particularly for the Philippine Sea Plate due to a lack of data for historical large events. Here the spectral inversion analysis is carried out on the data containing the 2004 off the Kii peninsula earthquakes, which are recognized as intra-plate events, to derive the source and the path effect separately. As a result we find the relatively low attenuation effect (high Qs values) along the wave-propagation path in the Kii peninsula region (Fig.3). The high-frequency excitations during the 2004 off the Kii peninsula earthquake sequence correspond to the empirical relationship derived from the database of crustal and inter-plate earthquakes (Fig.4).

3. Deep subsurface structure modeling for the evaluation of long-period ground motion

Exploration of deep S-wave structure is conducted to the Niigata plain where thick sedimentary layers raise large long-period motions. Microtremor array observation reveals the basin structure along the north-south coast line with the thickest sediments of 5 km near Niigata city (Fig.5). The postdiction of the long-period spectral level from the 2007 Niigata-ken Chuetsu-Oki earthquake shows the good agreement with the observed data by using the normal mode solution based on the estimated one dimensional deep S-wave structure model (Fig.6).

Future Developments

The methodology of broadband strong-motion prediction reflected the knowledge obtained in this study will be constructed and probabilistic approach such as seismic hazard analysis will be integrated to build the comprehensive strong-motion evaluation system.

Main Researcher: Yoshiaki SHIBA, Ph. D. and Hiroaki Sato,
Research Engineer, Earthquake Engineering Sector, Civil Engineering Research Laboratory

Reference

H.Sato, et al., 2007, “Exploration of deep S-wave velocity structure using microtremor array technique to estimate long-period ground motion”, CRIEPI Report N07004 (in Japanese)
Y. Shiba, et al., 2007, “Source and path characteristics of earthquakes occurring off the Kii peninsula”, CRIEPI Report N07007 (in Japanese)

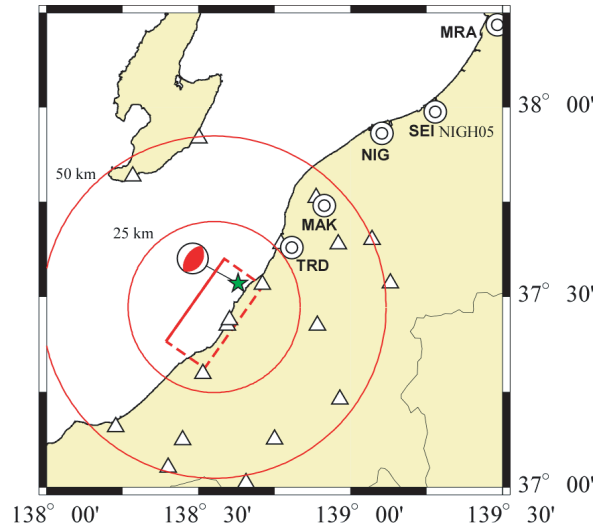

Fig.1 Fault plane of the 2007 Niigata-ken Chuetsu-Oki earthquake and strong-motion stations used in the source inversion analysis (triangles) together with the microtremor site (double circles)

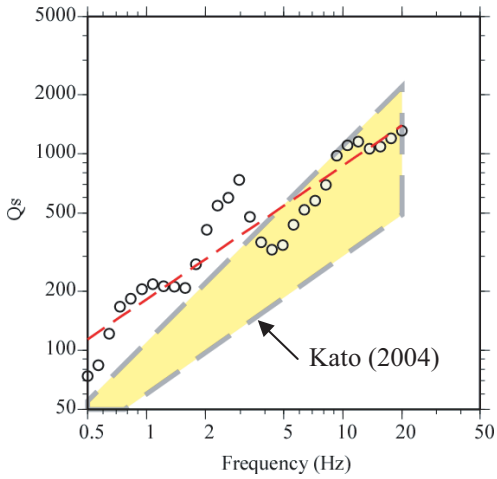

Fig.3 Comparison of the Qs values in the Kii peninsula (circles and red broken line) with those estimated in other regions of Japan (yellow colored area).

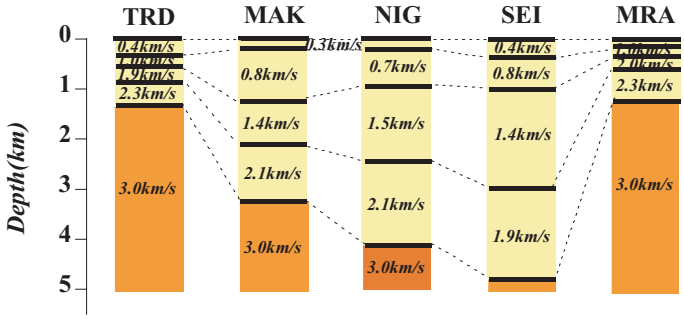

Fig.5 Deep S-wave velocity structures beneath the Niigata Plain. The seismic basement with S-wave velocity higher than 3 km/s forms basin structure.

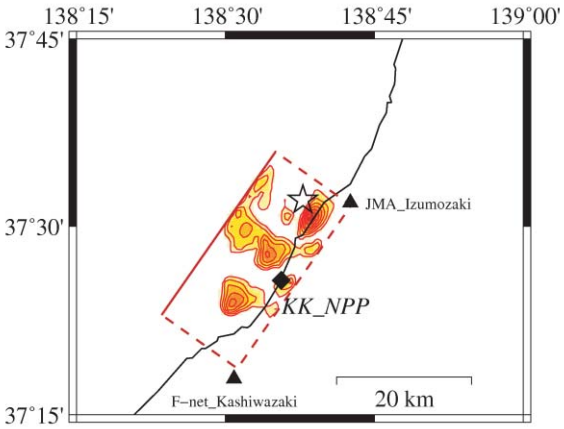

Fig.2 Estimated slip distribution model of the 2007 Niigata-ken Chuetsu-Oki earthquake

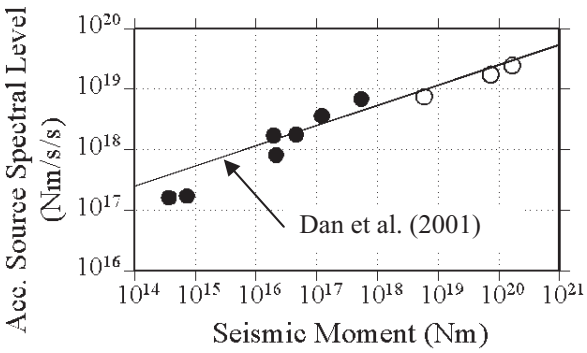

Fig.4 Relationship between the seismic moment and the acceleration source spectral level. Solid line shows the empirical scaling relation. Open and solid circles indicate intra-plate and inter-plate earthquakes respectively.

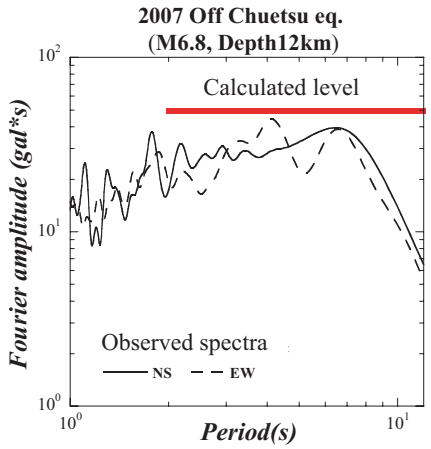

Fig.6 Comparison of observed acceleration spectra from the 2007 Niigata-ken Chuetsu-Oki earthquake with the spectral level (red line) estimated from the normal mode solution based on the deep S-wave velocity profile at SEI shown in Fig. 5.