Evaluation of Local Site Effects in Metropolitan Areas

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Summary

In order to evaluate local site effects on ground motion in metropolitan areas, the 250m mesh digital geomorphological classification maps are preparing for four metropolitan areas in Japan. The correlations of the geomorphological data with the average shear-wave velocity of ground to a depth of 30m and the site amplification factors are examined using the borehole logs and strong motion records, respectively. The shake maps are computed using the geomorphological map and the empirical attenuation relationship, and are compared with the observed isoseiual maps. The results show good agreements, suggesting the capability of the site factors estimated from the geomorphological map.

1. Introduction

It has been well recognized that consideration of local site effects is indispensable for strong motion prediction. In order to take account of the local site effects, the soil response analysis, which requires the soil profile model at the site, has been used. When the analysis is applied to a large metropolitan area, there may be difficulties in construction of the soil profile models in the area due to limitation of the available soil data.

The use of surface geology or geomorphology turns into a practical alternative for evaluation of the local site effects. In the U.S., for example, Park and Elrick (1998) examined the correlation of the geological units with the average shear-wave velocities of ground to a depth of 30 m (AVS) which is a convenient index for site amplification (Borcherdt et al., 1978), and showed the distribution of the average shear-wave velocities in the southern California from the geological map. Similarly, in Japan, Matsuoka and Midorikawa (1995) examined the correlation between the geomorphological units and the average shear-wave velocity is examined using the nationwide geomorphologic database, the Digital National Land Information (DNLI) (National Land Agency, 1992).

The nationwide database, however, has several problems such that 1) the different definition of the geomorphologic unit is used for each prefecture, 2) a certain amount of the errors is included, and 3) the mesh size used is 1km by 1km and not very fine. In this study, the engineering geomorphological classification maps with the 250m fine mesh size are developed for metropolitan areas. Then the correlation of the geomorphologic units with the average shear-wave velocity and the site amplification factors is examined. Finally the shake maps computed from the geomorphological map are shown.

2. Construction of Engineering Geomorphological Classification Maps in Urban Areas


The target areas for the mapping are 1) Tokyo metropolitan, 2) Osaka metropolitan, 3) Nagoya metropolitan, and 4) Sendai metropolitan, as shown in Fig. 1. The maps for Tokyo and Osaka metropolitan have been completed. Figure 2 show the 250m mesh map for Tokyo metropolitan.
3. Correlation of Geomorphologic Unit with Average Shear-wave Velocity

In order to examine the correlation of the geomorphological data with the average shear-wave velocities to a depth of 30 m (AVS), the database, which consists of the AVS data obtained from borehole logs at 1,785 sites and the corresponding geomorphological data is constructed. Using the database, the relations between the AVS and the geomorphological unit are compared for three regions divided by major tectonic lines.

A statistical hypothesis test for the relations reveals that the AVS in the central part of Japan tends to be lower than those in the northeast and southwest parts of Japan on several geomorphological units such as alluvial fan, delta and back marsh (See Fig. 3). Such regional difference of the AVS for each geomorphological unit is incorporated in a method for estimating the site amplification factor from the geomorphological data through the AVS (Matsuoka and Midorikawa, 1995). The nationwide amplification map from the DNLI is shown in Fig. 4.
4. Correlation of Geomorphologic Unit with Site Amplification Factor

To confirm the relationship between the geomorphological unit and site amplification, the spectral inversion analysis (Iwata and Irikura, 1986) is conducted to evaluate the site amplification factor from the strong motion records observed in Tokyo metropolitan. In total, 4533 records at 557 sites from 17 earthquakes are used in the analysis as shown in Fig. 5.

Fig. 5. Locations of Observation Sites.

The obtained site amplification factor for each geomorphological unit is shown in Fig. 6. At low frequencies, the amplification is higher at the reclaimed land and lower at the mountain. The results are consistent with those from the previous method (Matsuoka and Midorikawa, 1995).

![Fig. 6. Site Factors for Each Geomorphologic Unit.](image)

5. Examples of Shake Maps Considering Geomorphological Classification

In 2003, the three large earthquakes, i.e., the Miyagi-ken-oki earthquake (Mw7.0) on May 26, the Miyagi-ken-hokubu earthquake (Mw6.0) on July 26, and the Tokachi-oki earthquake (Mw8.0) on September 26, were occurred in Japan. In order to examine the applicability of the site factor estimated from the geomorphologic data, the distributions of the seismic intensity calculated using the site factor are compared with the observed isoseismal map for the earthquakes.

The peak velocity on engineering bedrock with a shear-wave velocity of about 600 m/s is computed for the earthquakes using the empirical attenuation relationship (Midorikawa and Ohtake, 2002). By multiplying the peak velocity on engineering bedrock and the site factor estimated, the peak ground velocity is obtained. Then, the peak ground velocity is converted to the JMA seismic intensity by employing the empirical relationship between the seismic intensity and peak ground velocity.

![Figs. 7. Comparison of Observed (left) and Computed (right) Intensity Maps.](image)
Figures 7 (a), (b) and (c) show the observed and computed seismic intensity maps for the Miyagi-ken-oki, the Miyagi-ken-hokubu, and the Tokachi-oki earthquakes, respectively. In the observed map, the strong-motion records obtained from K-NET, KiK-net, JMA, and the local governments are utilized. The results show good agreements in general, suggesting the capability of the site factors estimated from the geomorphological data.

Figure 8 shows the distribution of the peak ground velocities for the 1923 Kanto earthquake computed by using the 250m mesh geomorphological map. The computed distribution is consistent with the observed damage distribution shown in Fig. 9, but shows some discrepancies in the Miura peninsula. This may suggest smaller energy release beneath the Miura peninsula.

Acknowledgments

The strong motion data from the K-net, KiK-net, JMA-net and SK-net are used in this study.

References


Fig. 8. Distribution of Computed Peak Ground Velocities for the 1923 Kanto Earthquake.

Fig. 9. Distribution of Ratios of Collapsed Wooden Houses for the 1923 Kanto Earthquake.