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Properties and microstructure of a natural slip zone in loose deposits of red beds, southwestern China

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ABSTRACT

The loose deposits of red beds located in southwestern China are vulnerable to the occurrence of landslides. In this paper, a shallow progressive landslide developed in loose deposits of red beds was selected as a case study, and the physical and mechanical properties of the main slip zone were analyzed in detail. It was observed that the main slip zone of the progressive landslide is composed of fine-grained soils with substantial amounts of expansive clay particles (interlayered illite/smectite and interlayered chlorite–smectite). The one-dimensional consolidation test of the residual soils shows that the soils are overconsolidated. The shear stress versus shear displacement curves reveal that the slip zone soil has exhibited a strain softening behavior. The residual friction angle of the undisturbed slip zone soil determined by the ring shear tests is 7.2°, indicating that the residual strength of the soil is very low when in a saturated state. The microstructure of the slip zone was investigated using a combination of images captured by means of polarising microscopy (PM) and scanning electron microscope (SEM) techniques. It was found that the slip zone possessed generally softer structure with higher relative porosities than its confining materials. The microstructure of the slip zone is generally characterized by its softer structure and higher degree of alignment of fine silts, suggesting that the slip zone underwent two deformation processes (i.e. dilatancy and particle rearrangement). The global mechanical behavior of the investigated slip zone may be conceptualized as an overconsolidated clayey soil under drained conditions.

1. Introduction

The slip zone is one of the key elements of a landslide and bears rich characteristic signatures of the landslide. Analyses of the physical properties and microstructure of slip zones are very valuable for understanding the mechanisms of landslides and shear behaviors of soils (Wen and Aydin, 2003). Morgenstern and Tchalenko (1967) presented microstructural observations from natural slip zones developed in clays. Due to difficulties in locating, excavating and sampling natural slip zones during ground investigations, only a small number of microstructural observations of the natural slip zones have been reported in literature (e.g. Larue and Hudleston, 1987; Anson and Hawkins, 1999; Wen et al., 2001; Wen and Aydin, 2003, 2005; Kawamura et al., 2007; Yenes et al., 2009). On the other hand, some studies have been devoted to microstructural analyses of laboratory-produced shear zones consisting of different types of soils (e.g. Lupini et al., 1981; Klukanova and Modlitba, 1990; Dewhurst et al., 1996; Frost and Jang, 2000).

Landslide slip surfaces can be considered as shear zones where movement-related structures are recorded (Wen and Aydin, 2003). According to Yenes et al. (2009), shear zones may be subdivided into (1) brittle shear zones, with discontinuity surfaces along with the movement take place; (2) ductile shear zones, with ductile continuous strain along the shear zone and strain compatibility with the surrounding rocks; and (3) brittle-ductile shear zones, where ductile shear zone features appear accompanying discontinuity elements. On shallow landslides with low-plasticity dry materials in the sliding zone the deformation usually behaves in a brittle manner, whereas on high-plasticity wet materials it will be ductile (Larue and Hudleston, 1987).

The term red beds refers to a series of fuchsia or variegated sedimentary formation belonging to the Jurassic, Cretaceous and Tertiary strata, which are widely developed in southwestern China, a region characterized by high mountain relief and abundant precipitation. The shallow surface layers on the slopes in the area are generally composed of loose deposits (i.e. residual, alluvial, diluvial or colluvial deposits) caused by intense weathering, erosion or mass movement. In combination with the region's monsoon climate, engineering activities and weak geologic conditions, the region is highly susceptible to landslides (Chen et al., 2005, 2008). However, the deformation processes and mechanisms of the loose deposit landslides in red bed area are still

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poorly understood. Therefore, it is of great significance to study the development characteristics and properties of the slip zone for the purpose of landslide hazard mitigation and treatment.

The present study attempts to perform the following: (a) comprehensively investigate the physical and mechanical properties of a natural slip zone in loose deposits of red beds; (b) analyze the microstructural characteristics of the slip zone; and (c) interpret the deformation mechanism of the slip zone.

2. Site description

The investigated landslide occurred at the center of the resettlement site of Xin'an Township, Pingshan County, Sichuan Province, southwestern China (Figure 1). The resettlement site lies on the left bank of the midreaches of the Xiangjiaba reservoir. The microtopography is characterized by the valley slope landform. The natural slope ranges from 10 to 27° and the elevation from 380 to 470 m asl. The Wannian Mountain is located to the north of the resettlement site and its peak elevation is 527 m asl. This area has a monsoon climate and the mean annual rainfall for 1991–2004 was about 960 mm. The rainfall from June to September every year accounts for 70% of the annual total.

In the resettlement site, a mantle of Quaternary deposits overlies the Suining Formation of the Upper Jurassic System, which comprised fuchsia weathered sandy argillite (J_3S). The deposits are red in color and derived mainly from in situ weathering and partly from taluvium process. The main constituents of the soils are clays, with some minor

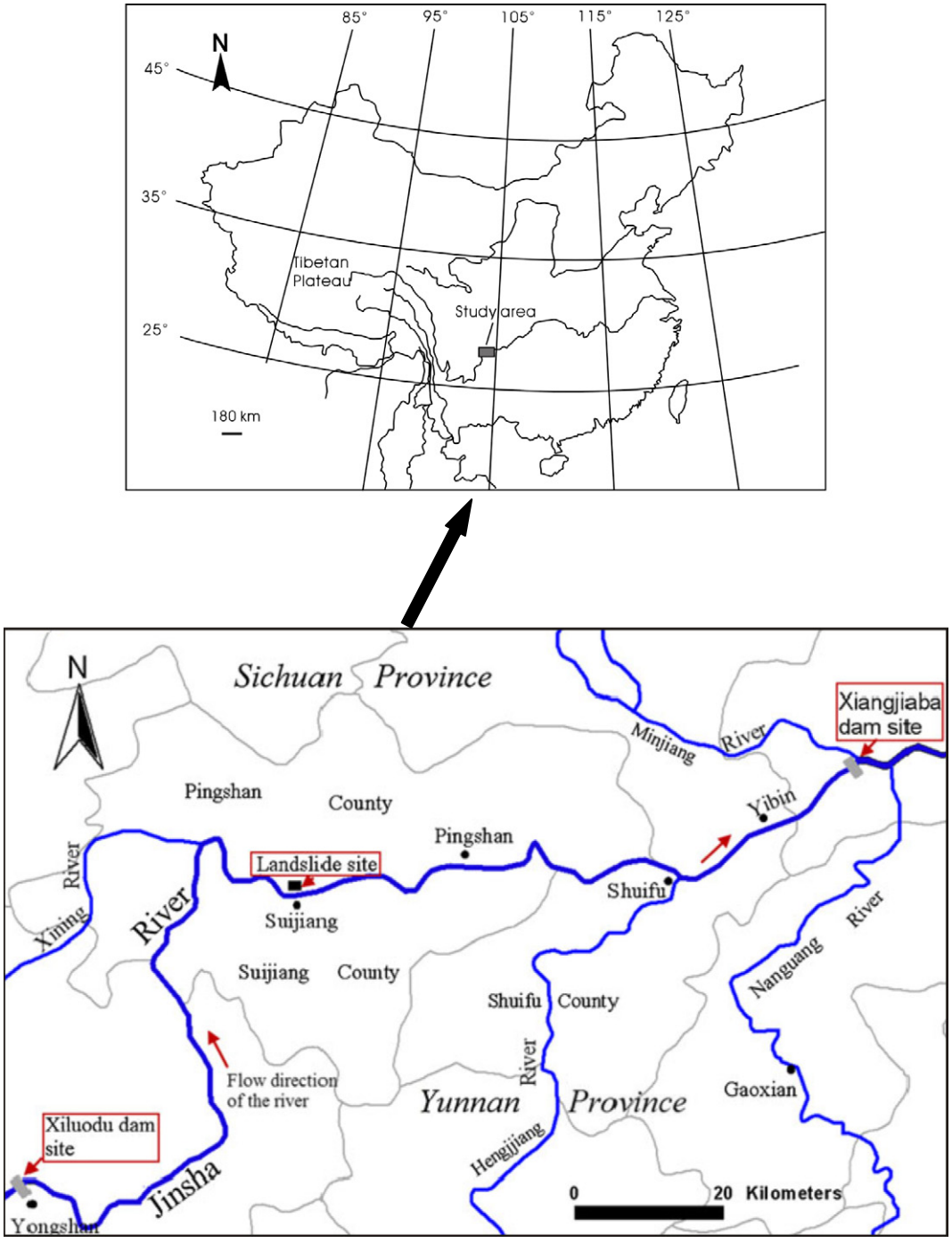

Fig. 1. Simplified map showing the location of the landslide.