Investigation on Failure Mechanism of Earthquake-Induced Landslide During Rainfall: a Case Study of Tandikat Landslide, West Sumatra, Indonesia

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1 Introduction

An earthquake with moment magnitude of 7.6 hit Padang, West Sumatra Province, Indonesia at 5:16 p.m. of September 30, 2009, and killed more than 1,000 people (EERI, 2009). This earthquake also induced a number of landslides that contributed to more than 60% of the total earthquake death toll. The most prominent landslides occurred in Tandikat, Padang Pariaman Regency, which buried hundreds of people and swept some villages. These landslides occurred in loose pumice-layered mountains during rainfall. The combination of the strong earthquake with the intense rainfall probably dramatically decreased the stability of slopes.

2 Tandikat landslides

Tandikat landslides occurred on mountainous areas around Mt. Tandikat. The morphology of the area consists of mountains and hills. The wide distribution of the landslides has a varied source slope inclination, ranging from the gentlest slope of 20 degrees to steepest slope of as high as 40 degrees.

A medium intensity rainfall started a few hours before the earthquake and continued until the earthquake took place. It is considered that rainfall might have greatly contributed to the landslide.

From filed investigation and observation, it was found that an impermeable clay stratum is overlain by porous pumice layer, which has fairly good permeability. The difference in permeability characteristics of the clay stratum and pumice can be considered to have caused saturation of the lower part of the pumice layer due to rainwater percolation.

A study of Tandikat landslide failure has been conducted by Wang et al. (2010) using an un-drained ring shear apparatus to confirm the grain crushing mechanism of a largely displaced pumice material. However, further study about the landslide and its initiation mechanism during rainfall is inevitable.

This paper aims to study more about initiation mechanism of landslide in pumice deposit, triggered by an earthquake during rainfall using cyclic triaxial test. This study shows the necessity of considering the combination of separate events of rainfall and earthquake.

3 Methods

An integrated study of landslide incorporating field investigation, laboratory work and numerical modeling are conducted in this paper. The field investigation consists of soil sampling and permeability test using falling-head permeameter test. Both static and stress-controlled cyclic triaxial (CTX) tests were used to obtain shear strength parameters and to examine dynamic behavior of pumice sand.

In order to assess water infiltration and soil saturation behavior during rainfall, one dimensional Green-Ampt model of rainfall infiltration in slopes was adopted from Chen and Young (2006).

In this study, shear strain is assumed to be the leading factor for pore pressure increase, which consequently reduces shear stiffness following a decrease in the confining pressure. The subsequent degraded shear stiffness value generates larger strain at the next loading cycle which increases the pore pressure more rapidly. It is the basic assumption of rigid block on quasi plastic layer model which was used to assess pore pressure increase and factor of safety.

4 Results

Infiltration assessment using Green-Ampt method showed that depth of wet front (z_w) had already surpassed a depth of 3 meters, which is the depth of impermeable sandy clay (Fig. 1). It suggests that during rainfall, water percolated into the pumice sand and hit the impermeable sandy clay layer generating a temporary perched groundwater which

consequently turned the lower part of pumice sand into a fully saturated layer.

The CTX test results as in Fig. 2 show that effective confining pressure and initial shear stress greatly influence the cumulative shear strain. The reference cumulative shear strain increases linearly with the effective confining

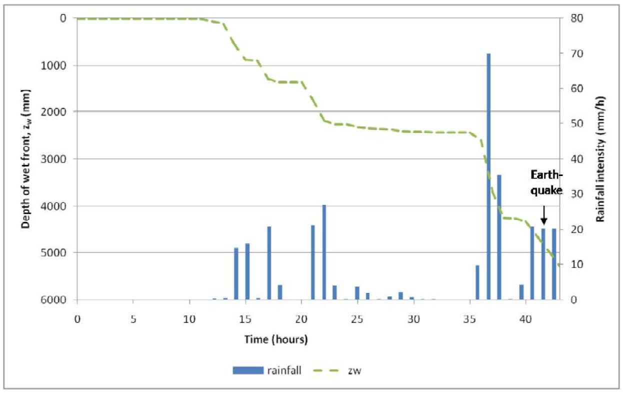

Fig 1. Time history of earthquake acceleration (EQ Acc), pore pressure ratio (r_u), factor of safety considering ru (FoS with r_u) and without considering ru (FoS w/o r_u)

pressure, which suggests that a saturated shallow pumice sand layer has more risk of pore pressure increase during earthquake rather than a deeper layer, while a soil mass with larger initial shear stress needs more cumulative shear strain to increase pore pressure ratio to some certain value. This suggests that gentle slopes are more prone to pore pressure increase during earthquake rather than steep slopes.

The final result of pore pressure prediction using rigid block on quasi plastic layer assumption and actual earthquake acceleration on 3-m deep pumice sand deposit suggests that slope failure occurred due to pore pressure

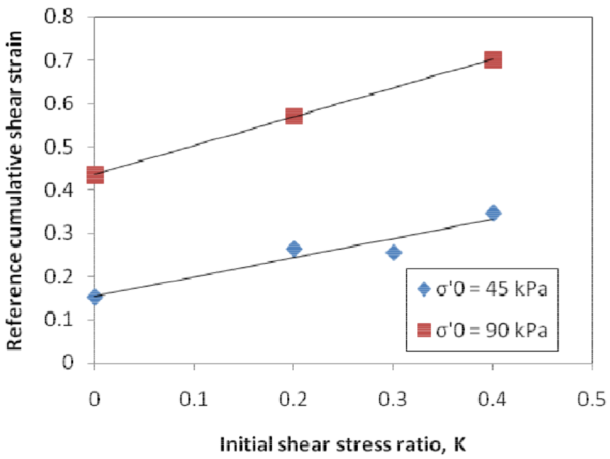

Fig 2. Initial shear stress ratio versus reference cumulative shear strain for ó'$_0$=45 kPa and 90kPa.

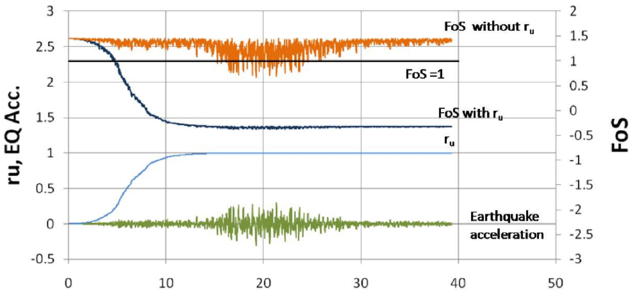

Fig. 3. Time history of earthquake acceleration, pore pressure ratio (r_u), factor of safety considering ru (FoS with r_u) and without considering ru (FoS w/o r_u)

build up (Fig. 3). The factor of safety rapidly decreased before earthquake acceleration attained its peak value where the energy of the earthquake had not reached the maximum.

5 Concluding remarks

The stability analysis of Tandikat landslide using rigid block on quasi plastic layer assumption and actual earthquake acceleration suggests that slope failure occurred due to pore pressure build up. The factor of safety rapidly decreased before earthquake acceleration attained its peak where the energy of the earthquake had not reached the maximum. This suggests that disastrous landslide would probably happen due to smaller earthquake if the sliding zone was saturated. This also portrays a high risk of catastrophic earthquake-induced landslide in tropical region which has high amounts of rainfall.

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