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Monitoring insights on the co-seismic responses of a deep-seated landslide

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1. Introduction

In recent years, earthquakes have triggered numerous landslides, resulting in severe damage to local properties and great loss of lives directly. To mitigate this kind of geohazards, great efforts had been paid to the study on understanding the properties of coseismic landslides (Wasowski et al, 2011). By now, the coseismic site responses, especially the amplification effects, on the initiation of landslides had been analyzed by means of various methods, and the results showed that the coseismic responses can be affected by various factors especially in those deep-seated landslides, where the geological and topographical conditions are more complicated (Del Gaudio and Wasowski, 2007; Burjanek et al, 2012; Massa et al, 2014). However our understanding on the coseismic site response of deep-seated landslides is still limited. Particularly, there are many potential deep-seated landslides in the accretionary prism mountains that may be activated by the coming Nankai and/or Tonankai mega thrust earthquakes. Thus, better understanding the coseismic response of deep-seated landslides will be of great importance. In this study, we focused on understanding the features of coseismic response and vibrating behaviors by means of real time monitoring on a target deep-seated landslide in Azue area, which was reactivated by the heavy rainfall in 2004 in Naka town, Tokushima prefecture (hereinafter called Azue landslide).

2. Method

Six seismometers were installed on different locations of Azue deep-seated landslide (Fig.1) for in-situ long-term strong motions monitoring. Until now, many earthquakes events with different magnitudes and epicentral distances were recorded (example records are shown in Fig. 2 (a)). Meanwhile, local microtremor was also recorded by ambient noise monitoring and some geophysical surveys (ERT and MASW) were performed for detecting the detailed geological conditions of the landslide blocks (Fig.1). By using these records, the site responses, especially the amplification effects on different locations of the landslide have been analyzed.

3. Results and conclusion

The results showed that different locations own different amplification features:

(1) In terms of the strong motion, the mean spectral ratios from coda waves showed that the amplifications on the location of P2 present obvious single peak on 5 Hz (amplification factor of 6) and without the predominant amplification direction. However on landslide block A (P3), there were two peaks emerged. One was on 3 Hz (amplified factor of 2) alone 45° N (azimuths rotate from N orientation in clockwise) and another on was on 10 Hz (amplification factor of 3) alone 150° N. The results on P4 (near boundaries of block A) also presented two peaks on the similar frequencies as P3, but showed smaller amplification factor than P3 (about 2). However the amplification directions were different from P3, alone 150° N and 100° N respectively. In addition, the amplifications on bedrock (P1) outside of the landslide area presented ambiguously small peak values, which were treated as almost no amplifications

(the results of P03 as example are shown in Fig. 2(b)).

(2) The dense ambient noise records on landslide block A and B showed that the amplification patterns (single peak and multiple peaks) were different on the whole monitoring areas. All amplification factors were smaller than 8 and the peaks distributed in frequency ranging from 10 Hz to 30Hz approximately. We examined the amplification factors along different directions, and found that the amplification directions were almost consistent for the areas near the boundary of landslide blocks, and the main amplifications directed following the dip of the slope. The results of block-A are exampled in Fig. 3.

In summary, the results revealed that the amplifications on Azue landslide blocks were more complicated than the toe part of the slope with landslide deposits or the bedrock. These phenomena may result from seismic energy redistribution due to the complex anisotropic geological settings in the landslide blocks.

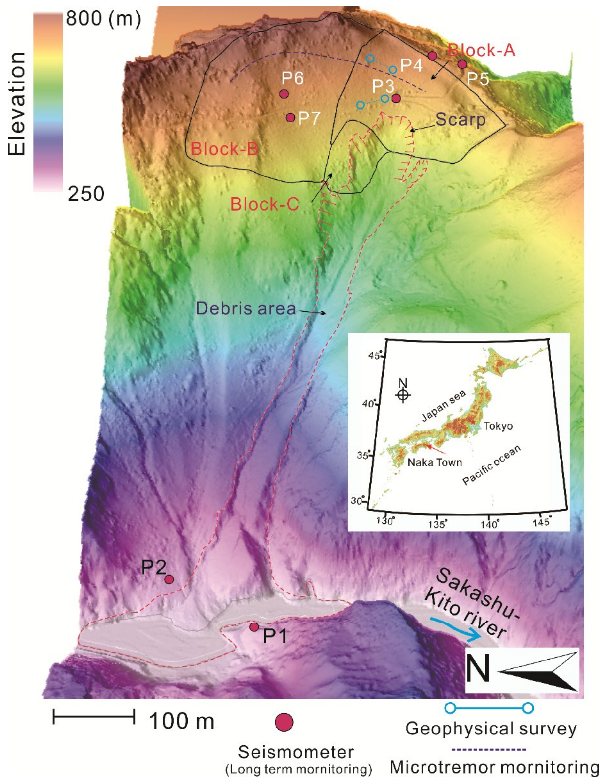

Fig.1 Azue deep-seated landslide and locations of monitoring system and the area of geophysical surveys performed.

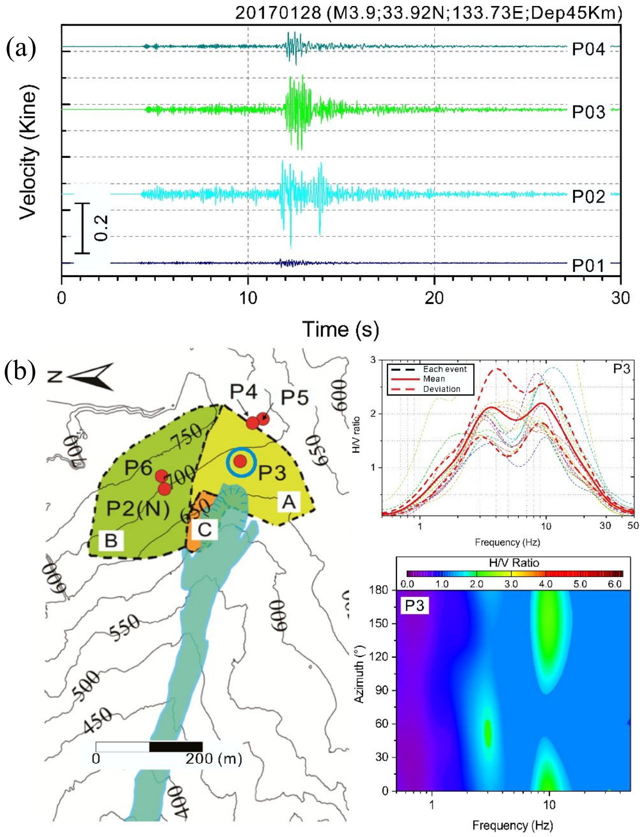

Fig.2 (a) seismic motion records (EW component) on different locations; (b) amplification features (H/V rations) on P03. For amplification direction (right bottom graph), the values of 0 to 180 indicate the azimuths form North to South clockwise

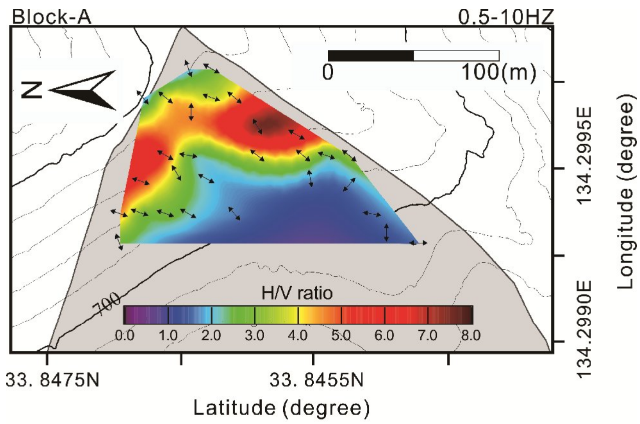

Fig.3 Amplification distribution on landslide block-A in frequency band of 0.5 to 10 Hz. Black arrows indicate the amplification directions