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Effect of geotextile reinforcement on cyclic undrained behavior of sand

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ABSTRACT

Dynamic behavior of reinforced soil are evaluated relative to a number of factors including: strain level, density, number of cycles, material type, fine content, geosynthetic inclusion, saturation, and effective stress. This paper investigates the dynamic behavior of saturated reinforced sand under cyclic stress condition. The cyclic triaxial tests are conducted on remolded specimens under various cyclic stress ratios (CSR) which reinforced by different arrangement of non-woven geotextile. Aforementioned tests simulate field reinforced saturated deposits during earthquake or other cyclic loadings. This analysis revealed that the geotextile arrangement played dominant role on dynamic soil behavior and as geotextile close to top of specimen, the liquefaction resistance increased. Meanwhile, the results demonstrate that the effects of arrangement of reinforcement layers on deformation and shear modulus are considerable.

1. Introduction

Soil reinforcement is a technique of enhancing the strength characteristic of soils. In recent decades, the application of reinforced soil structures has been developed in the marine environments for coastal protection, quay and harbor structures. Due to the soil saturation, these soil structures are prone to liquefaction that is defined as loss of strength of saturated sand by generation of excess pore pressure under undrained loading condition. The devastating nature of this type of failure attracted the attention of researchers in this area and considerable work has been done to evaluate the susceptibility to liquefaction (Seed and Idriss [1], Martin et al. [2], Vaid and Chern [3] Seed et al. [4], Shibata and Teparaksa [5], Naeini and Baziar [6], Idriss and Boulanger [7], Stamatopoulos [8], Askari et al. [9], Flora et al. [10], etc.).

In the other hand, many researches were conducted to investigate the behavior of reinforced soils (Chandrasekaran et al. [11], Boominathan and Hari [12], Latha and Murthy [13], Chen et al. [14], Noorzad and Omidvar [15], Wang et al. [16], etc). Ling and Tatsuoka [17] conducted a study on silty clay reinforced with three types of geosynthetics, two geotextiles, and a geogrid under plane strain conditions. They found that consolidation stress ratio and the drainage condition during the subsequent loading have a profound influence on the reinforcement effect. Krishnaswamy and Isaac [18] performed cyclic triaxial tests on reinforced soil specimens and concluded that the deployment of reinforcement has a significant effect on increasing the liquefaction resistance of sand. Taha et al. [19] demonstrated the behavior of geo reinforced residual soil using drained triaxial samples, shown that the reinforced systems increased strength-deformation properties in a significant manner. Ashmawy et al. [20] reported that reinforced soils exhibit an improvement in strength-deformation characteristics under monotonic loading conditions, due to the additional "pseudo" confinement caused by the lateral restraint and shear mobilization. Haeri et al. [21] illustrated that geotextile inclusion increases the peak strength, axial strain at failure, and ductility. Moghaddas Tafreshi and Asakereh [22] explored role of strain level on strength of wet reinforced non-plastic beach silty sand using triaxial compression tests. They showed that the number of layers of reinforcement, confining pressure and strain level is key factors affecting strength values of the reinforced soil.

One of the most important parameters in evaluation of dynamic behavior of aforementioned soil structures is shear modulus. Maximum shear modulus, G_{max}, is a key parameter for predicting the dynamic behavior of soils that evaluated relative to a number of factors including strain level, density, number of cycles, material type, fine content, geosynthetic inclusion, saturation, and effective stress. Many experimental investigations carried out on sandy soils through resonant column test or improved cyclic triaxial test in early studies (Hardin and Richart [23], Hardin and Black [24], Drnevich and Richart [25], Kokusho [26]) showed that the small strain shear modulus G_{max} was basically related to the mean effective principal stress and void ratio (e) of the soil, and even over consolidation ratio OCR for cohesive soil. Shear modulus of silty sand reinforced by randomly distributed carpet waste and geotextile strips subjected to cyclic loading studied by Shahnazari

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et al. [27]. The results demonstrate that the effects of this kind of reinforcement on the shear modulus in low confining pressures (less than 100kPa) are negligible and in high confining pressures are considerable. Bhandari and Han [28] studied the geotextile-soil interaction under a cyclic wheel load using the Discrete Element Method (DEM). The results explained that the depth of the geotextile considerably affected the degree of interaction between the geotextile and the soil.

Naeini and Gholampoor [29] performed a series of cyclic triaxial tests to examine dry silty sand reinforced with geotextile when subjected to dynamic loading. The results indicate that geotextile inclusion and increased confining pressure increase the axial modulus and decreased cyclic ductility of dry sand for all silt contents examined.

Geotextile reinforced soil has been achieved considerable attention in the literature. However, there is little information on the dynamic behavior of geotextile reinforced saturated sand. The main objective of this paper is to study the results of a number of isotopically consolidated undrained cyclic triaxial tests on isotopically consolidated Firouzkuh #161 sand loose samples reinforced with different arrangement of geotextile layers, to characterize the role played by these inclusion on the dynamic behavior. Meanwhile, the effect of geotextile arrangement and Cyclic Stress Ratio (CSR) on G_{max} and maximum axial modulus E_{max} investigated.

2. Experimental apparatus and material used

2.1. Cyclic triaxial setup

Specimens were tested in a cyclic triaxial device. The device is instrumented with LVDT, a load cell, pore pressure and a cell pressure transducer and a computer controlled data acquisition system (Fig. 1).

2.2. Material used

2.2.1. Sand

The sand used in this study is Firouzkuh #161 crushed silica sand. This type of sand has a golden yellow color and has a uniform aggregation, which henceforth briefly named Firouzkuh Sand (Fig. 2). Firouzkuh sand has recently been used in studies in laboratory stress-strain tests and studies on cyclic loading and liquefaction behavior and defined as standard sand in Iran (Ghalandarzadeh and Ahmadi [30], Ghahremani et al. [31]). Toyoura and Sengenyama standard sands that their characteristics are described in this paper were compared to Firouzkuh sand (Table 1). Grain size distribution curves of the last two mentioned sands are presented in Fig. 3

2.3. Geotextile

Table 2 presents the properties of non-woven PET geotextile.

Fig. 1. Cyclic triaxial device set.

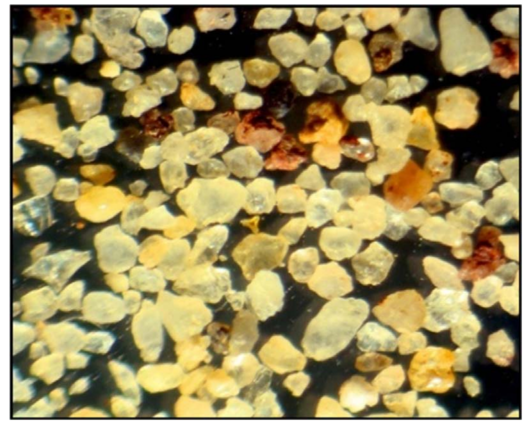

Fig. 2. Magnified picture of Firouzkuh sand grains.

Table 1
Firouzkuh sand physical characteristics and comparing with Toyoura and Sengenyama Sands.

Sand Type	G_s	e_{max}	e_{min}	D_{50} (mm)	C_u	C_c
Firouzkuh #161	2.685	0.943	0.603	0.27	1.87	0.88
Toyoura	2.65	0.977	0.597	0.17	–	–
Sengenyama	2.72	0.911	0.55	0.27	–	–

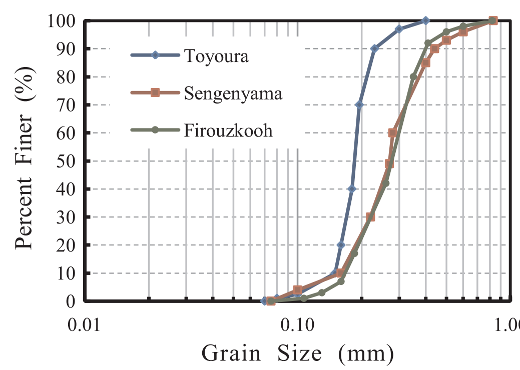

Fig. 3. Grain size distribution curve of Firouzkuh sand compared with the curves.

Table 2
Geotextile properties.

Properties	Unit weight	Thickness	Puncture strength	Wide width tensile
ASTM method	D-5261	D-5199	D-4833	D-4595
Unit	gr/m^2	mm	N	kN/m
	500	3.5	1100	23.1

3. Experimental procedure

3.1. Sample preparation

The tests were performed on samples with a slenderness coefficient of 2, and a height of 14 cm. With a density of 13 kN/m^3, corresponding to a relative density of 27%, the dry sand specimens were prepared according to dry deposition technique in pouring the sand through a funnel in a mould by maintaining a constant funnel zero height above the sand surface (Ishihara [32]). Generally, two types of physical models can be used for modeling of reinforced earth structures: reduced-stress model and centrifuge model. In considering the effect of soil dilatancy, it is possible to substitute looser soil in reduced-stress models to simulate dense soil in a full-scale structure (Bolton [33]).