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学　位　論　文　内　容　の　要　旨

博士の専攻分野の名称　　博士（工学）　　氏名　NGUYEN BINH THANH

学　位　論　文　題　名

Effect evaluation of grass on shallow slope stability of unsaturated volcanic soil in seasonal cold region

(積雪寒冷地の不飽和火山灰質土斜面表層の安定性に及ぼす植生の影響評価)

Vegetation has been recognized as an environmentally friendly method for stabilizing soil slope through hydro-mechanical effects. In terms of hydrological effects, transpiration could induce soil matric suction hence result in an increase in soil shear strength and a decrease in coefficient of permeability. In addition, the presence of vegetation roots could cause the change in soil hydraulic properties. Vegetation roots enhance water retention capacity and reduce coefficient of permeability of soil. These effects minimize infiltration into soil slope. Furthermore, soil shear strength at the potential slip surface of slope is increased due to the tensile shear strength provided by roots. As a result, the landslide-prone areas might be stabilized due to the hydro-mechanical effects of vegetation. Quantifying the hydrological properties of soil with different vegetated ages is vital to predict the long-term performance of vegetated soil slope. However, measuring the hydraulic properties (i.e. SWCC and unsaturated coefficient of permeability) of soils is time-consuming and costly. Currently, the simple model to estimate the hydraulic properties of vegetated soil is not available. Moreover, there is a lack of understanding about relationship of soil shear strength and root content at different grass ages. Comprehensive field measurements and numerical studies were rarely carried out to properly consider hydro-mechanical effects of grass on instability of soil slope. In addition, researches often studied the vegetation species in tropical or subtropical regions (i.e. Vetiver grass, Bermuda grass, Ivy tree), whereas seldom have studies paid attention to vegetation species which are commonly used in the seasonal cold region.

To overcome the above-mentioned limitations, this study investigates the effects of grass age on hydraulic properties of coarse-grained volcanic soil, namely: Komaoka soil. The soil-water characteristic curves (SWCC), unsaturated coefficient of permeability, outflow, runoff, and the variations in volumetric water content/matric suction under different rainfall intensities are measured by carrying out column tests. In addition, permeability tests are performed to determine the saturated coefficients of permeability of bare soil and grassed soils. The experimental results reveal that the grass age has an influence on the hydraulic properties of Komaoka soil. At the same volumetric water content, grassed soil with higher grass age has higher matric suction. Both saturated and unsaturated coefficient of permeability are significantly reduced with the increase in the grass age. Moreover, there is a decrease in the outflow and an increase in the runoff for grassed soil with higher grass age. Matric suction decreases later in grassed soil than that of bare soil under rainfall events. The new model is proposed to estimate the unsaturated coefficient of permeability of coarse-grained soil due to the effects of grass roots. The good agreement between estimations and experimental results shows that the proposed model is useful

to capture the decrease in unsaturated coefficient of permeability of grassed soil.

In order to investigate the reinforced strength of the grassed soil, a series of consolidated drainage (CD) compression tests were performed on root-reinforced soils with different grass ages. Experimental results reveal that there is significant increase in peak shear strength, effective cohesion of grassed soil as the grass root volume ratio is increased, whereas a slightly higher effective angle of internal friction is observed. Furthermore, the volumetric strain is decreased with the rise in root volume ratio.

In this research, a field study was carried out on unsaturated soil slopes. The field measurement consisted of two neighboring cut slopes, namely bare slope and grassed slope. Field measurement results reveal that grass has influences on reducing and stabilizing the soil water content, increasing matric suction, and lowering soil temperature in warm seasons. In winter, the gap of matric suction between bare slope and grassed slope is greater than that in other seasons. In addition, the soil temperature of grassed slope is higher than bare slope. The approach of coupled nonisothermal-seepage numerical analysis for unsaturated soil slope considering impacts of grass is suggested. The good agreement regarding to soil temperature and volumetric water content between simulation and field measurement indicates that the proposed approach is useful to consider the influences of grass on the hydro-thermal behaviors of unsaturated soil lope against climate variations. Furthermore, the slope stability analysis has been performed considering enhanced shear strength of soil due to grass roots. The higher values of FOS and maximum depth of slip surface of grassed slope presents that the grass is effective to resists the shallow landslide-prone area. The application of the recommended numerical approach is expected to contribute to pre-design study of grassed unsaturated soil slopes.

The thesis includes 9 chapters. Chapter 1 introduces the background, objectives, and organization of this study. Chapter 2 reviews past studies related to effects of vegetation on unsaturated soils. Chapter 3 illustrates the soil slope measurements. Chapters 4 and 5 show the effects of grass age on hydraulic properties of saturated and unsaturated soil, respectively. A new model for estimating hydraulic properties of grassed soils is presented in chapter 6. Chapter 7 shows the mechanical properties of saturated soil at different grass ages. The numerical approach of coupled nonisothermal-seepage numerical analysis for unsaturated soil slope considering impacts of grass is suggested in chapter 8. Finally, chapter 9 summarizes the conclusions obtained in this study and gives the recommendation for further studies.