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Fluctuations in pore-water pressures triggered by earthquakes at the Busuno landslide

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1. Introduction

Many strong earthquakes (EQs) of magnitude >6, such as the 2004 Mid Niigata prefecture EQ and the 2008 Iwate-Miyagi inland EQ above magnitude 6 have occurred over the past few decade. As dynamic stresses from EQs act upon the slope, pore-water pressure increases in soils with low permeability, which causes destabilization of the slope.

Okamoto et al. (2006) reported spike-like fluctuations in pore-water pressure in the landslide masses during the Mid Niigata prefecture EQ activity. However, they did not examine the relationship between fluctuations in pore-water pressure and seismic vibration characteristics. This study seeks to identify the fluctuations in pore-water pressure in the landslide masses that result from EQ seismic motion.

2. Methods of monitoring

We observed pore-water pressure and seismic motions at the Busuno landslide site in Joetsu City, Niigata Prefecture, Japan. We analyzed the seismic motions of five EQs, namely the 2004 Mid Niigata prefecture EQ of M6.8 (EQ1), its largest aftershock of M6.5 (EQ1'), the 2007 Niigataken Chuetsu-oki EQ of M6.8 (EQ2), the 2011 Naganoken Hokubu EQ of M6.6 (EQ3), and its largest aftershock of M6.6 (EQ3'). We installed a seismometer at the Busuno landslide in 2010. Analysis of strong motions that occurred before 2010 (EQ1-2) was conducted using data from the National Research Institute for Earth Science and Disaster Prevention (NIED) K-NET database Yasuzuka. To estimate the fluctuations in pore water pressure due to the EQs, we evaluated attenuation relationships for peak ground acceleration (PGA) and velocity, taking into consideration the effects of the fault type and site conditions (Si and Midorikawa, 1999).

We installed piezometers (pore water pressure gauges) in areas where large movements were observed in past years, and pore-water pressure was recorded every 10 min. Five piezometers (P21, P22, P23, P31, and P33) were installed in 2002, and pore-water pressure during EQ1, EQ1', and EQ2 was observed. These piezometers were crushed by heavy snow in 2006, and two new ones (P61 and P62) were installed and recorded the data during EQ3 and EQ3'. As the piezometers recorded measurements every 10 min, the peak pore-water pressure immediately following an EQ is not always recorded. We calculated a damping curve for the pore-water pressure data, and the peak of the curve was assumed from the decreasing trend of the data. The damping curve was applied to the positive pore-water pressure data.

3. Results and discussion

All piezometers showed fluctuations in pore-water pressures during the five EQs. The fluctuations in pore-water pressures increased with the Peak Ground Acceleration (PGA). EQ3 showed the highest PGA (NS 236 gal, EW 382 gal, and UD 108 gal) and the largest increase in pore-water pressure (14 kPa). Other EQs caused much lower fluctuations, of 2 kPa and less.

We believe the effects of a heavy snow pack on the slope were the cause of the largest increase of pore-water pressure. A layer of ~3 m of snow covered the landslide area during EQ3 (March 12, 2011), thus subjecting the sliding surface to greater pressure.

The data from the five EQs showed correlations between PGA, Peak Ground Velocity, and the dominant frequency of up and down directional movement and fluctuations in the pore-water pressure before and after the EQ events.

References

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National research institute for earth science and disaster prevention (NIED). Kyoshin-network (K-NET) http://www.k-net.bosai.go.jp/k-net/

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