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# Microstructural observations of shear zones at cohesive soil-steel interfaces under large shear displacements

Belgacem Mamen*[1] and Farid Hammoud[2a]

[1]*Department of Civil Engineering, Faculty of Science and Technology, University Abbés Laghrour of Khenchela, Algeria*
[2]*Department of Civil Engineering, Faculty of Technology, University Mustapha Ben Boulaid of Batna, Algeria*

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**Abstract.** Failure mechanism which can affect geotechnical infrastructures (shallow foundations, retaining walls, and piles) constitutes one of the most encountered problems during the design process. In this respect, the shear behavior of interfaces between grained soils and solid building materials, as well as those between cohesive soils should be investigated. Therefore, a range of ring shear tests with different cohesive soils and stainless-steel interfaces have been carried out through the Bromhead apparatus that allows simulating large displacements along a failure surface. The effects of steel rings roughness and soil type on the residual friction coefficient and the shear zone features (structure, thickness, and texture orientation angle) have been investigated using the Scanning Electron Microscopy. The obtained results indicate that the residual friction coefficient and the structural characteristics of the shear zone vary according to the surface roughness and the soil type. Scanning electron microscopy reveals that the particles inside the shear zone tend to be re-oriented. Also, the shear failure mechanism can be identified along with the interface, within the soil, or simultaneously at the interface and within the soil specimen.

**Keywords:** failure mechanism; Bromhead apparatus; large displacements; cohesive soils; shear zone features; surface roughness

## 1. Introduction

Many geotechnical infrastructures, including shallow foundations, retaining walls and piles, made of construction material are often surrounded by fine-grained soil. Knowledge of soil-construction material interface shear behavior is one of the most important steps in the geotechnical design process. Consequently, a variety of laboratory shear tests have been extensively conducted through direct shear or simple shear tests to explain the interface shearing between soil and different building materials used in construction (Morgenstern and Tchalenko 1969, Tsubakihara *et al.* 1993, Takizawa *et al.* 2005, Li *et al.* 2012, Feligha *et al.* 2015, Wu and Yang 2017, Lee *et al.* 2017, Han *et al.* 2019, Heidemann *et al.* 2020). These experimental results have improved understanding of fine-grained soils shear behavior, but they could not adequately show the shear characteristics of fine-grained soils under large shear displacements.

As compared to the conventional direct shear and the simple shear devices, ring shear apparatus allows unlimited shear deformation of the specimen and recreates in the laboratory exactly the field conditions. Therefore, ring shear apparatus has been widely used to assess the shear behavior of soil under significant shear displacements such as the residual strength characteristics (Lemos *et al.* 2000, Wan and Kwong 2002, Meehan *et al.* 2007, Kimura *et al.* 2013, Eid *et al.* 2015, Xu *et al.* 2018, Eid *et al.* 2019) and shear band characteristics (Hicher *et al.* 1995, Wafid Agung *et al.* 2004, Fukuoka *et al.* 2006, Torabi *et al.* 2007, Li and Aydin 2013, Suzuki *et al.* 2017). Significant literature points out that the shear zone evolution in soils at the microscopic level is commonly accompanied by the variations in the grain size distribution (Wang *et al.* 2002, Coop *et al.* 2004, Jiang *et al.* 2016), the grain contact (Grelle and Guadagno 2010), the grain orientation (Chen *et al.* 2014), and the grain shape (Sadrekarimi and Olson 2010, Wei *et al.* 2018).

However, only a limited amount of work has studied the shear zone evolution in fine grained-soils at the microscopic level through ring shear tests (Mandl *et al.* 1977, Lupini *et al.* 1981, Khosravi *et al.* 2013, Al-Bared *et al.* 2019, Wang et al 2020). Mandl *et al.* (1977) have investigated the structural evolution of shear zones and the accompanying changes in texture and stress state in granular material undergoing continued shearing. As a conclusion, the shear zone can be compactive or dilative. Lupini *et al.* (1981) have conducted ring shear tests to measure the drained residual strength of cohesive soils. Three shearing modes in this study have been identified: a turbulent mode, a sliding mode and a transitional mode. All those modes depended on the clay fraction (% < 2 μm) and the particle size. In order to illustrate the effect of the shear displacement rate on the measured shear strengths, the particle arrangement and the surface asperities of the shear surface, slow and fast ring shear tests have been conducted on pre-sheared discontinuities in kaolinite by Khosravi *et al.* (2013). According to the test results, the “threshold” and “fast

*Corresponding author, Associate Professor
E-mail: belgacem.mamen@univ-khenchela.dz
[a]Professor
E-mail: f.hammoud @univ-batna2.dz


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