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Ring shear tests on slip zone soils of three giant landslides in the Three Gorges Project area

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ABSTRACT

Reactivation of large-scale landslides along the reservoir banks of the Three Gorges Project (TGP) is recognized as the most likely form of geohazards threatening safety and operation of the dam and the navigation. This study presents an investigation into the naturally drained shear properties of slip zone soils of such landslides. Twenty-seven specimens of slip zone soils of three giant landslides are tested at three shearing rates (0.1, 1 and 10 mm/s) by means of a large ring shear apparatus accommodating abundant coarse particles in the specimens. It is observed that a) soils with higher plasticity index or liquid limit tend to have lower residual shear strength; this influence of the Atterberg limits on the residual shear strength weakens as the shearing rate increases; b) even small variations in the particle size distribution (*PSD*) cause notable differences in shear properties. The *PSD* parameters, such as the coefficient of curvature, sand content, ratio of gravel content to the sum of remaining contents, and ratio of coarse fraction to fine fraction, have close correlations with the residual strength; and c) the residual strength is clearly affected positively by particle symmetry (quantified by elongation) and negatively by surface smoothness (quantified by convexity).

1. Introduction

Around 2490 landslides of various scales have been identified in the Three Gorges Project (TGP) area in Central China, and more than 70 failures have occurred since 1982 causing at least 363 fatalities (Dai et al., 2004; Liu et al., 2004; Wen et al., 2007). Some of the seemingly dormant landslides have significant reactivation potential as the water level rises up with the completion of the dam construction and impoundment of the reservoir. The Qianjiangping landslide, one of the landslides investigated in this study, occurred just 14 days after the reservoir water level rose from 95 m to 135 m, though earlier investigations of slope stability in the TGP area discovered no sign of its activity (Dai et al., 2004).

Investigation into the residual strength of slip zones is of great importance for better understanding and mitigating landslides, though this involves mechanical uncertainties and practical difficulties in locating and sampling the slip zone (Hutchinson, 1988; Wen and Aydin, 2005). Since the early 1960s (Skempton, 1964), both the drained and undrained residual strength were extensively studied using a variety of experimental techniques (Bishop, 1971; Lupini et al., 1981). Previous research revealed Atterberg limits (liquid limit *LL* and plasticity index I_p), particle shape (symmetry and smoothness), stress history (over-consolidated ratio, OCR), testing methods (triaxial, ring shear or direct shear) and testing conditions (normal stress level and shearing rate) as the most influential parameters of shear behavior (Skempton, 1964; Kenney, 1967; Townsend and Gilbert, 1973).

This study presents an investigation into the naturally drained shear properties of slip zone soils of three giant landslides in the Three Gorges Project Area. These soils typically contain abundant coarse particles which necessitate a large ring shear apparatus for determining the residual shear strength. This study is a rare example of a systematic series of such tests designed to explore possible relationships between the residual shear strength and Atterberg limits, shear rate, particle size distribution (*PSD*) and a number of selected *PSD* parameters, including the coefficient of curvature (C_c) and sand content.

2. Nature of investigated landslides

In the present study, samples are collected from the slip zones of three landslides (Qianjiangping, Xietan and Tanping) in the TGP area (Fig. 1). These effectively represent a large number of landslides in this area, in terms of materials and nature of their slip zones, which are either exposed or accessible through an exploration adit or shaft.

Qianjiangping landslide (QJP) (Fig. 2) is a representative of the landslides developed along bedding planes of weak rocks. It occurred

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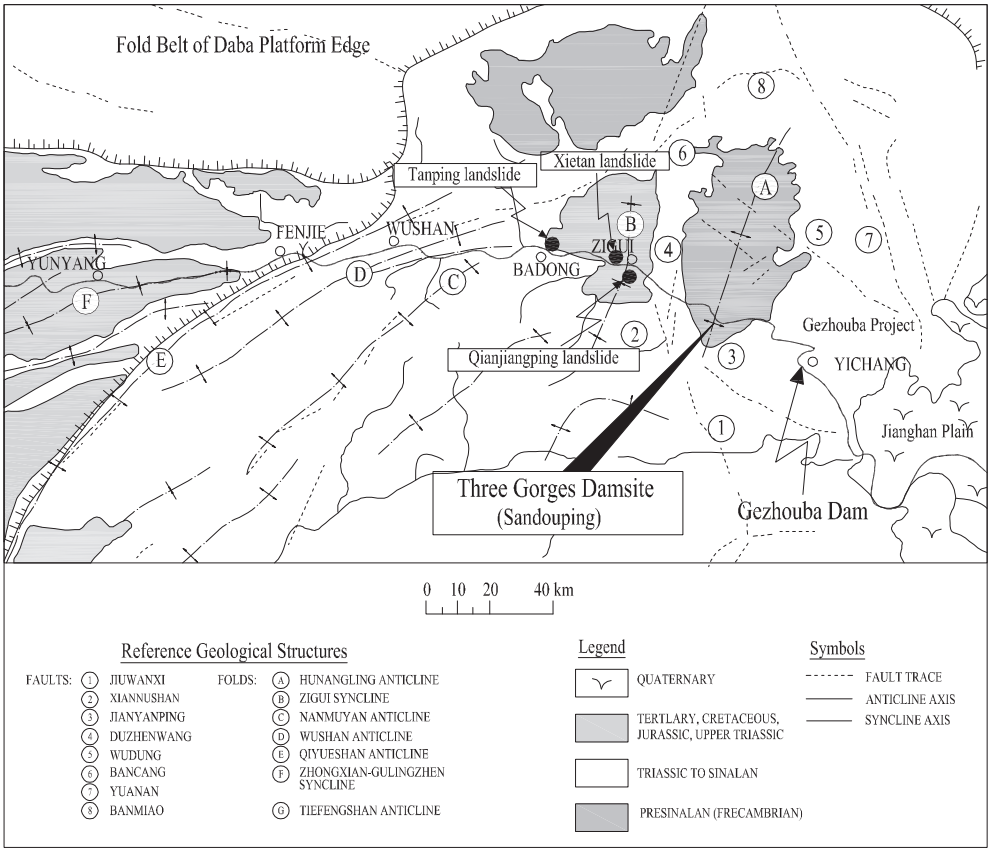

Fig. 1. Geological map of the Three Gorges Project area (after Mason, 1999).

Fig. 2. General view of Qianjiangping landslide (Liao et al., 2005).

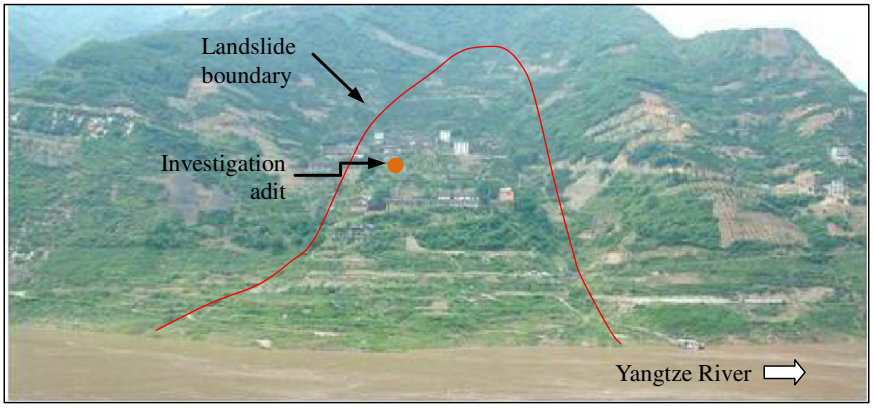

Fig. 3. General view of Xietan landslide.