Unsaturated Creep Behaviors of Weak Intercalated Soils in Soft Rock of Badong Formation

ZHU Yan-Bo1 http://orcid.org/0000-0001-7542-0454; e-mail: zhuyanbobd@126.com
YU Hong-Ming2 http://orcid.org/0000-0002-4986-2344; e-mail: yuhongming55@163.com

1 College of Geology Engineering and Geomatics, Chang’an University, Xi’an 710054, China
2 Faculty of Engineering, China University of Geosciences, Wuhan 430074 China


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Abstract: The cutting slopes in soft rock of redbed appeared in Yichang-Badong highway often suffer from the instability along weak intercalations, so the creep behaviors of weak intercalated soils are crucially important for the stability of cutting slopes. Because the deformation of weak intercalated soils is significantly affected by water content due to the strong water sensitivity, it is necessary to study the influence of matric suction on the creep behaviors of weak intercalated soils. In order to find out the unsaturated creep characters of weak intercalated soils, a GDS unsaturated triaxial apparatus was used. Then the triaxial creep experiments on weak intercalated soil samples under varying matric suction were conducted to obtain the unsaturated creep curves. The results show that the weak intercalated soils have obvious creep behaviors, and the creep strain is in nonlinear relationship with stress and time. When the matric suction is constant, a larger deviator stress will lead to a larger creep strain; When the deviator stress is constant, a smaller matric suction will lead to a larger creep strain. Based on the Mesri creep model, an improved creep model for weak intercalated soils under varying matric suction was established, in which the relationship of stress-strain was expressed with a hyperbolic function, and the relationship of strain-time was expressed with power functions in stages. Then an unsaturated creep model including stress-matric suction-strain-time for weak intercalated soils was established based on the power function relationship between matric suction and $E_d$ (a parameter of the improved creep model). The comparison of the calculated values of creep model and the experimental values shows that the creep behaviors of weak intercalated soils can be predicted by the unsaturated creep model by and large.

Keywords: Badong formation; Weak intercalated soils; Unsaturated creep behaviors; Soil triaxial apparatus; Creep model

Introduction

Yichang-Badong Highway passes the purplish red soft rock strata in Middle Triassic Badong Formation ($T_b^p$), the so-called "redbed". Numerous cutting slopes develop there and weak intercalations (Figure 1) with poor engineering properties in some cutting slopes are outcropped. This area is significantly affected by seasonal atmospheric cycles, especially in the rainy and hot summer. During the rainy seasons, the strength and deformation of the weak intercalations will deteriorate, which will worsen the stability of cutting slopes. The weak intercalated soils in cutting slopes are mostly unsaturated and under matric suction, thus they are usually stable. When the cutting slopes are dug out, however, water
content increases in the intercalated soils and matric suction decreases in the rainy season, so strength and deformation behavior of intercalated soils deteriorate, making the cutting slopes prone to instability.

Studies show that weak intercalations have certain rheological behaviors (Li and Kang 1983; Zhang and Peng 1997; Wang et al. 2007; Yang et al. 2008; Cheng et al. 2009). When the creep deformation accumulates in weak intercalated soils, the slopes under external influences will be more likely to slide along the weak intercalations.

Therefore, the creep behavior of weak intercalated soils is an important factor that affects the stability of cutting slopes. Current researches on creep behavior of soils focus on their saturated state, but the transformation of water content from unsaturated state to saturated state takes a long period of time and matric suction will also change at the same time, which affects the strength and deformation behavior of weak intercalated soils. Therefore it is necessary to study the unsaturated creep behavior of weak intercalation soils to guide the stability analysis and evaluation of this type of engineering cutting slopes.

The creep of saturated soil has been extensively studied in the past several decades. Many creep models based on laboratory tests have been put forward (Cheng 2009; Vaid et al. 1977; Augustesen et al. 2004; Lingaard et al. 2004). In these models, the relationship of stress-strain is usually expressed with a hyperbolic function (Charles 1989) and the relationship of strain-time is expressed with a power function (Singh and Mitchell 1968; Mesri et al. 1981). Many practical empirical models have been proposed as well, such as the Mesri model and the Singh-Mitchell model (Singh and Mitchell 1968; Mesri et al. 1981), which are widely used on the creep behaviors of various soils. These two models are later improved based on the experiments by Wang et al. (2005, 2006) to predict the creep behaviors of various soils.

However, there is little research on the creep behaviors of unsaturated soil compared with saturated soil. By measuring suction with a tensiometer, the unsaturated kaolinite clay was used in uniaxial compression creep test (Kierzkowski 2007) and unsaturated triaxial creep test (Schwarz et al. 2006). The creep behaviors of unsaturated expansive soil (Xiao et al. 2009; Ma 2012) and unsaturated loess (Cheng 2005) were also studied. Based on the unsaturated soil elastoplastic model (Alonso et al. 1990), an unsaturated soil visco-elastoplastic model considering the effects of suction and time was constructed by Priol et al. (2007). By controlling suction with a gas phase method, the one-dimensional compression creep behaviors of rockfill dam filling were studied, and the correlation between compression coefficient and total soil suction was revealed by Oldecop and Alonso (2007). Unsaturated triaxial creep test was conducted on a landslide sliding zone to build a creep model in consideration of matric suction (Lai et al. 2009, 2012).

In this paper, the exposed weak intercalated soils in soft rock cutting slopes along Yichang-Badong Highway were studied. A GDS unsaturated triaxial apparatus was used to conduct unsaturated creep experiments of weak intercalated soils. Based on the results, an unsaturated creep model of stress-suction-strain-time was built. The research shows that water content has significant effects on the creep behaviors of weak intercalated soils. This study can also provide new insights for analyzing and evaluating the long-term stability of this type of cutting slopes in anyplace.

1 Soil samples, Instruments and Methods

1.1 Properties of the weak intercalated soils

Soils were collected from the exposed weak