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NATIONWIDE SITE AMPLIFICATION ZONATION STUDY USING JAPAN ENGINEERING GEOMORPHOLOGIC CLASSIFICATION MAP

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SUMMARY

Systematic and detailed information on the local geological and ground conditions plays an important role in nationwide disaster-mitigation systems. For that purpose we developed the "Japan Engineering Geomorphologic Classification Map (JEGM)", which is a nationwide GIS-based map containing the attributes of geomorphologic unit, subsurface geology, slope gradient, and relief energy in approximately 380,000 grid cells of 1 x 1 km each in size across the country. In order to test whether our geomorphologically-defined units accurately reflect the ground conditions, a site amplification evaluation and susceptibility assessment for liquefaction are necessary to be performed. In this paper, we investigate the relationship between the proposed geomorphologic classification unit of our system and the site amplification factors (PGA, PGV, and the response spectra) of 77 JMA sites countrywide, determined from 3,990 strong motion records by previous studies. Then, we calculate the average and variance of the site amplification factors at every geomorphologic unit. Our new geomorphologic classification system shows a smaller variance at each unit compared with previous classifications. Developed JEGM will be allowed detailed estimation of the site amplification factor nationwide, to be used for the calculation for near real-time ground shaking maps.

INTRODUCTION

The possibility of occurrences of Tokai, To-Nankai, and Nankai earthquakes threaten us to create a need for a unified system to evaluate seismic hazards over a wide area and across administrative districts. The research group of authors has been building nationwide geomorphology and ground-condition maps based on a 1 km square grid cell with the intent to construct a ground reference database for a disaster-mitigation system that enables evaluation of a variety of hazards all over Japan [1]. A feature of this database named as "Japan Engineering Geomorphologic Classification Map (JEGM)," is that the land-classification standard, which lacked unity between prefectures in existing nationwide databases [2-4] and their original maps [5], have been unified throughout Japan to make evaluation across administrative districts easier. In

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addition, interpretation of geomorphologic units using large scale topographic maps has improved the spatial resolution accuracy of geomorphologic boundaries.

One of the most important tasks for dealing with earthquake hazards is the evaluation of site effect in strong ground motion. In general, detailed ground information, such as the S-wave velocity structure of the ground, is necessary to accurately evaluate site amplification factors. However, across wide object area it is difficult and unrealistic to use an analytical approach based on such a soil structure model. Therefore, the distribution of amplification within a wide area typically has been estimated using simple and easier methods, such as average S-wave velocity of the ground based on geomorphologic units [6], or site amplification factors estimated directly from geomorphologic classification [7-10] using information on land-classification and subsurface geology.

In this study, with such background conditions in mind, we examined the relationship between the geomorphologic classification proposed for the JEGM and site coefficients obtained from strong motion records analysis to verify the applicability of the JEGM to evaluate site amplification factors.

STATION COEFFICIENT OF ATTENUATION RELATIONSHIP

Molas and Yamazaki [11] and Shabestari and Yamazaki [12] used 3,990 sets of observation records from 1,020 earthquakes, obtained from Japan Meteorological Agency (JMA) 87-type strong-motion seismographs, to develop an attenuation relationship formula for peak ground acceleration PGA), peak ground velocity (PGV), instrumental seismic JMA intensity and response spectrum. They also calculated the amplification factor (station coefficient) at the object station relative to the average site-effect of all observation stations. The records they used were those for earthquakes with a magnitude larger than 4.0, and with both two horizontal components larger than 1.0 Gal. Included were recent big earthquakes, such as the 1993 Kushiro-Oki earthquake, 1993 Hokkaido Nansei-Oki earthquake, 1994 Hokkaido Toho-Oki earthquake, 1994 Sanriku Haruka-Oki earthquake, and 1995 Hyogoken-Nanbu earthquake.

In this study, we used station coefficients for PGA, PGV, and the velocity response spectrum attenuation relationship formula as an index of amplification factors of strong motion observation stations. Station names of 77 observation points and station coefficients are provided in this paper [8-11].

RELATIONSHIP BETWEEN GEOMORPHOLOGIC CLASSIFICATION AND STATION COEFFICIENT

Initially, geomorphologic units for 77 stations were obtained from land-classification maps at a scale of 1: 50,000 that constituted the basic data for the JEGM. Then, the station coefficients for the attenuation relationship formula of PGA, PGV, and velocity response spectrum were calculated. They were grouped by geomorphologic unit in the observation stations. Then, we calculated scatters (variance) of station coefficient for each geomorphologic unit. Table 1 shows geomorphologic classification obtained from the JEGM, as well as the Digital National Land Information (DNLI) classification and classification according to Onishi, et al. (1999).

Because geomorphologic classification standards for DNLI differ from prefecture to prefecture, it is necessary to integrate geomorphology to apply it across Japan. Therefore, the number of classifications is fewer compared to other systems. In the figures shown below, geomorphologic unit names based on the above three types of classification methods are represented by IDs used in Table 1. Geomorphologic classification schemes in each of the JEGM, DNLI and classifications by Onishi et al. all differ, with items of the same name not necessarily equivalent due to their different classification standards.

Table 1. Classification IDs of geomorphologic classification by JEGM, DNLI, and Onishi et al.

Classification by Japan Engineering Geomorphologic Classification Map		Classification by Digital National Land Information	Classification by Onishi et al.
Mountain (W1)	Alluvial fan (W11)	Mountain (N1)	Mountain (O1)
Piedmont (W2)	Natural levee (W12)	Volcano (N2)	Volcanic foot (O2)
Hill (W3)	Back marsh (W13)	Plateaus, Terrace (N3)	Hill (O3)
Volcano (W4)	Former river (W14)	Lowland (N4)	Terrace (rock) (O4)
Volcanic foot (W5)	Delta (W15)	Lowland (slightly high) (N5)	Terrace (sand & gravel) (O5)
Volcanic hill (W6)	Sand bar (W16)	Land fill, polder (N6)	Terrace (volcanic ash) (O6)
Rock terrace (W7)	Sand dune (W17)		Alluvial fan (O7)
Gravel terrace (W8)	Reclaimed land, polder (W18)		Delta (sand) (O8)
Loam terrace (W9)	Land fill (W19)		Delta (mud, clay) (O9)
Valley plain (W10)			Sand bar, sand dune (O10)
			Land fill (O11)

Figure 1 shows variances by geomorphologic classification for station coefficients of PGV. When we calculated the variance of station coefficients, three observation stations with peculiar station coefficients were excluded: “Matsushiro”, “Ajiro” and “Wakkanai” [8-10]. As to the JEGM classification, there was only one station each that belonged to “volcano” and “dune”, so we did not calculate variances. In classification with DNLI, variance is large in almost all geomorphologic units. This is due to the reasons discussed above in the use of combined multiple geomorphologic units. Variances in lowland geomorphologic units of the JEGM (back marsh W13, delta W15, sand bar W16) are a little smaller than variances of lowland geomorphologic units in other classifications. However, for compared to the classification methods of the JEGM and Onishi et al., variances of loam terrace (W9), gravel terrace (W8), alluvial fan (W11), volcanic ash (O6), sand and/or gravel terrace (O5), alluvial fan (O7) are slightly larger. When we examine plateaus, terraces or alluvial fans in detail, locations of their formation differ significantly. Some are in plains and near alluvial lowlands and some are at the margin of mountains and hills. Therefore, it is understood that the influence of adjacent geomorphologic units were reflected in the result.

Figures 2 through 4 show the variance of in station coefficient velocity response spectra by each geomorphologic segment. At the period range of about 0.1 second, variances are larger for any

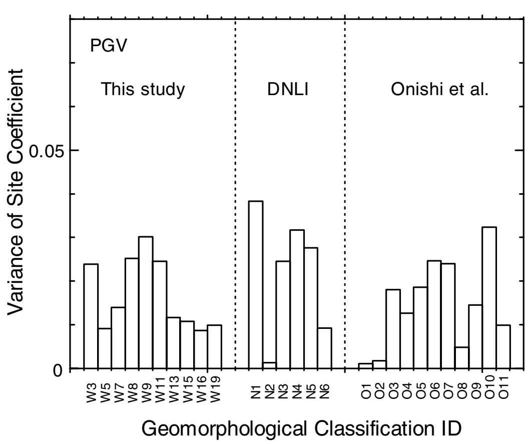

Figure 1. Variance of the station coefficient of PGV for each geomorphologic classification

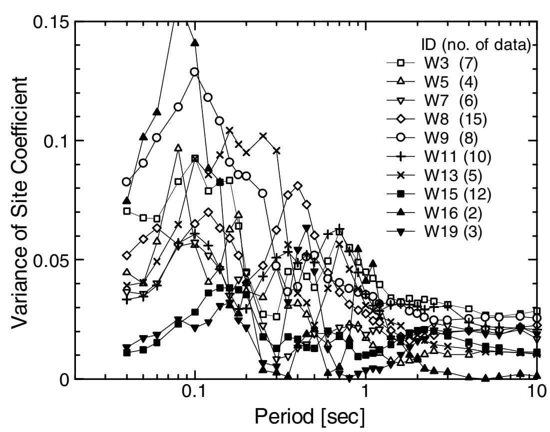

Figure 2. Variance of station coefficient of velocity response spectrum for each geomorphologic classification based on JEGM

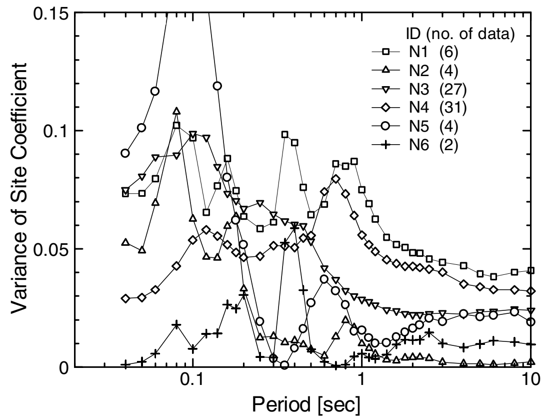

Figure 3. Variance of the station coefficient of velocity response spectrum for each geomorphologic classification based on DNLI

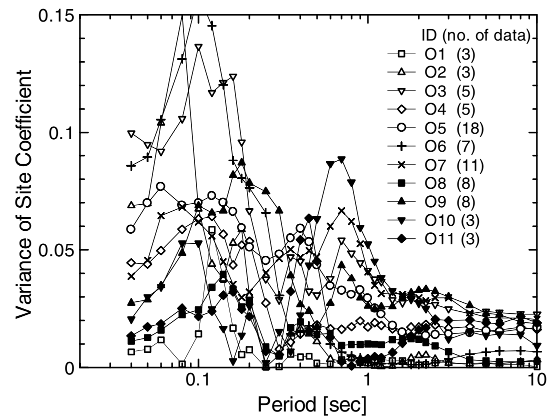

Figure 4. Variance of station coefficient of velocity response spectrum based on geomorphologic and surface geologic classification by Onishi et al.

classifications, while at a period range of about 1 second, which is regarded to be important for evaluation of ground motion [13], variances for each geomorphologic unit of the classification in our study, shown in Figure 2, are more concentrated compared with other classifications (Figures 3 and 4), and the values are rather small. It suggests that classification with the JEGM is valid to evaluate the site effects.

Figure 5 shows variances of estimated error for PGA, PGV, and velocity response spectrum for overall data when we assume station coefficient average for each geomorphologic unit as estimated value. Classification with DNLI has a much larger error variance and exceeds those of the two other classification methods. As discussed above, it seems to have been caused by the use of combined multiple geomorphologic units. Alternatively, both the JEGM and classification by Onishi et al., classified in details using 1:50,000 land-classification maps and this contributed to the results with smaller error variances. When classifications by JEGM and the method of Onishi et al. are compared for each PGA, PGV, and velocity response spectrum, both features may be interpreted as having almost the same level of estimated accuracy. However, when we examine, in detail, the error variance of station coefficients of velocity response spectra for a period shorter than 0.2 seconds, our study classification, JEGM, is smaller, while for periods longer than 0.2 seconds classification by Onishi et al. shows smaller error variances. In classification by Onishi et al., they added detailed classification of subsurface geology, such as classifications of delta as “with sand” and “with mud or clay” that resulted in smaller scatter. Some items, such as a volcanic ash (O6) that features a comparatively large amount of data but with smaller variances, strongly influenced to make the total estimate data error smaller. As shown in Figure 5, classification by Onishi et al. is reliable as to classification accuracy of 77 JMA stations. However, classification by Onishi et al. was proposed on the premise that geomorphologic classification scheme and subsurface geology of the DNLI be used. When the classification is applied to wide areas, issues associated with the original map [5] of DNLI (disunity of geomorphologic classification standards and low spatial resolution due to small scale map) arise and it is hard to say that amplification factors can be evaluated accurately.

Figure 6 shows the station coefficient of velocity response spectrum by each geomorphologic classification based on the JEGM. Concerning mountains and terraces, within a range of periods of 0.3 seconds or shorter, the station coefficient values are large; while on lowlands the values are larger for periods longer than 0.3 seconds. This trend basically agrees the findings of previous studies [10, 14].

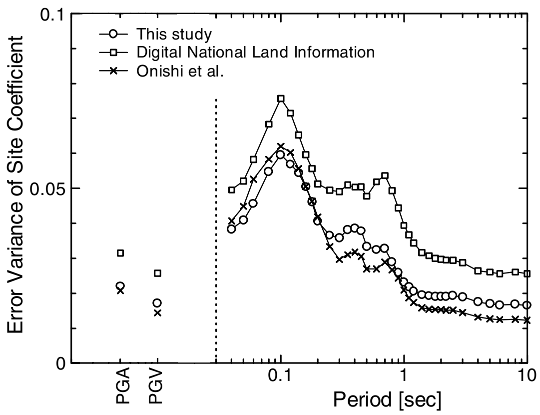

Figure 5. Error variance of total data for station coefficient of PGA, PGV, and velocity response spectra

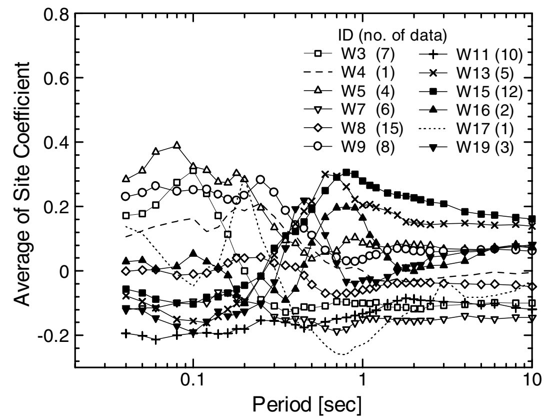

Figure 6. Station coefficient of velocity response spectra by each geomorphologic classification on JEGM

We will be able to generalize the discussion, above, as follows. The nationwide Japan Engineering Geomorphologic Classification Map developed in our research group and its land-classification standard has proved to be suitable to evaluate the site amplification based on the station coefficient in the same manner as that of the classification by Onishi et al. In addition, unlike existing methods [3, 4, 6-10] that employed Digital National Land Information, nationwide geomorphology is classified using a unified standard, so it is expected to achieve an evaluation of the site effect equally and uniformly, regardless of the object area.

CONCLUSION

We examined the relationship between the station coefficients obtained from attenuation relationships formulated from observation records collect nationwide by type 87 strong motion seismographs and geomorphologic classification obtained from the Japan Engineering Geomorphologic Classification Map (JEGM). The purpose was to verify whether nationwide JEGM, developed under a unified land-classification, are applicable to the evaluation of site amplification factors.

We identified significant trends in station coefficients for each geomorphologic unit and we confirmed that a scatter in a period range of about 1 second, regarded as important for the evaluation of seismic ground motion, is small. Therefore, the proposed land-classification standard is verified to be applicable to ground motion evaluation and offers the potential to evaluate site effects with more equal and uniform accuracy than conventional methods.

However, our study is based on data from a limited number of 77 stations, so there are some geomorphologic units that we could not evaluate. We think it necessary to collect more ground condition data, such as PS-logging data to clarify the amplification factors for all geomorphologic units, improve the accuracy of site amplification estimation and build a nationwide amplification map.

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