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Role of halloysite on the initiation and movement of coseismic landslides occurring on tephra slopes

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Landslides occurring on tephra slopes during earthquake are normally characterized by their high mobility and long runout, and usually present significant hazard to human safety and the built environment. This kind of landslides could be well exampled by those triggered by the 2016 Kumamoto earthquake on Minami Aso area, Kumamoto, and by those triggered by the 2018 Hokkaido Eastern Iburi Earthquake in the hills near the epicenter. Field study on those landslides revealed that most of the landslides occurring on tephra slopes are shallow but destructive, the displaced landslide materials mainly consist of tephra, and their sliding surfaces are mostly developed within the weathered tephra layer, where the water content is very high and a clay mineral of halloysite resulting from the weathering of volcanic glass is normally presented. Similar phenomena had also been reported in the landslides occurring on tephra slopes in other countries. Therefore, it is believed that the presence of halloysite has played a bad effect on the initiation of slope instability and the post failure movement of the displaced landslide materials for these coseismic landslides occurring on tephra slopes. Nevertheless, the role of halloysite on the initiation and the movement of landslide remains has not been clarified, although some research based on case studies had been conducted and some preliminary results had been achieved. Hence, this study aims at clarifying the role of halloysite on the initiation and movement of landslides occurring on tephra slopes, through field investigation of some landslides triggered by recent earthquakes in Japan, and the conduction of a series of experimental works. The details are list below.

The first phase of this study is to confirm whether the sliding surface contains halloysite or not and the shape of halloysite through XRD test, SEM detection and TEM detection. By field trip to Minami Aso, Kumamoto and Atsuma, Hokkaido, the samples were taken back to the laboratory for testing and detection. The results show that: 1) The existence of Halloysite has been confirmed in the sliding surfaces for those landslides occurring in Minami Aso area and Atsuma area. 2) The halloysite in the sample taken from Minami Aso area presents the shape of tubular one, while that in the sample taken from Atsuma area, Hokkaido shows the shape of platy or crumpled lamellar.

The second phase of this study aims at examining the effects of introduction of halloysite on the water retention of tephra materials through pF tests. The samples were prepared by adding different contents of halloysite to the tephra materials taken from Minami Aso area, Kumamoto, or to the silica sand sample. Field examination on the weathered tephra layer with formation of halloysite and the results of pF tests indicate that: 1) the weathered tephra layer with formation of Halloysite normally maintains high water content under natural conditions. 2) The sample containing halloysite showed higher water retention capacity then the mixture of tephra with fine silica sand. Namely, besides the small particle size,

halloysite's special structure may elevate the potential of water retention capacity.

The third phase of this study involves in examining effect of halloysite on the shear behavior of tephra material. The program includes: 1) Using a in situ direct shear box to perform shear tests on samples in disturbed or undisturbed states with natural water content on the landslide field. 2) Making mixture of tephra materials with different content of halloysite or with different contents of fine silica sand, and conducting undrained ring shear tests on these mixtures in saturated state with different initial densities. The tests results show that: 1) Adding halloysite to tephra material changes the peak shear resistance of the sample. As the halloysite content increases, the peak shear resistance decreases. However, the peak shear strength for the mixture of tephra with 10% of silica powder became small and became greater with further increase of the silica powder. 2) The sample containing halloysite showed a higher brittleness index, which means that the soil layer containing halloysite may suffer from higher post failure mobility. 3) Halloysite reduced the energy required for shear failure in denser soils. This means that given the earthquake motion being the same, landslides on tephra slopes containing high content of halloysite may be easier to be triggered. 4) Halloysite reduced the energy required for sliding rapidly. Therefore, potential energy can be converted into kinetic energy faster and then elevate the sliding mobility.

In summary, through these above-mentioned works, it has been clarified that introduction of halloysite in the tephra can elevate the water retention capacity such that the tephra can be in high water content state in natural condition. Introduction of halloysite does not affect the peak shear strength of tephra materials, but can elevate the liquefaction potential, such that the shear failure could be easily triggered and the mobility of displaced landslide material be elevated.