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Ambiental Vibration H/V Characteristics Across the Transition from Obaku Hills to Ogura-Ike Lowland

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Introduction

Seismic site effects refer to the modification of seismic waves caused by the presence of soft surface sediment deposits overlying harder sediments or bedrock. These contrasts in mechanical properties can significantly alter ground motion characteristics.

The fundamental resonance frequency of soils and local ground-motion amplification are commonly investigated to characterize seismic site effects, particularly in sedimentary basins influenced by seismic sources. Various analytical methods have been developed for this purpose; however, site effects in mountainous or hilly areas remain less well understood.

This research aims to evaluate the applicability of site-effect assessment methods developed for sedimentary basins when applied to hilly terrains.

Location of the study area

The study area is located in the southeastern part of the Kyoto Basin, extending from Obaku Hill to Ogura-ike. Obaku Hill is characterized by Middle to Late Pleistocene sedimentary deposits, including gravel, sand, and mud, with outcrops of the Osaka Group exposed at different elevations. The area extends westward to Ogura-ike, where an ancient lake once existed; this area has since been reclaimed through drainage and is recognized as the deepest depression in the Kyoto Basin (Akamatsu and Komazawa, 2003).

The Uji River flows through the central part of the study area from southeast to northwest, separating these geomorphological units and strongly influencing the alluvial deposition regime and the development of ancient geological structures associated with paleoriver systems.

In the eastern portion of the study area, the active Obaku fault system has been identified as a reverse fault striking NNE–SSW (Koizumi et al., 2002).

Overall, the study area represents an exemplary transition zone between hilly terrain and lowland basin deposits, influenced by a potential seismic source.

Methodology

The use of ambiental vibration records (microtremors) to estimate site response was first introduced in Japan in the 1950s (Kanai et al., 1954). Among the techniques developed for evaluating site effects using microtremor data, the horizontal-to-vertical spectral ratio (H/V or HVSR) method is one of the most widely applied. Originally proposed by Nakamura (1989), this method provides a practical approach for interpreting microtremor measurements.

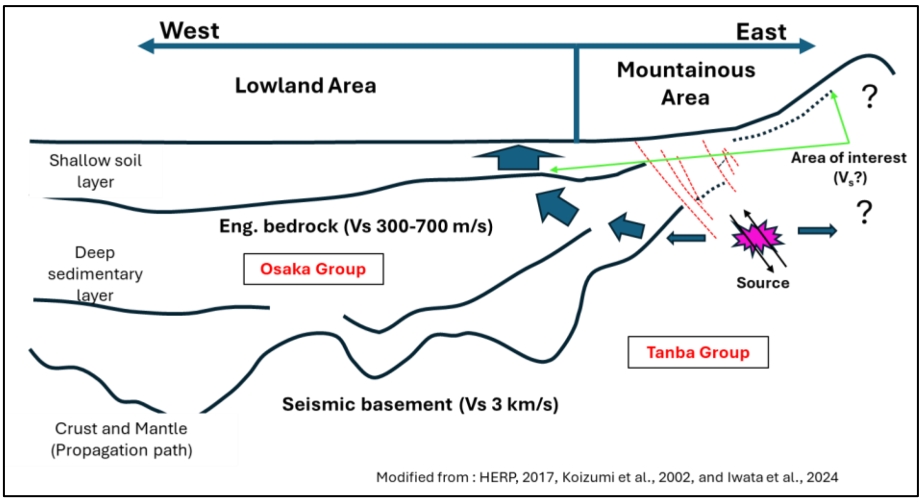

Figure 1. Model profile of mountainous area to low-lying terrain with a seismic source below

Subsequently, Lermo and Chávez-García (1994) compared site-response estimates derived from microtremor records with those obtained from the standard spectral ratio method using earthquake recordings. They concluded that HVSR analysis of microtremors can reliably determine the dominant period of sedimentary deposits subject to dynamic amplification within the 0.1–20 Hz frequency range, while also providing a preliminary estimate of the amplification level.

In the study area, a total of 80 microtremor measurements were acquired using an Atom-3C passive seismic system (OYO Corp. and Geometrics Inc.). Each measurement consisted of three-component ambient vibration recordings for HVSR analysis, collected with a 2-Hz triaxial geophone at a sampling frequency of 100 Hz and a recording duration of approximately 20 minutes.

Preliminary results

Preliminary HVSR results shown in Figure 2 indicate a clear fundamental frequency peak (f_0) across all areas of the study region. The western lowland is characterized by low fundamental frequencies, with f_0 ranging from 0.29 to 0.4 Hz. In the central area, corresponding to the transition from the alluvial plain toward the foothills, f_0 values increase to between 0.4 and 0.7 Hz. In the hilly zone, the fundamental frequency is higher, ranging from 0.9 to 2 Hz.

The lower f_0 values observed in the lowland areas are attributed to the presence of thick sedimentary deposits overlying the seismic basement corresponding to Mesozoic to Paleozoic rock. Higher-mode peaks (f_1) observed around 3 to 4 Hz likely reflect the impedance contrast between Holocene soil layer and Pleistocene sediments corresponding to so-called engineering bedrock. Toward the hilly areas, the reduction in thickness of shallow soil layer results in an increase in f_0, and higher-mode peaks become less distinct.

References

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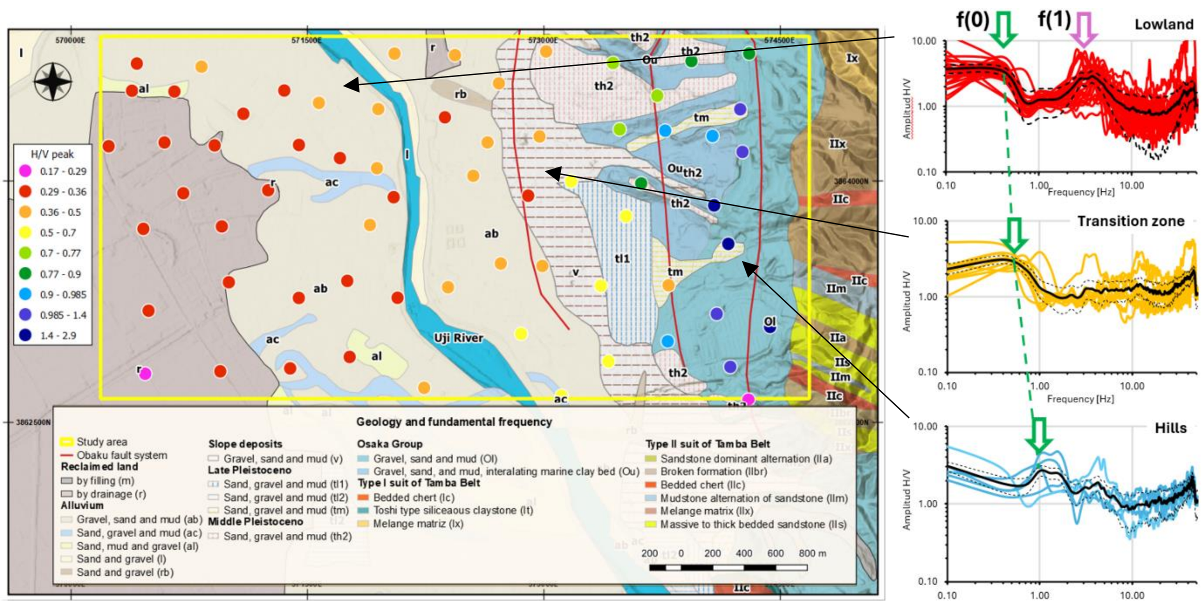

Figure 2. Fundamental frequency map (left) and three examples of H/V function sets in characteristic areas (right).