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Pullout behavior of polymeric strip in compacted dry granular soil under cyclic tensile load conditions

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A B S T R A C T

Assessment of the reinforcement behavior of soil under cyclic and monotonic loads is of great importance in the safe design of mechanically stabilized earth walls. In this article, the method of conducting a multistage pullout (MSP) test on the polymeric strip (PS) is presented. The post-cyclic behavior of the reinforcement can be evaluated using a large-scale pullout apparatus adopting MSP test and one-stage pullout (OSP) test procedures. This research investigates the effects of various factors including load amplitude, load frequency, number of load cycles and vertical effective stress on the peak apparent coefficient of friction mobilized at the soil-PS interface and the pullout resistance of the PS buried in dry sandy soil. The results illustrate that changing the cyclic tensile load frequency from 0.1 Hz to 0.5 Hz does not affect the pullout resistance. Moreover, the influence of increasing the number of load cycles from 30 to 250 on the peak pullout resistance is negligible. Finally, the effect of increasing the cyclic tensile load amplitude from 20% to 40% on the monotonic pullout resistance can be ignored. The peak apparent coefficient of friction mobilized at the soil-PS interface under monotonic and cyclic load conditions decreases with the increase in vertical effective stress.

1. Introduction

Polymeric strip (PS) is a type of geosynthetics which is frequently used in mechanically stabilized earth walls (MSEWs). By considering the failure mechanisms in the MSEWs, direct shear and pullout tests are performed to investigate the soil-reinforcement interaction behavior (Palmeira, 2009). In the pullout conditions, the length of reinforcement which is located behind the rupture surface (anchorage length) is tested because the interaction is mobilized in this area. Several studies have been done on these strips such as Lo (1998, 2003). In these two studies, the behavior of PS was evaluated under monotonic conditions. The behaviors of other types of reinforcements under monotonic conditions have been evaluated by several researchers. Palmeira (2004) used numerical and experimental approaches to evaluate the soil-geogrid interaction. Abdi and Arjomand (2011) performed the pullout tests to study the interaction of clays reinforced with geogrids encapsulated in thin layers of sand. Esfandiari and Selamat (2012) carried out the pullout tests on metal strips with transverse members, in combination with π-Buchingham theorem and statistical analysis. Suksiripattanapong et al. (2013) studied the influences of soil properties, dimension and spacing of the transverse members on the pullout mechanism of the bearing reinforcement which is composed of a longitudinal member and a set of transverse members. Alam et al. (2014) investigated the pullout behavior of a steel grid reinforcement using experimental and numerical approaches. In order to increase the pullout resistance of the steel strip, Mosallanezhad et al. (2015) introduced a novel reinforcing element which is composed of a series of extra elements (anchors) attached to the conventional steel strip. Mosallanezhad et al. (2017) introduced a new and simple reinforcement system including transverse geogrids connected to a base geogrid with a 45° angle. They conducted the large-scale pullout tests to evaluate the performance of this reinforcement for increase in pullout resistance.

Moraci and Cardile (2009) conducted a multistage pullout (MSP) test to study the influence of various factors including cyclic tensile load frequency and amplitude, vertical effective stress and tensile stiffness of the geogrid on the post-cyclic pullout resistance. The

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Table 1
Specifications of the polymeric strip provided by the manufacturer.

Ultimate tensile strength (kN)	Strip width (mm)	Strip mass (kg/100 m)	Strip length (mm)
75.4	90 ± 2	25.6	700

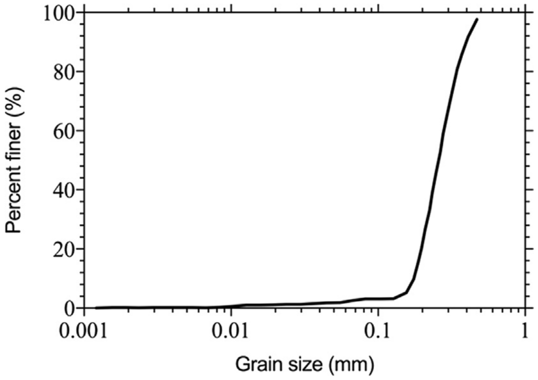

Fig. 1. Particle size distribution curve of the soil.

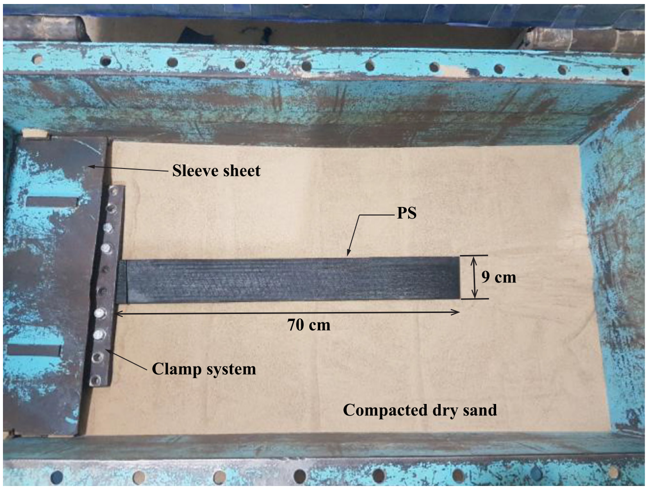

Fig. 3. Placement of strip, clamp system and sleeve sheet in the laboratory.

geogrid was surrounded by granular soils. Their results depicted that the effect of the cyclic tensile load frequency on the test results is negligible. Furthermore, the cyclic tensile load amplitude at the vertical effective stresses greater than 50 kPa affects the pullout resistance, and it can be ignored at the lower vertical effective stresses (e.g. 10 kPa and 25 kPa).

Design methods for the MSEWs subjected to static loading are relatively well studied. But the behavior of embedded geosynthetics subjected to repeated loadings is rarely reported. Such research is required to improve the design of MSEWs under traffic and seismic loading conditions. Moreover, in order to study the internal stability of the MSEWs subjected to cyclic loads, it is essential to estimate the pullout resistance and the interface apparent coefficient of friction mobilized in the anchorage zone. Thus, the behavior of these types of reinforcements under cyclic conditions is important for the safe design. In addition, in many situations, the cause of rupture of MSEWs is the lack of seismic considerations in the design (Ling et al., 2001). Furthermore, these walls are exposed to different types of loads, such as dead loads, repeated loads caused by vehicle traffic, impact loads caused by compaction of soil layers, and earthquake loads. Therefore, a number of researches have been done on reinforcing systems over the past two decades (Cai and Bathurst, 1995; Ling et al., 1997; Bathurst and Hatami, 1998; Nouri et al., 2006; Nova-Roessig and Sitar, 2006; Latha and Krishna, 2008; Moraci and Cardile, 2012; Tang et al., 2013; Liu et al., 2015; Panah et al., 2015; Cardile et al., 2017).

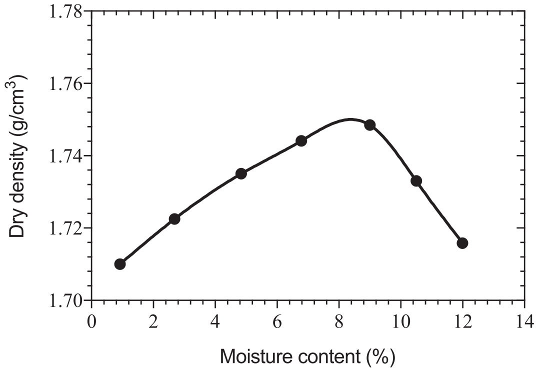

Fig. 2. Compaction curve of the soil.

In general, the pullout resistance at different levels of reinforcement is expressed by the following equation:

$$P_\mathrm{r} = F^* \alpha \sigma'_\mathrm{v} L p \tag{1}$$

where P_r is the pullout force, F^* is the coefficient of pullout resistance, α is the scale correction factor, σ'_v is the vertical effective stress in the reinforcement level, p is the section perimeter of the strip, and L is the anchorage length.

The post-cyclic pullout resistance (P_rc) and monotonic pullout resistance (P_rm) are equal to the shear forces mobilized along the reinforcement:

$$P_\mathrm{rc} = \tau_\mathrm{ac} L p \tag{2}$$

$$P_\mathrm{rm} = \tau_\mathrm{am} L p \tag{3}$$

where τ_am and τ_ac are the average apparent shear stresses under monotonic and post-cyclic conditions, respectively. Using Eqs. (1)–(3), the relationships between shear stresses and σ'_v are obtained as

$$\tau_\mathrm{ac} = \mu^\mathrm{c}_\mathrm{s/GSY} \sigma'_\mathrm{v} \tag{4}$$

$$\tau_\mathrm{am} = \mu_\mathrm{s/GSY} \sigma'_\mathrm{v} \tag{5}$$

where $\mu_\mathrm{s/GSY}$ and $\mu^\mathrm{c}_\mathrm{s/GSY}$ are the monotonic and post-cyclic peak apparent coefficients of friction mobilized at the soil-PS interface, respectively.

Table 2
Soil properties.

D_{10} (mm)	D_{30} (mm)	D_{60} (mm)	c_u	c_c	Composition (%)			Soil classification		G_s	e_max	e_min
					Fines passing #200 sieve	Sand	Gravel	USCS	AASHTO			
0.15	0.19	0.27	1.8	0.89	4	96	0	SP	A-2-4 (0)	2.65	0.87	0.55

Note: c_u - uniformity coefficient; c_c - coefficient of curvature; G_s - specific gravity; e_max - maximum void ratio; e_min - minimum void ratio.

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