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Technical note

Uniaxial compression behavior of geotextile encased stone columns

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ABSTRACT

The bearing capacity and failure mechanism of encased stone columns are affected by many factors such as encasement length, relative density, strength and stiffness of the encasement material. In soft soils where surrounding soil pressure is low, especially in the top section, the stone columns may be close to a uniaxial compression state, where the uniaxial compression strength controls the bearing capacity of the stone columns. A series of large-scale triaxial tests on ordinary stone columns and uniaxial tests on geotextile encased stone columns have been performed. The stone columns were 300 mm in diameter and 600 mm in height. Samples of four different relative densities, and five types of geotextiles were used in the tests to study the effect of initial void ratio and encasing materials on the uniaxial compression behavior of the stone columns. The results show the uniaxial compressive strength of the encased stone columns is not affected by the initial void ratio but mainly by the tensile strength of the encasing geotextiles. The stress strain curves of the encased stone columns under uniaxial loading condition are nearly liner before failure, which is similar to the tensile behavior of the geotextiles.

1. Introduction

Stone columns have been more frequently used in recent decades to improve the bearing capacity of soft ground, apart from their function as vertical drains (Rowe and Li, 2005; Kazimierowicz-Frankowska, 2007; Briançon and Villard, 2008; Ghazavi and Lavasan, 2008; Li and Rowe, 2008; Rowe and Taechakumthorn, 2008; Chen et al., 2008; Bergado and Teerawattanasuk, 2008; Basudhar et al., 2008; Salem et al., 2017; Basack et al., 2017). In very soft soils, e.g. with undrain strength less than 15 kPa, the effectiveness of stone columns will be reduced as the confining pressure on the stone columns may not be sufficient enough (Huges and Withers, 1975). In this case, extra support on stone columns can be achieved by using geosynthetics encasement, where the goesythetics can provide high confining pressure to the stone columns to improve their bearing capacity and stiffness (Raithel et al., 2005; Black et al., 2007; Malarvizhi and Ilamparuthi, 2007; Gniel and Bouazza, 2009; Yoo, 2010; Zhang et al., 2012; Dash and Bora, 2013; Elsawy, 2013; Ghazavi and Afshar, 2013; Wu and Hong, 2014; Chen et al., 2015; Gu et al., 2016; Ou Yang et al., 2017), and seismic resistance (Cengiz and Güler, 2018).

Many researchers have studied the behavior of encased stone columns using laboratory and insitu tests, theoretical and numerical models. Research has been done on small-scale model stone columns in soft soils to investigate the failure mechanisms of encased stone columns. Murugesan and Rajagopal (2010) found that geosynthetic-encased stone columns are higher in stiffness and do not have a strain softening response comparing to ordinary stone columns which are softer with significant strain-softening behavior. Model tests on encased stone columns in soft soils showed that bulging of the stone columns is one of the major failure mechanisms (Ghazavi and Afshar, 2013; Malarvizhi and Ilamparuthi, 2007). Chen et al. (2015) found that bending failure could occur in stone columns under embankment loading. Yoo and Lee (2012) monitored the performance of full scale tests on stone columns and found that the inclusion of encasement can considerably reduce the lateral bulging in stone columns. Miranda et al. (2017) studied the effect of geotextile encasement on the behavior of stone columns and found that the bearing capacity of fully penetrated encased stone columns is 70% higher than that of normal stone columns.

Rajagopal et al. (1999) performed a series of triaxial compression tests on 200 mm height-100 mm diameter geocell-sand composites, and found that the inclusion of geocell could add apparent cohesive strength to cohesionless soil. The authors also found that the frictional strength of the soils is not affected by the reinforcement. Wu and Hong (2009)

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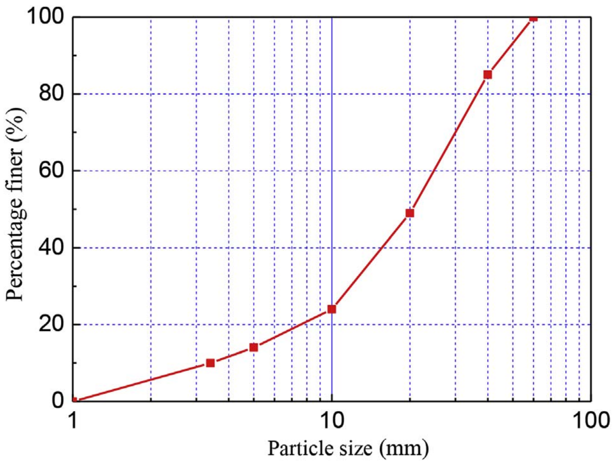

Fig. 1. Particle size distribution of the gravels used in the tests.

carried out triaxial compression tests on sand columns of two densities encased with three types of geotextile. Apparent cohesion has been observed in the encased sand columns and the value increases with the increase of geotextile strength. Gniel and Bouazza (2010) investigated the effect of encasement length on stone column behavior and found that the longer the encasement the higher the column's axial stiffness and the higher the bearing capacity. Miranda and Costa (2016) carried out triaxial compression tests on stone columns of two densities and two geotextiles. The results showed that the effect of geotextile on improving the bearing capacity of stone columns is more significant at lower confining pressures. Hong et al. (2016) performed model tests on geotextile-encased granular columns under undrained conditions and found that the failure of the stone columns was mainly in the top section of the columns, where the uniaxial compression strength of stone columns (confining pressure is low and can be omitted) controls the bearing capacity of the stone columns. Mohapatra et al. (2017) performed direct shear tests and three dimensional numerical modelling on encased stone columns and found that the inclusion of geotextiles could greatly increase the shear resistance of stone columns.

In this paper, a series of large scale triaxial tests were performed on ordinary stone columns and uniaxial compression tests on geotextile encased stone columns to investigate the behavior of the encased stone columns under uniaxial loading conditions. Stone columns, with the size of 300 mm diameter and 600 mm high, of different relative densities encased with geotextiles of different strengths have been tested to determine the effect of initial void ratio and geotextile strength on the behavior of stone columns. A numerical model was proposed to describe the UCS of the encased stone columns.

Table 1
Tensile properties of the geotextiles used in the tests.

Types	Peak strength (kN/m)		Strain at peak strength (%)		Secant modulus (kN/m)			
					Peak strength		5% strain	
	Axial	Radial	Axial	Radial	Axial	Radial	Axial	Radial
I	33	33	15	15.5	220	213	292	266
II	44	43	14.5	15.3	304	281	405	337
III	52	52	11.2	16.6	464	313	579	386
IV	65	65	16.4	16.0	396	406	592	438
V	91	98	18.2	24.6	500	398	549	254

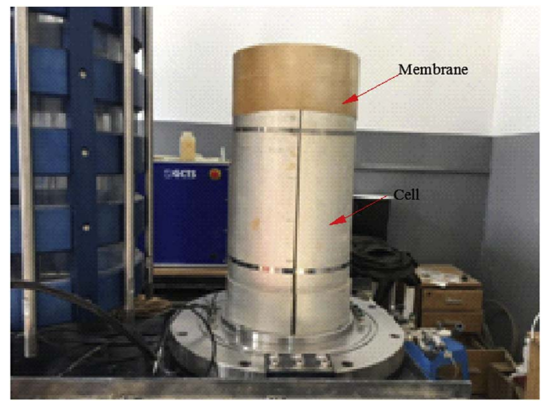

Fig. 3. Preparation of samples used in the large scale triaxial cell.

2. Test program

2.1. Material properties

2.1.1. Gravel

The gravel of crushed limestone was used in the tests. The particle size distribution of the gravels is shown in Fig. 1, with d_{50} = 20 mm, coefficient of uniformity C_u = 7.31, coefficient of curvature C_c = 1.65. The maximum and minimum densities of the gravel were 2050 kg/m^3 and 1370 kg/m^3 respectively. The tests were performed as per Chinese

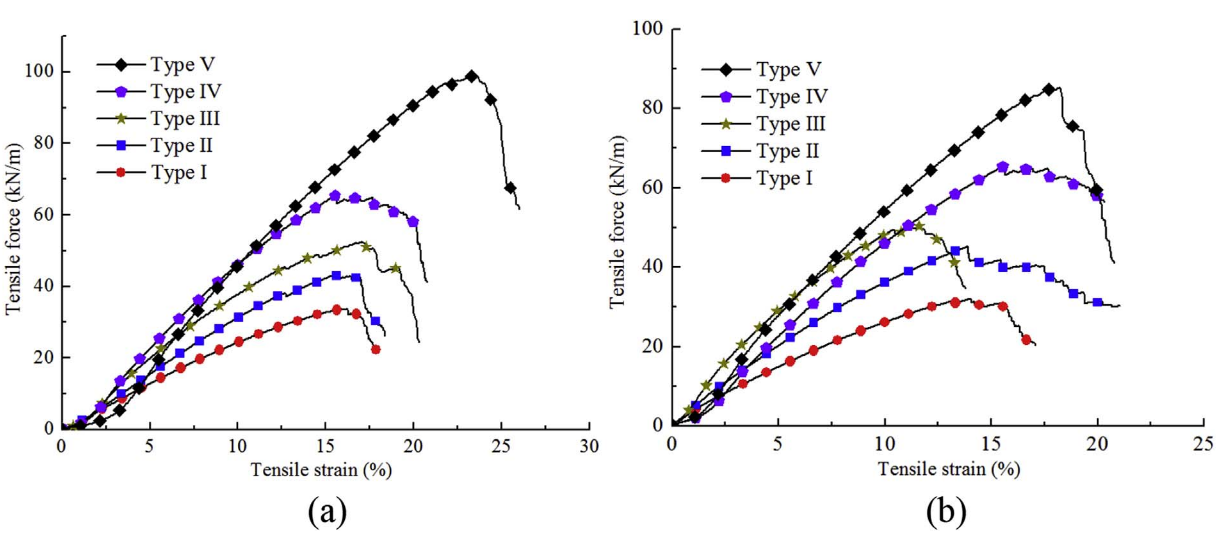

Fig. 2. Tensile tests on typical polypropylene woven geotextiles, (a) radial direction, and (b) axial direction.