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Field study of treatment for expansive soil/rock channel slope with soilbags

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ABSTRACT

A full-scale field test in the South-to-North Water Transfer Project (SNWTP) in China was conducted on a 60 m long expansive soil/rock channel slope reinforced with soilbags. The field test involved the construction of the soilbags, the rising and falling of the channel water level as well as the natural and artificial rainfalls. During the testing period, in-situ monitoring of water contents, earth pressures and lateral displacements was conducted. It was found that: 1) the water content of the expansive soil/rock slope changed slightly with the rainfalls and other environmental factors after the reinforcement with soilbags; 2) the earth pressure measured under the soilbags layer was close to its overburden pressure with no swelling pressure of the expansive soil contained in the bags; and 3) the lateral displacement of the expansive soil/rock channel slope mainly occurred before the construction of the soilbags layer and tended to be stable after the completion of the soilbags layer. The monitored results suggested the effectiveness of soilbags to prevent moisture migration, mitigate the swelling potential and enhance the slope stability.

1. Introduction

Expansive or swelling soil is a highly plastic soil that typically contains montmorillonite and other active clay minerals. It exhibits significant swelling and shrinking upon wetting and drying (Dif and Bluemel, 1991; Zemenu et al., 2009; Ito and Azam, 2010), and usually an abundance of cracks and fissures develop in the upper part of the soil profile (Morris et al., 1992; Shi et al., 2002; Li et al., 2012). There are many factors that govern the behaviors of an expansive soil, among which the primary ones are the availability of moisture, and the amount and type of the clay-size particles in the soil (Day, 2000). Therefore, the treatment ways for expansive soils may be classified into two categories: one is the so-called mechanical and chemical stabilization (Estabragh et al., 2014) and the other is to retard moisture movement within the soil. The mechanical stabilization may include the sand cushion method (Satyanarayana, 1969), the cohesive non-swelling (CNS) layer method (Katti, 1979), the deep soil mixing (DSM) method (Madhyannapu et al., 2009; Madhyannapu and Puppala, 2014) and the synthetic reinforcement method (Al-Omari and Hamodi, 1991; Aytekin, 1997; Ikizler et al., 2008, 2009; Viswanadham et al., 2009a,b; Trouzine et al., 2012). In the chemical treatment method, lime is the most effective and economical added materials (Chen, 1988; Calik and Sadoglu, 2014). Besides, calcium chloride, fly ash and cement are also commonly used (Desai and Oza, 1977; Cokca, 2001; Al-Rawas et al., 2005; Sharma et al., 2008). The retardation of moisture movement within soils may be achieved by the coverage with natural grass cover (Zhan et al., 2007) or geomembrane and geotextile cover (Bouazza et al., 2014; Heibaum, 2014; Safari et al., 2014).

Now in China, the South-to-North Water Transfer Project (SNWTP) with three diversion routes, respectively named as the eastern, the central and the west lines, is under construction. The central diversion route is 1200 km long, of which about 180 km open channel has to pass through the expansive soil land (Ng et al., 2003). Hence, the stability of the expansive soil channel slope is particularly important for the project. The basic way to stabilize the expansive soil channel slope is to replace the expansive soils near the surface of the channel slope (about 2 m thick) with non-

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expansive soils. However, as non-expansive soils have to be taken from areas far away from the construction site, the soil replacement way is expensive and also has some expropriation and environmental problems. Therefore, alternative ways of treating expansive soil slope have to be studied. In recent years, extensive studies have been made during the construction of the SNWTP and many other methods have been proposed for the treatment of expansive soil slopes, one of which is the use of soilbags filled with expansive soils.

Soilbags, namely geotextile bags filled with soil or soil-like materials, are commonly used in improving the bearing capacity of traditional earthworks (Matsuoka and Liu, 2006). In recent years, soilbags have been developed in some other geotechnical engineering, such as, construction of coastal protection barriers (Martinelli et al., 2011), prevention of frost heave (Li et al., 2013), reduction of mechanical vibration (Liu et al., 2014), and inclusion of retaining walls constructed in expansive soils (Wang et al., 2015). This study presents the use of soilbags to treat the expansive soil/rock channel slope. Fig. 1 shows the schematic view of the treatment for expansive soil/rock channel slope using soilbags (only the right bank is given although the left bank was treated in the same way). The expansive soils excavated in the construction field are filled into woven polypropylene bags to form soilbags, which are then arranged on the surface of the expansive soil slope to be treated. The assembly of soilbags arranged on the slope is regarded as a reinforcement layer and takes effect of restraining the expansion and contraction of expansive soils.

In the companion paper of reference (Liu et al., 2012), the reinforcement principle of soilbags and a conventional limit equilibrium equation for the stability analysis of the reinforced expansive soil slope have been presented. A series of laboratory tests were conducted and it was found that soilbags can enhance the strength and restrict the swelling deformation of the expansive soil. The permeability coefficient of the soilbag assembly ranges from 10^{-5} cm/s to 10^{-6} cm/s, which makes it possible to minimize the variation of the water contents not only in the soilbag assembly (the reinforced layer) but also in the underlying expansive soils, probably caused by the rainfall or the change of the underground water. The soilbags assembly has also a relatively high equivalent coefficient of interlayer friction because of the “interlocking effect” in the gaps between soilbags.

In this current paper, a full-scale field study of enhancing expansive soil/rock channel slope with soilbags is presented. The field test involved the construction of soilbags, the rising and falling of the channel water level as well as the natural and artificial rainfalls. During the testing period, in situ monitoring of water contents, earth pressures and lateral displacements was conducted, from which the effectiveness of enhancing expansive soil/rock channel slope with soilbags was evaluated.

2. The test site and soil profile

The test site is located in the city of Xinxiang, about 100 km North of Zhengzhou, Henan Province, China. The site is a semiarid area with an average annual rainfall ranging from 557 mm to 752 mm. About 60–70% of the annual rainfall occurs in the flood season during June and August. The average daily evaporation is about 1.3 mm and the maximum one is 5 mm.

The test site was selected on a cut slope that was prepared as part of an excavation canal (see Fig. 1). The total length of the test channel is 60 m. The slope had a mean excavation depth of 30 m, and an inclination angle of 22° (slope ratio 1:2.5) to 33.7° (slope ratio 1:1.5). The soil profile in the cut slope mainly consists of the following four layers:

(1) Brown-yellow heavy silt loam layer. It is distributed in the uppermost slope with a thickness of 2–7 m and characterized as a non-expansive soil.
(2) Gray-white marlite with a thickness of 17–18 m. The detritus minerals of the marlite are mainly composed of calcite (49–66%) and silica (10–44%); the clay minerals are mainly composed of montmorillonite and illite, accounting for 20–35% of the total mineral components. The montmorillonite and illite leads the marlite to be an expansive soil/rock with a free swelling ratio ranging from 40% to 60%. There exist many gravels and block stones as well as some invisible cracks and fissures in this layer.
(3) Brown clay rock with a depth of 7–8 m. The detritus minerals of this layer are mainly composed of calcite (9–31%) and silica (37–50%). The clay minerals account for 26–47% of the total mineral components with more montmorillonite than illite. The free swelling ratio of this layer ranges from 50% to 70%, characterizing as a medium expansivity.
(4) Brown-red sandy conglomerate distributed below the bottom of the channel. The free swelling ratio of this layer is about 50%.

The treatment of the channel slope with soilbags is mainly involved in the second and the third layers, i.e. the marlite layer and the clay rock layer. The characteristics of these two expansive soil/rock layers are given in Table 1.

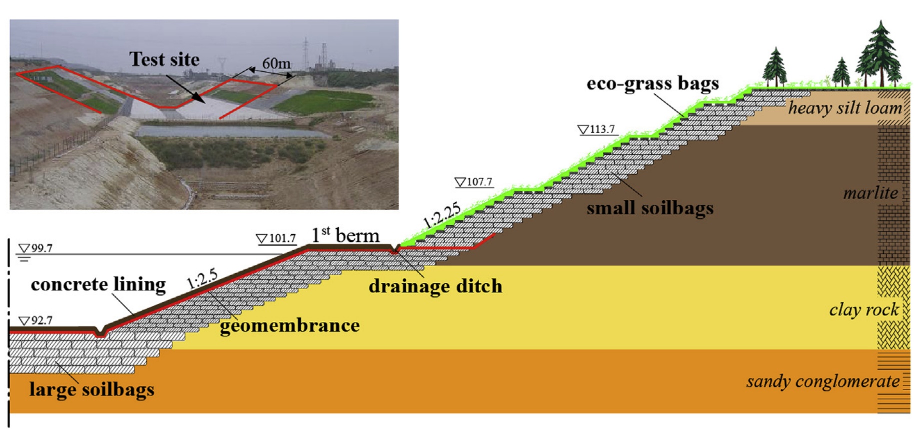

Fig. 1. Schematic view of the treatment for expansive soil/rock channel slope using soilbags.