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Effect of densification on shear strength behavior of argillaceous siltstone subjected to variations in weathering-related physical and mechanical conditions

Y. Yin [a], B.Y. Zhang [a,b], J.H. Zhang [a,*], G.L. Sun [a]

[a] *State Key Laboratory of Hydroscience and Engineering, Tsinghua University, Beijing 100084, China*
[b] *Sanjiangyuan Collaborative Innovation Center, Qinghai University, Xining 810016, China*

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ABSTRACT

In order to study the effect of densification due to weathering on the strength behavior of soft rocks, this paper presents results of consecutive weathering and direct shear tests performed on an argillaceous siltstone. A specimen prepared with fresh argillaceous siltstone first underwent combined water and temperature variations under various stresses. Densification in weathering-related physical and mechanical conditions was indicated by measured dry densities. Then the weathered specimen was subjected to direct shear without remolding. The effect of densification during weathering on the shear strength behavior obtained from the subsequent direct shear tests was discussed. The study highlights that: (1) Densification during weathering is significant at stress values greater than 200 kPa. (2) Weathering leads to a 44% strength reduction of the fresh material with a stress of 50 kPa. (3) Weathering induced densification with a stress of 1400 kPa enhances the shear strength of the fresh material up to 259%.

1. Introduction

The first dam construction dates back to pre-pharaoh times of 3750 B.C. (Vogel, 2009). Some of these ancient dams are still in operation. Good examples are the ancient irrigation works, such as the old earth dams in Sri Lanka, the former Ceylon (Brohir, 1934), and the Dujiangyan dam built in 256 B.C. in Southern China (Chen, 2003). For decades, high rockfill dams have been built all over the world for hydroelectric purposes. A thin clay core or concrete face is supported by rockfill shoulders. It is, in many instances, the most economical and safe design for such dams (Cooke and Sherard, 1987; Sherard and Cooke, 1987; Hunter and Fell, 2003). However, long term dam behaviors are of particular interest if they are constructed from soft rocks.

Rockfillls used for dam construction are usually characterized by granular structure and wide range of grain size distribution. Its maximum size varies, for instance, from 300 mm of marl fragments for a motorway embankment in Portugal (Alonso and Cardoso, 2009) to 800 mm of argillaceous siltstone for a rockfill dam in China (Zhang et al., 2015). Its shear strength depends on the properties of the parent rock, the gradation, and the density (Marshal, 1973). Weathering induced degradation will take place during the dam operation when the rock is exposed to the environment where there are air, temperature, and water content variations. Soft rocks are more sensitive to weathering, such as drying/wetting and temperature variations (e.g. Pye and Miller, 1990; Erol and Ozkeskin, 2001; Nishiyama et al., 2005; Francois and Laloui, 2010).

Strength reduction of weathered soft rock was found significant (Sayao et al., 2005; Oldecop and Alonso, 2007). Cetin et al. (2000) examined the unconfined compressive strength of the weathered vesicular basalt at the Ataturk Dam in Turkey and found it was one tenth of that of the sound aphanitic basalt. Woo et al. (2010) studied the shear strength of joints in a porphyritic granite in terms of direct shear tests and indicated that it was reduced by 20–25% due to weathering. Miscevic and Vlastelica (2010) correlated the strength degradation of marls under wetting–drying process to unweathered strength and number of weathering cycle. Chiu and Ng (2014) used rock density to quantify the effect of chemical weathering. Zhang et al. (2015) reported that degradation and densification are two major mechanisms associated with strength behavior of weathered rocks.

To study the effect of densification due to weathering on the soft rock strength behavior, consecutive weathering and direct shear tests were conducted on argillaceous siltstone fragments using a weathering test apparatus (Zhang et al., 2014). Dry densities were measured of the specimen during combined water and thermal weathering under different stresses in order to examine the significance of densification. The effect of densification on the shear strength behavior of the weathered argillaceous siltstone was then discussed.

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* Corresponding author.
E-mail address: cezhangjh@tsinghua.edu.cn (J.H. Zhang).

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2. Methodology and test procedures

Zhang et al. (2014) presented a weathering test apparatus for soft rocks. Its split cell accommodates a specimen 150 mm in diameter and 150 mm in height. It functions as both an oedometer for weathering and a shear box for performing shearing tests. The apparatus, Fig. 1a, allows a direct shear test to be performed on a specimen right after weathering (Zhang et al., 2014). Using this apparatus, particle breakage

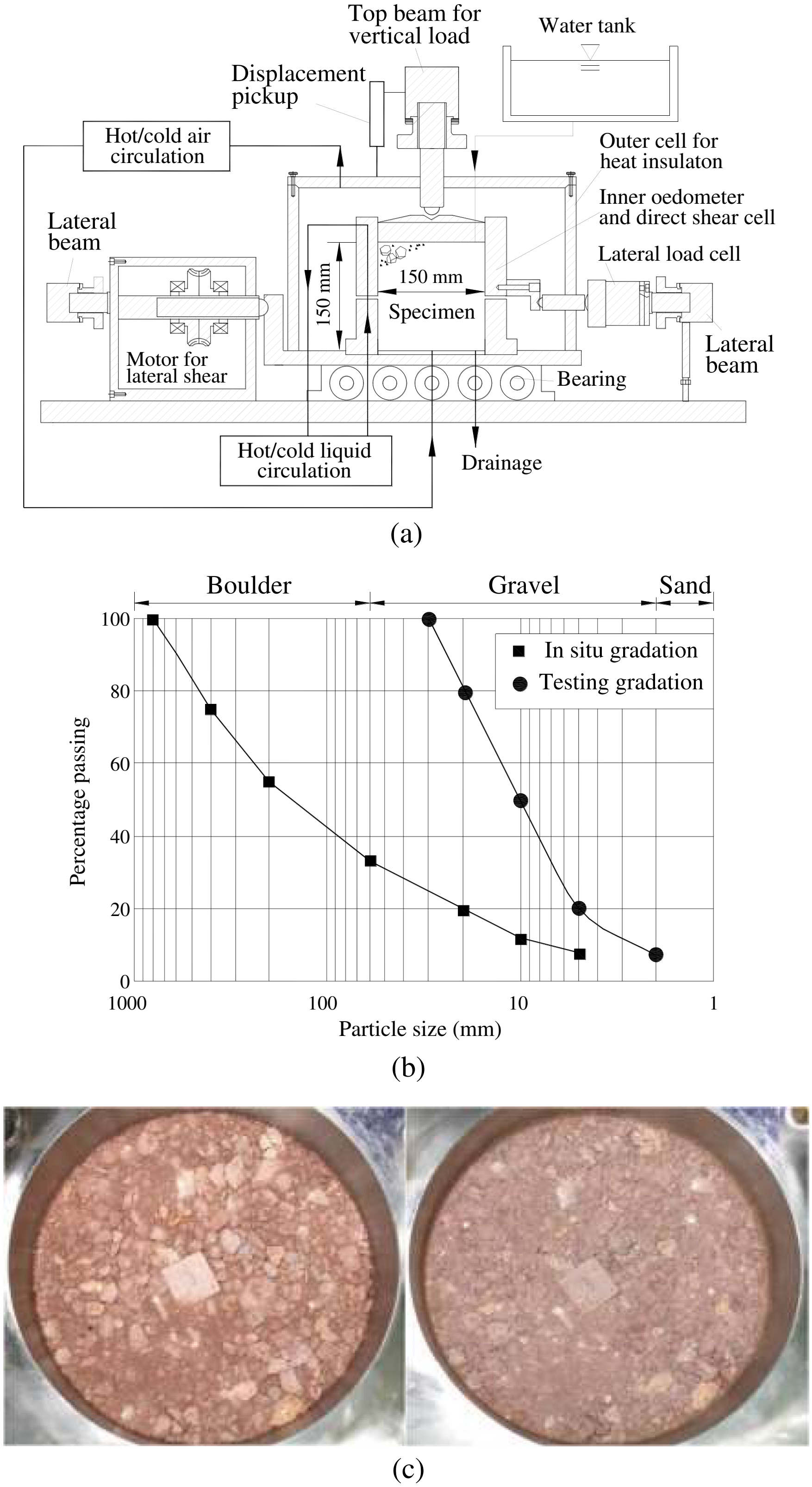

Fig. 1. (a) General scheme of the weathering test apparatus revised from Zhang et al. (2014); (b) Grain size distribution for materials used in tests (Zhang et al., 2015); (c) A specimen before and after weathering.