UNIVERSITI TEKNOLOGI MARA

EFFECT OF HYDRAULIC HYSTERESIS ON SHEAR STRENGTH OF UNSATURATED SAND

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ABSTRACT

Soil in the field is subjected to variations in the water content due to water infiltration and evaporation processes that put the soil under either drying or wetting conditions. The shear strength of soil is affected by hydraulic hysteresis (the difference between drying and wetting). Defining the shear strength of unsaturated soil based on the two independent stress state variables approach was under argument by other researchers since the mentioned approach is not incorporating the variation of degree of saturation under given suction caused by the hydraulic hysteresis. In this research, the suction controlled triaxial test was used to conduct experiments on sand under different hydraulic phases (first drying, first wetting and second wetting). On top of that, the pressure plate extractor was modified to measure the wetting portion of SWCC. According to the test results, it was found that hydraulic hysteresis reduces with increasing the confining pressure and with increasing the drying-wetting cycles. Moreover, Although the maximum shear strength was obtained from the specimens under drying condition, the difference between the drying and wetting shear strengths was not significant for the tested soil. Also, the shear strength of unsaturated sand at any suction below the air entry value is equivalent to the saturated shear strength. The SWCC was found to be capable of not only estimating unsaturated soil property functions but also anticipating the shear strength behaviour of soil under different hydraulic phases. Based on the strong correlation between the SWCC and the apparent shear strength, this research has developed a shear strength model that incorporate the effect of hydraulic hysteresis and the alternate D-W cycles. The model was successfully validated by using experimental results from previous studies.

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CHAPTER ONE
INTRODUCTION

1.1 Research Background

When soil is unsaturated, its water pressure is less than the atmospheric pressure; this situation is represented as a negative pore pressure or 'suction'. A negative pore pressure contributes to an increase in the shear strength of the soil due to the presence of suction stresses (Lu and Likos, 2006). Matric suction is sensitive to environmental conditions: it increases under drying conditions and decreases under wetting conditions. Notably, this variation affects the mechanical behaviour of unsaturated soils (Chiu et al., 2014; Fredlund, 2006; Hatami et al., 2016; Hong et al., 2016).

Unsaturated soil mechanics are more complicated than classic saturated soil mechanics not only because of the complex role of suction but also because, at a given suction, the degree of saturation is not unique for a soil under drying and wetting conditions due to hydraulic hysteresis (Azizi et al., 2017; Rahardjo et al., 2004; Thu et al., 2006). In other words, at an identical suction, the degree of saturation during the wetting phase is less than that during the drying phase. Therefore, for a soil undergoing wetting, a fully saturated state cannot be attained even when the applied suction is zero (Estabragh et al., 2017; Liu et al., 2018; Dastjerdi et al., 2014).

During rainwater infiltration, the soil water content increases and eliminates the suction stresses which are considered stabilizing factors that pull the soil particles together. Therefore, during rainy seasons, soil is prone to failure (Li et al., 2016; Pasculli et al., 2017). Similarly, when a soil experiences D-W cycles due to varying seasonal climatic conditions, the soil strength and the water retention capacity of the soil both decrease; consequently, major geotechnical problems may arise (Allam and Sridharan, 1981; Cardoso et al., 2012; Chen and Ng, 2013; Pires et al., 2008; Tang et al., 2016; Zemenu et al., 2009). Therefore, D-W cycles have been regarded as a destructive environmental factor (Harrison et al., 2012).

D-W cycles affect the shear strength of unsaturated soil in two ways: first, D-W cycles produce variations in SWCC parameters (e.g., the air entry value and residual