and used with little specific expertise: a usually justifiable assumption, though as always it is important to know enough to recognize poor performance when it does occur.

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Cross-references

Earthquake, Location Techniques
Earthquakes, Strong-Ground Motion
Free Oscillations of the Earth
Gravimeters
Seismic Noise
Seismogram Interpretation
Seismology, Rotational

SEISMIC MICROZONATION

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Definition

Seismic microzonation. The mapping of an area on the basis of various factors that can affect the intensity of ground shaking, such as seismic hazard, geological conditions, and topographical features, so as to account for the effects of local conditions on earthquake-induced damage.

Introduction

Local site conditions affect the intensity of ground shaking, and as a consequence, the extent of earthquake-induced damage. The amplitude, frequency content, and duration of strong ground motion are significantly influenced by local site conditions. A well-known example is the 1985 Mexico City earthquake. Although the fault rupture of the earthquake was about 350 km away from Mexico City, the city sustained catastrophic damage due to the strong amplification of the ground motion by soft soil deposits (Seed et al., 1988). The 1989 Loma Prieta earthquake caused extensive damage in the San Francisco Bay Area. The San Francisco Bay mud significantly influenced the amplitude, frequency content, and duration of ground shaking and resulted in the collapse of the northern portion of the I-880 Cypress Viaduct (Earthquake Engineering Research Institute, 1990; Kramer, 1996). Seismic microzonation provides the basis for site-specific risk analysis, which can assist in the mitigation of earthquake-induced damage.

Methodology

Seismic microzonation typically involves the mapping of predominant periods, soil amplification factors, topographical conditions, liquefaction susceptibility, etc. To draft microzonation maps for a particular region, various data such as existing geological maps, borehole survey data, seismic observation data, and microtremor observation data are collected. Since seismic microzonation entails spatial classification of soil conditions in a small area (e.g., a city), geological data are required for not just a single location, but for many locations. In this regard, geological classification maps are most often used as one of the data sources. However, to classify the target area in a more quantitative manner, actual soil profiles obtained from borehole survey data or seismic observation data are better sources. Unfortunately, in most cases, the borehole survey data and/or seismic observation data available for a small area are insufficient. Thus, microtremor observation data have emerged as a popular source for dense spatial information on site amplification characteristics. Three examples of seismic microzonation are described hereafter.

Example 1. Seismic microzonation based on geomorphological classification maps

Several seismic microzonation studies in Japan have employed geomorphological and geological data from the Digital National Land Information (DNLI), which is a GIS database that covers the whole of Japan with a 1×1 km mesh, to estimate site amplification characteristics (Matsuoka and Midorikawa, 1995; Fukuwa et al., 1998; Yamazaki et al., 2000).

Wakamatsu et al. (2004) drafted the Japan Engineering Geomorphologic Classification Map (JEGM) on the basis of the analysis of local geomorphological features at scales of 1:50,000, and all the attributes were digitized and stored in a GIS database. They recently extended the JEGM to 250 × 250 m grid cells that were categorized into 24 classes on the basis of geomorphological characteristics.

The shear-wave velocity averaged over the upper 30 m (V_s^{30}) is often used as a simplified index of site conditions (Building Seismic Safety Council, 2003). Region-wide site condition maps for California were constructed on the basis of V_s^{30} and the classification of geological units (Wills et al., 2000). The Next Generation of Ground-Motion Attenuation Models (NGA) project was launched in an attempt to collect all publicly available site condition information at strong motion stations. V_s^{30} is used in the absence of site condition information (Chiou et al., 2008). Matsuoka et al. (2006) constructed a nationwide V_s^{30} distribution map using the nationwide shear-wave velocity datasets for Japan, which were obtained from 1,000 K-NET and 500 KiK-net seismic stations and the JEGM.

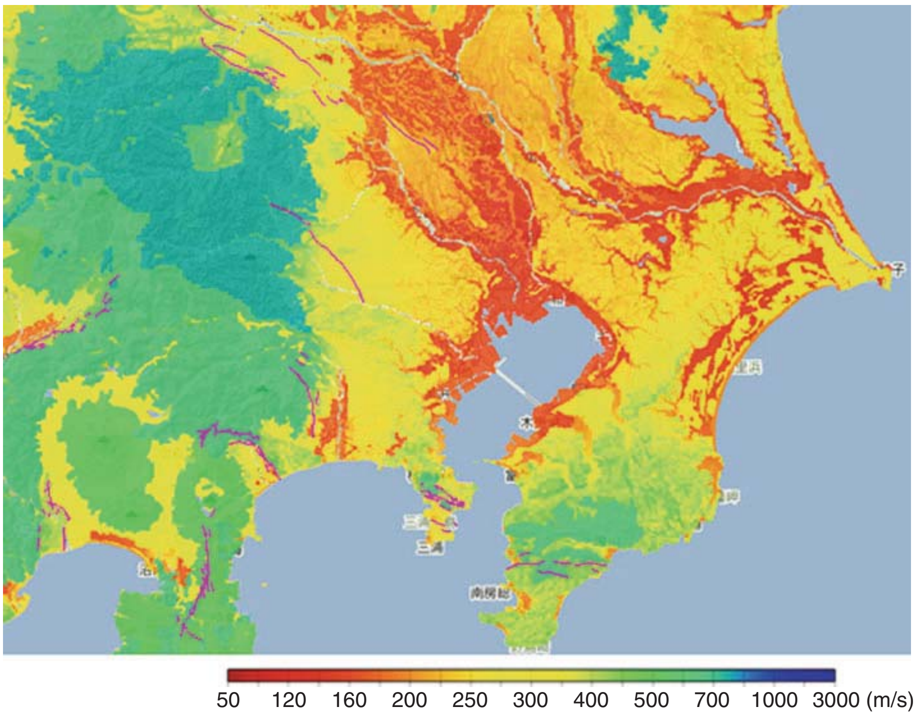
The National Research Institute for Earth Science and Disaster Prevention (NIED), Japan, has developed an open web system that interactively provides seismic hazard maps for Japan; this system is called the Japan Seismic Hazard Information Station (J-SHIS) (Fujiwara et al., 2006). J-SHIS uses the JEGM and V_s^{30} distribution map to draw probabilistic seismic hazard maps for the whole of Japan made by the Headquarters of Earthquake Research Promotion, Japan (Figure 1).

Example 2. Seismic microzonation based on dense borehole data and GIS

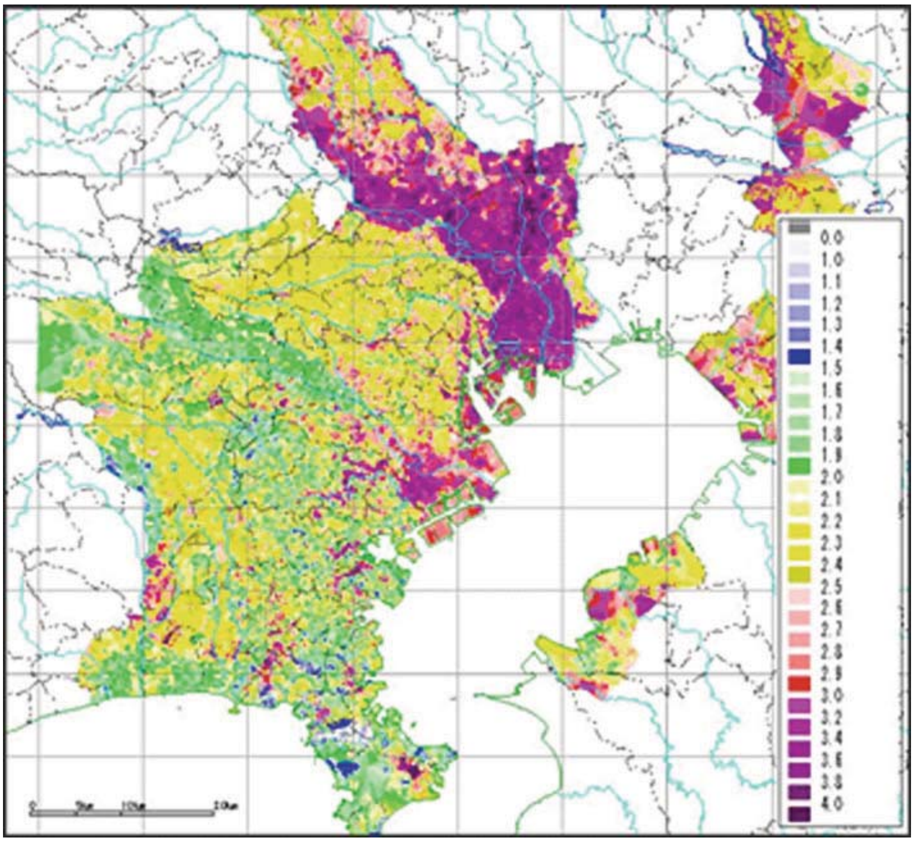
Since 2001, the Tokyo Gas Co., Ltd. has been operating the *Sup*er-Dense *Re*al-time *M*onitoring of *E*arthquakes (SUPREME) system, having about 4,000 seismometers (SI-sensors), in order to control natural-gas supply soon after the occurrence of earthquakes (Shimizu et al., 2006).

This system employs a GIS to interpolate the monitored spectral intensity (SI) values by using subsoil data from 60,000 boreholes. The digitized borehole data specify the location, depths of soil layers, classification of subsurface soil, standard penetration test (SPT) blow counts, surface elevation, and elevation of the ground water table. Thus, microzonation of the area on the basis of individual borehole data is possible. Shear-wave velocities are estimated from an empirical relationship by using the SPT-N values; then, the average shear-wave velocities in the top 20 m of soil at a borehole site are used to estimate the amplification factors of the SI values (Figure 2).

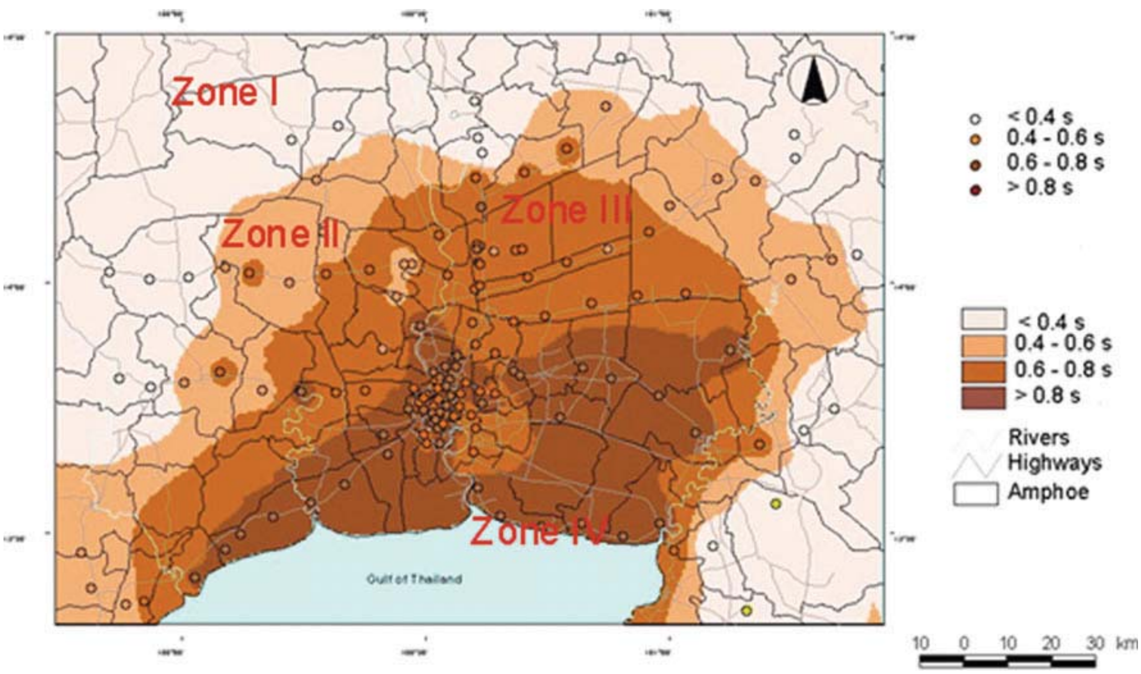
The accuracy of seismic microzonation can be confirmed after several years of operating a dense seismic network by evaluating the seismic records obtained for moderate to small earthquake events occurring in that period.



Seismic Microzonation, Figure 1 V_s^{30} distribution map of Tokyo metropolitan area (http://www.j-shis.bosai.go.jp/).



Seismic Microzonation, Figure 2 Site amplification map of Tokyo and surrounding areas, developed using dense borehole data.



Seismic Microzonation, Figure 3 Microzonation of greater Bangkok area on the basis of variation in predominant period.

Example 3. Seismic microzonation based on microtremor measurements

Microtremor measurements have emerged as a popular tool for determining the dynamic properties of soil layers, and hence, are being widely employed for seismic microzonation. In this method, ambient vibrations (of the order of microns) on the earth's surface are measured. The main sources of these vibrations are traffic and industrial and human activities (Kanai, 1983; Lermo and Chavez-Garcia, 1994). Microtremor measurements can be used to determine the predominant period of vibrations at a site. Nakamura (1989) proposed the horizontal-to-vertical (H/V) spectral ratio method, in which the predominant periods of ground vibrations are determined from the ratio of horizontal and vertical Fourier spectra of the microtremors recorded at a site. Konno and Ohmachi (1998) drafted a map of fundamental periods and amplification factors for the 23 wards of Tokyo on the basis of microtremor measurements carried out at 546 stations.

Tuladhar et al. (2004) drew a seismic microzonation map for the greater Bangkok area, Thailand, on the basis of microtremor observations carried out at 150 sites. The predominant periods of these sites were obtained by using the H/V method. The estimated predominant periods were validated by comparing them with the transfer functions obtained from one-dimensional wave-propagation analysis conducted at eight sites. According to the variation in the predominant period of the ground, the greater Bangkok area was classified into four zones as follows: Zone I (period less than 0.4 s), Zone II (0.4–0.6 s), Zone III (0.6–0.8 s), Zone IV (longer than 0.8 s). Figure 3 illustrates the microzonation of the greater Bangkok area on the basis of variation in the predominant period.

Summary

The objectives and methodologies to perform seismic microzonation are described and some examples are presented. The three major methods introduced to achieve seismic microzonation are the uses of geomorphological classification maps, dense borehole datasets, and microtremor measurements. The results of seismic microzonation are compiled for a GIS to draft microzonation maps and they can be used to predict ground motions during disastrous earthquakes and thus can assist in the mitigation of earthquake-induced damage.

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Cross-references

Earthquakes, Intensity
Earthquakes, Strong-Ground Motion
Seismic Hazard
Seismic Zonation
Seismicity, Intraplate
Seismology, Global Earthquake Model