



Experimental study on vibration reduction by using soilbags



Si-Hong Liu^a, Jun-Jun Gao^{a,*}, Yan-Qiao Wang^b, Li-Ping Weng^c

^a College of Water Conservancy and Hydropower, Hohai University, Xi-Kang Road 1#, Nanjing 210098, China

^b School of Civil Engineering, Hefei University of Technology, Tun-Xi Road 193#, Hefei 230009, China

^c Business School of Hohai University, Xi-Kang Road 1#, Nanjing 210098, China

ARTICLE INFO

Article history:

Received 14 July 2013

Received in revised form

19 November 2013

Accepted 19 December 2013

Available online 15 January 2014

Keywords:

Soilbags

Vibration reduction

Damping effect

Laboratory tests

Soilbag-filled trench test

ABSTRACT

The effectiveness of soilbags in reducing mechanical vibration is investigated, and the influential factors are examined through a series of laboratory tests, including cyclic lateral shear tests, vertical excitation tests and small shaking table tests as well as a soilbag-filled trench field test. The test results illustrate that soilbags have a relatively high damping ratio and variable horizontal stiffness, which are greatly influenced by the materials inside the bags at low vertical stress but become nearly independent of the materials inside the bags at high vertical stress. We find that vertical and horizontal vibrations can be effectively reduced through the use of soilbags.

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1. Introduction

Vibrations due to traffic, piling, blasting, industrial activities, construction and natural accidents such as earthquakes can potentially damage buildings, adversely impact people's lives and affect sensitive equipment and technical processes (Murillo et al., 2009). Thus, the reduction or isolation of these vibrations has become an important issue in recent years.

In general, the adverse effects of vibrations can be prevented by implementing a suitable wave barrier or isolation measures between the source and the structure to be protected. Different types of wave barriers, varying from stiff concrete walls or piles to sufficiently flexible gas cushions and geofoam, have been developed and implemented (Horvath, 1997; Wang et al., 2006; Zarnani and Bathurst, 2008). Among these barriers, both open and in-filled trenches are the most widely used in practical applications because they present effective and low-cost isolation measures (Adam and von Estorf, 2005). Laminated rubber bearings and damping isolation devices are also commonly used in spite of their relatively high installation and maintenance costs.

In recent years, soilbags, which are composed of geotextiles and are filled with soil or soil-like materials, have been widely used in the reinforcement of soft building foundations and retaining walls

(Matsuoka and Liu, 2003, 2006; Liu and Matsuoka, 2007) and in the construction of dikes and revetment (Martinelli et al., 2011; Oberhagemann and Hossain, 2011), even though they were initially considered as temporary structures for fighting floods (Kim et al., 2004). These applications are mainly the result of increased research on soilbags. Matsuoka and Liu (2003) experimentally and theoretically investigated the mechanical performance of soilbags; they found that soilbags have a very high compressive strength. For example, an ordinary polypropylene (PE) bag filled with crushed stones or sand (approximately 40 cm by 40 cm by 10 cm) can withstand a load of up to 230–280 kN. The high compressive strength of soilbags can theoretically be explained by an additional cohesion that develops in soilbags resulting from the tensile forces in the bags under an external load. The mechanical performance of soilbags was further studied by Xu et al. (2008). Lohani et al. (2006) conducted a series of full-scale loading tests on soilbag piles, and the effects of soilbag material, backfill soil type, number of soilbags in the pile and effects associated with the end restraint at the top and bottom ends of the soilbag pile were evaluated. The mechanical behavior of a soilbag under vertical compression was numerically investigated by Tanton and Bauer (2008a,b) using a micro-polar hypoplastic model for the soil behavior and an elastic-ideally plastic model for the wrapping material. In particular, the influence of the interface behavior between the soil and the bag material on the stress–strain behavior of the soilbag structure and the influences of the initial density of the soil, mean grain size and the rotational resistance of the soil particles at the interface were

* Corresponding author. Tel.: +86 15205152405; fax: +86 25 83786727.
E-mail address: gaojunjun700@163.com (J.-J. Gao).

examined. Ansari et al. (2011) numerically analyzed the mechanical behavior of a soilbag subject to compression and lateral cyclic shear loading and reported that the stiffness and compressive load capacity of a soilbag are considerably higher than those of an unwrapped granular material. Studies on the use of soilbags as reinforcement for soft building foundations have shown that soilbags not only significantly increase the bearing capacity of foundations but also reduce traffic-induced ground vibrations when buried into the foundation (Matsuoka and Liu, 2003). The effect of soilbags on vibration reduction has been preliminarily illustrated through several laboratory and field tests (Matsuoka et al., 2005; Nakagawa et al., 2009). A soilbag-barrier field test was simulated by Ye et al. (2011) using the dynamic finite element method, and the vibration damping effect of soilbags was numerically assessed. It has been suggested that the extension and contraction of the bag and the frictional motion of the soil particles within the bag play significant roles in dissipating vibrational energy (Matsuoka et al., 2005). Yamamoto et al. (2003) performed a series of large-deformation laboratory tests on soilbags filled with silica sand and introduced an “equivalent damping ratio” to evaluate the vibration reduction of soilbags. It was found that this ratio was much higher for an assembly of soilbags in comparison to concrete structures and steel structures by ratios of 6 and 15, respectively.

This paper presents a further study on the vibration reduction effect of soilbags and its influential factors. A series of laboratory tests including cyclic lateral shear tests, vertical excitation tests and small shaking table tests and a soilbag-filled trench field test were conducted.

2. Cyclic lateral shear tests

2.1. Test apparatus

The vibration reduction of soilbags is associated with the dynamic properties of soilbags, which can be investigated through cyclic lateral shear tests. A simple apparatus was designed to conduct cyclic lateral shear tests on the soilbags. As shown in Fig. 1, the apparatus consists of two electrically controlled wheels that pull the soilbag specimens horizontally, a vertical loading frame and a data acquisition system. The level of the two wheels can be adjusted using screws in accordance with the height of the soilbag specimens. A rigid platen is placed on the top of the soilbag column. The vertical load is applied to the rigid platen by means of an oil jack and is measured by a load cell. The horizontal (shear) force, from which the shear stress of the soilbag column is calculated by dividing by area of the soilbag (1600 cm^2), is applied by pulling the rigid platen with a steel chain and is subsequently measured using two load cells connected to the two wheels. The horizontal (shear) deformation of the soilbag column, from which the shear strain of the soilbag column is calculated by dividing by the height of the

soilbag column, is measured by two displacement meters attached to two ends of the rigid platen.

2.2. Soilbag samples

Three types of soils, two sands (the relatively fine sand is herein called river sand, and the other is denoted as coarse sand) and a loamy soil acquired near the laboratory, were used to fill the PE bags. The properties of the filled soils are listed in Table 1, and the particle size distributions are shown in Fig. 2. The properties of the PE bags are as follows: the mass per square meter is 110 g; the warp and weft tensile strengths are 25 kN/m and 16.2 kN/m, respectively; the warp and weft elongations are both less than 25%; and the warp and weft tensile modulus are 161 kN/m and 138 kN/m, respectively. Approximately 30 kg of soil was used to fill each bag, and the bag mouth was sealed with a manual sewing machine. Next, the soil-filled bag was placed on the ground and compacted with a small plate vibrator. After compaction, each soilbag had dimensions of approximately 40 cm long, 40 cm wide and 10 cm high, which is similar to the soilbag used by Matsuoka and Liu (2006) and corresponds to the smallest soilbag used in practical applications (as it can be easily handled by workers). Four soilbags were piled vertically to form one sample.

2.3. Test scheme

First, cyclic lateral shear tests were conducted on the soilbags filled with river sand under four vertical stresses of 50 kPa, 100 kPa, 200 kPa and 300 kPa. Under each vertical stress, the samples were cyclically sheared up to the shear strain $\gamma_{\max} = 0.25\%$, 0.5% , 0.75% and 1.0% , respectively. For the soilbags filled with either the coarse sand or the loamy soil, cyclic lateral shear tests were performed under the four different vertical stresses given above, but the samples were sheared up to the same maximum shear strain $\gamma_{\max} = 1.0\%$.

2.4. Results and discussion

Figs. 3 and 4 illustrate the measured stress–strain hysteresis loops of the river sand bags under different vertical stresses and different maximum shear strains, respectively. Each sample was laterally sheared for four cycles, and the stress–strain hysteresis loops are nearly identical. It was found that the stress–strain hysteresis loop enlarges with increasing maximum shear strain at the same vertical stress as well as with increasing vertical stress at the same maximum shear strain.

From the stress–strain hysteresis loop (see Fig. 5), the shear modulus G and equivalent damping ratio h_{eq} can be estimated as follows:

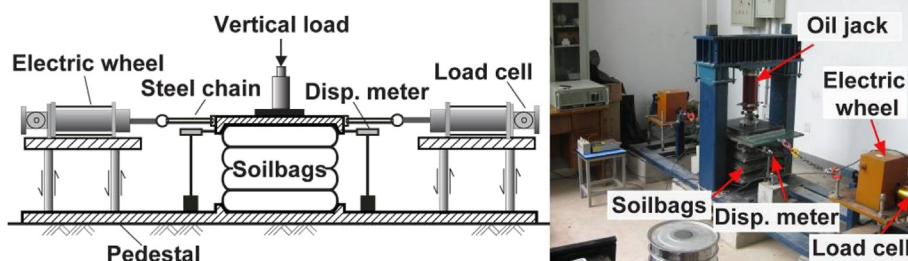


Fig. 1. Cyclic shear test on the soilbags.

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