STABILITY OF UNSATURATED SOIL SLOPES COVERED WITH MANGROVE

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Most soils in Singapore are mainly residual soils with deep groundwater table. Therefore, a significant part of residual soil in Singapore is located within the unsaturated zone where the pore-water pressures are negative. The negative pore-water pressure contributes additional shear strength to the unsaturated soil (Fredlund and Rahardjo, 1993). As rainwater infiltrates into the slope, pore-water pressure in the slope increases (matric suction decreases), and the additional shear strength due to matric suction will decrease or even disappear, causing the slope to be more susceptible to failure. Therefore, it is important to have a preventive measure for slopes that are prone to failure due to rainfall. One possible preventive measures for rainfall-induced slope failures is the use of green technology to mechanically reinforce slopes and to improve the aesthetics of the environment (Greenwood, 2007).

In this study, the unsaturated properties of soil consisting roots of Mangrove and their effects on the stability of slope located in residual soil from Old Alluvium (Figure 1) during rainfall are investigated. *Melastoma malabathricum* (Figure 2) was selected in this study since this type of Mangrove is best suited for tropical climatic condition such as in Singapore. *Melastoma malabathricum* is classified as a shrub that belongs to the *Melastomataceae* family (Omar et al., 2013). The laboratory tests were carried out to obtain the index properties, saturated properties (i.e. permeability, shear strength) and unsaturated properties (i.e. unsaturated shear strength, soil-water characteristic curve or SWCC) of soil with and without roots of *Melastoma malabathricum*. Organic content tests were conducted to determine the percentage of roots within soil specimen with and without roots of *Melastoma malabathricum*. The presence of roots of Mangrove changed the properties of the soil from silty sand to sandy silt. Hence, the soil with roots of Mangrove had higher saturated volumetric water content, higher air-entry value (Figure 3), lower saturated permeability (Figure 4) and higher shear strength as compared to the soil without roots.

Seepage analyses were carried out to observe the variations of pore-water pressure during rainfall within soil with and without *Melastoma malabathricum*. Figure 5 shows the numerical model of slope with *Melastoma malabathricum* and its boundary condition. The rainfall intensity of 18 mm/h was applied on the surface of the slope for 10 h. This amount of rainfall was taken from Intensity-Duration-Frequency (IDF) curve of Singapore based on 50 years return period. The pore-water pressure output of the seepage analyses was be used for the slope stability analysis. Bishop's simplified method was used in the stability analyses to obtain variations in factor of safety with time. Figure 6 shows the decrease in the factor of safety for the slopes with and without *Melastoma malabathricum* during rainfall. The reduction in the factor of safety for the slope without *Melastoma malabathricum* was much higher as compared to the reduction in the factor of safety for the slope with *Melastoma malabathricum*. This happened since the unsaturated permeability of the soil with roots of *Melastoma malabathricum* is lower than that of the soil without roots. As a result, it is more difficult for the rainwater to flow down beyond the root depth of the soil with *Melastoma malabathricum*. The results from slope stability analyses indicated that *Melastoma malabathricum* performed well as a vegetative cover in reducing the infiltration of the rainwater into the slope.

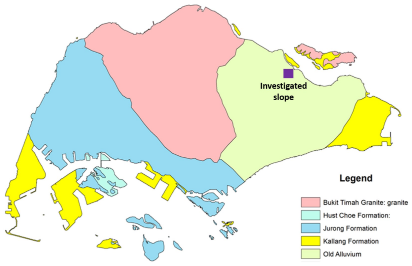

Figure 1. Location of the investigated slope

Figure 2. *Melastoma malabathricum*

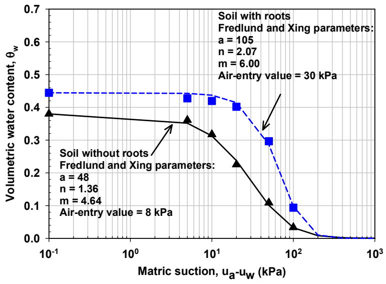

Figure 3. SWCC of soils with and without roots of *Melastoma malabathricum*

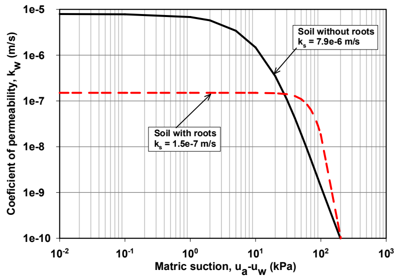

Figure 4. Permeability function of soils with and without roots of *Melastoma malabathricum*

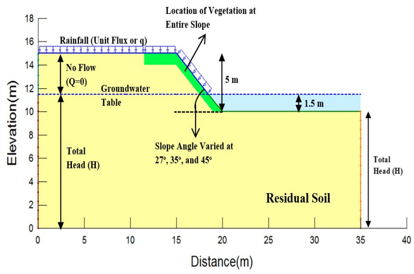

Figure 5. Numerical model for seepage and stability analyses of soil with *Melastoma malabathricum*

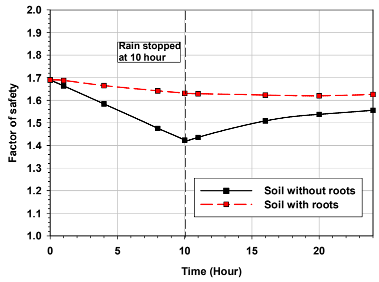

Figure 6. Factor of safety variations of soil slopes with and without *Melastoma malabathricum*

Keywords: unsaturated soil, Mangrove, seepage, stability, soil-water characteristic curve

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