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Numerical Simulation on Deep-Seated Gravitational Slope Deformation in Sedimentary Rocks

〇Yanli HOU, Masahiro CHIGIRA

Study and knowledge on Deep-Seated Gravitational Slope Deformation (DSGSD) are very important for landside hazard mitigation especially in mountain country because many catastrophic landslides often occur in DSGSD influenced area. This study is aimed to identify the triggering factors for DSGSD and to clarify the initiation and development of shear band with numerical simulation. In this study, a rock slope has been taken as an example which is located in the Kii-mountains of Nara Prefecture in west Japan and is mainly composed of shale, sandstone and green rock.

The numerical simulation was performed based on a continuum-based finite difference method FLAC, which has been widely used in slope stability analyses and the Mohr-Coulomb constitutive model was adopted. To acquire reasonable mechanical parameters for the numerical modeling, rock mass classification was carried out and the properties of the slope materials were obtained from available literature data, laboratory and field tests. The strengths of the rock mass were calibrated by taking into account the long-term strength degradation. The incision process of the river at the slope toe was simulated in four different and instantaneous steps by a sequential elimination of the corresponding elements in order to reproduce the realistic physical change of the system.

The numerical simulation demonstrated that an upward and river channel-oriented displacement occurred at the slope toe due to the elastic rebound of unloading induced by the river incision. Although a few elements ever entered into plastic state, no evident shear band was formed when the shear strength of the materials was high. If the shear strength was reasonably reduced, the simulation results revealed that a shear band was firstly developed at the upper part of the slope at the preliminary stage of the river incision. With the development of the river incision and lowering of river bed, a new shear band developed rapidly at the lower part of the slope and the two shear bands gradually connected with each other. Therefore, the river incision enhanced the height and the steepness of the slope, which caused the redistributed stress concentration at the slope toe, resulting in an increased slope deformation and the development of the shear band. The agreement between numerical simulation shear band and disintegrated and pulverized zones of drilled cores supports an idea that these weak zones of cores are formed mainly due to DSGSD induced by river incision while not the former brittle tectonics.

According to the study, the following two factors are necessary to be considered for the development of DSGSD in Kii-mountains, i.e. the river incision and the strength degradation of the rock mass. River incision is a primary triggering mechanism of DSGSD phenomenon provided that the rock mass strength gradually decreases. The strength degradation occurs in long-term temporal and spatial-scales due to various reasons such as the weathering/alteration, the mechanical damage as well as the damage-induced acceleration of water circulation and weathering. In a long-term perspective, the deformation damage, the weathering, the strength degradation and the further progressive damage, all of these processes interactive with each other and result in the development of the shear band and even lead to the catastrophic landslide.