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Shear strength of purple soil bunds under different soil water contents and dry densities: A case study in the Three Gorges Reservoir Area, China

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ABSTRACT

Purple soil bunds are embankments constructed along the contour on purple soil sloping farmlands, and play a key role in controlling soil erosion. The soil shear strength makes a significant influence to the bund stability; however, few reports have documented how purple soil shear strength responds to the soil physical properties. The main goal of the present study was to determine how indicators of soil shear strength vary with the soil water content and dry density. In this study, we collected soil samples from 3 purple soil bunds in Zhong County, in the Three Gorges Reservoir Area in China, and performed an unconsolidated undrained triaxial compression test to study the soil shear strength in terms of the cohesion (c), internal friction angle (φ), and the principal stress difference (σ_1–σ_3). The test results show that when the dry density was constant and the soil water content increased, the soil cohesion increased and then decreased, and the results fitted to a quadratic curve. As the soil water content increased, the internal friction angle of the soil bunds decreased and displayed a first-order exponential decay. As the soil water content increased and the confining pressure remained constant, the principal stress difference decreased rapidly. When the soil water content was constant and the dry density increased, the soil cohesion, internal friction angle, and the total principal stress difference increased, although at different rates. In general, the water content had a greater effect on the cohesion, internal friction angle, and the principal stress difference than the dry density, but there were little or no interaction between water content and dry density. Furthermore, except when the water content was 6%, the stress–strain characteristics were similar across the range of water contents. For a low water content, fixed confining pressure, and an increasing dry density, the curves gradually changed from the hardening type to the weak hardening type and then to the softening type. In most cases the curves corresponded with the hardening type as the confining pressure increased.

1. Introduction

Bunds are embankments constructed across the slope and along the contour on sloping farmlands to mark the boundaries between land plots and define their ownership, generally made of stone, soil or a combination of both (Walle et al., 2017). They cut the slope length and intercept runoff to reduce the volume and erosivity of the surface flow on sloping farmlands (Gebrernichael et al., 2005; Amare et al., 2014; Jemberu et al., 2017). Eroded sediment between two level bunds is deposited behind the lower bund and sloping farmlands gradually change into a bench terrace (He et al., 2009). Farmers, especially those in mountainous areas, have experience in cultivating plants such as soybeans, lima beans, and sorghum on various types of soil bunds, and have achieved both economic benefits and positive outcomes for soil conservation (Gebremedhin et al., 1999; Raes et al., 2007; Zhang et al., 2015a). Although agri-spillways (Rodrigo-Comino et al., 2017), hedgerow (Bu et al., 2008; Cao et al., 2015), contour ploughing and no-tillage (Constantin et al., 2010) have been proven to be efficient to reduce soil losses, the erosion reduction effect of these measures are not estimated as good as the bunds at the rainy season with luxuriant foliage (Monsieurs et al., 2015; Wei et al., 2016).

As the most important cropland resource in the Three Gorges Reservoir area, the purple sloping farmland has suffered severe soil erosion, which has great impact on the operation life of the Three Gorges Reservoir and local eco-environment (Wei et al., 2016). The Sloping Land Conservation Program (SLCP) is an important program

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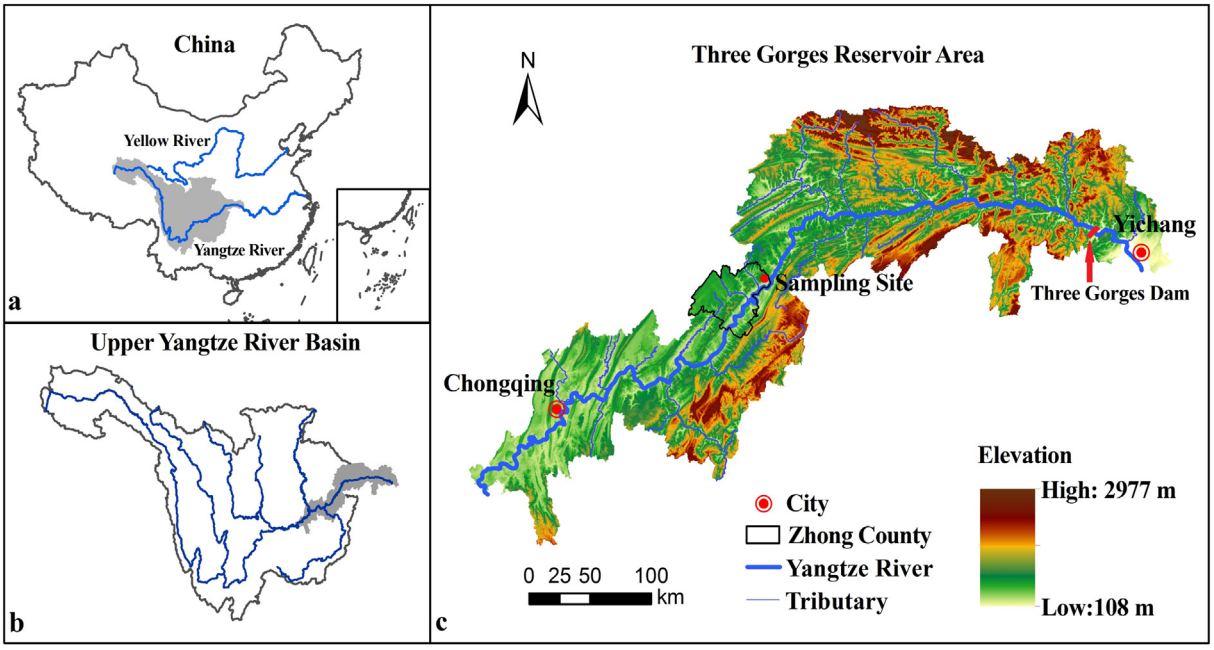

Fig. 1. The location of the study area, with a picture of bund landscape on slopping farmlands (photo taken: 18 March 2014).

Table 1
Properties of sampled soil.

Soil type	Soil texture	Mean porosity/%	Bulk density/(g cm^{-3})	Grain composition/%		
				Clay (< 0.002 mm)	Silty (0.002 to 0.05 mm)	Sandy (> 0.05 to 2 mm)
Purple soil	Silt loam	43.39	1.47 ± 0.04	6.2 ± 1.72	78.1 ± 2.27	15.7 ± 2.56

laid out for sloping farmland consolidations and low- and medium-yield farmland upgrades in the Three Gorges Reservoir Area. Stone and soil bunds are planned and built under this program. While stone bunds have the advantages of being stable and easy to walk on, they are expensive to build and their construction is both labor- and machine-intensive. Soil bunds are therefore preferred because they cost less to construct and achieve similar reductions in soil erosion as the stone bunds (Sudhishri et al., 2008; Cao et al., 2015; Fan et al., 2015). To date, studies of soil bunds have mainly focused on planting screening fences, hedgerow construction, and monitoring their effectiveness (e.g. Lin et al., 2009; Amare et al., 2014; Lacoste et al., 2014; Fan et al., 2015).