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ORIGINAL ARTICLE

Rainfall-induced landslides by deficit field matric suction in unsaturated soil slopes

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Abstract
Landslides are mainly triggered by decrease in the matric suction with deepening the wetting band by rainfall infiltrations. This paper reports rainfall-induced landslides in partially saturated soil slopes through a field study. A comprehensive analysis on Umyeonsan (Mt.) landslides in 2011 was highlighted. The incident involves the collapse of unsaturated soil slopes under extreme-rainfall event. Fundamental studies on the mechanism and the cause of landslides were carried out. A number of technical findings are of interest, including the failure mechanism of a depth of soil and effect of groundwater flow, the downward movement of wetting band and the increase of groundwater level. Based on this, an integrated analysis methodology for a rainfall-induced landslide is proposed in this paper that incorporates the field matric suction for obtaining hydraulic parameters of unsaturated soil. The field matric suction is shown to govern the rate of change in the water infiltration for the landslide analysis with respect to an antecedent rainfall. Special attention was given to a one-dimensional infiltration model to determine the wetting band depth in the absence of the field matric suction. The results indicate that landslide activities were primarily dependent on rainfall infiltration, soil properties, slope geometries, vegetation, and groundwater table positions. The proposed methodology has clearly demonstrated both shallow and deep-seated landslides and shows good agreement with the results of landslide investigations.

Keywords Slope · Landslide · Rainfall · Infiltration · Unsaturated soil

Introduction

Rainfall-induced landslides are generally defined as traveling processes of soils in mountainous areas, particularly in areas covered by shallow soils of different grading and origin. (Jeong et al. 2008; Cascini et al. 2010; Kim and Jeong 2017). These areas are often recorded in pyroclastic deposits in Central America and New Zealand (Capra et al. 2003; Ekanayake and Phillps 2002), weathered soils in Hong Kong and Japan (Take et al. 2004; Wang et al. 2002), weathered colluvial deposits in Hong Kong and Korea (Fuchu et al. 1999; Park et al. 2013). In particular, flow-type landslides (Hungr et al. 2001) represent significant threats to lives, livelihoods and infrastructure in mountainous areas. For example, when South Korea experienced heavy rainfall recorded in June and July 2011, some 151 landslides occurred in the Umyeonsan Mt. region affecting 13 villages. Because the mountain is located in urban area of Seoul, these landslides had significant impact on society.

The triggering mechanisms of natural slope failures generally governed by a complex interaction between hydrological and geotechnical processes, which depends on irregular topography, hydro-geotechnical contexts by properties and boundary conditions, such as permeability and the initial state of the slope (Sorbino and Nicotera 2013). The rainfall is one of the most frequent landslides triggering factors, which can directly infiltrate the slope surface or indirectly provide increases in groundwater from the bedrock or aquitard (Kim et al. 2014). In a geotechnical perspective, the main reason of slope failures is the loss of effective stress with the loss of matric suction caused by rainfall infiltration in soil. Many researchers (Fredlund et al. 2012; Jeong et al. 2008; Kim et al. 2014) studied rainfall-induced landslides based on laboratory and field tests as well as numerical

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