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Effect of fiber content on the liquefaction potential of improved soils

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ABSTRACT

The use of randomly distributed fibers as soil reinforcement has recently become more popular due to a more satisfactory performance compared with conventional reinforcements. Most previous investigations have focused on the strength and deformation characteristics of fiber-reinforced soil. The liquefaction behavior of fiber reinforced soils has recently received interest since fiber addition is currently considered as a new way of soil improvement to prevent soil liquefaction. Studies indicate that when soils are reinforced with synthetic or natural fibers, a reduction is observed in the number of cycles required to initiate liquefaction under undrained loading conditions. In this study, a regression analysis was performed in the current study by using the results of the previous studies. The obtained formula is able to capture the effect of fiber percentage and relative density of the cohesionless soil on the cyclic stress ratio values with a good agreement.

Introduction

The liquefaction of saturated loose sands is defined as the loss of soil strength due to excessive pore pressures under seismic waves. During earthquakes, liquefaction causes reductions in the bearing capacity of soils and causes excessive settlements [1].

The occurrence of liquefaction has encouraged the interest of many investigators and remarkable work has been carried out to evaluate liquefaction susceptibility. Properties of soil could be improved by using reinforcement materials to eliminate the liquefaction hazard [2].

Soil reinforcement with randomly distributed fibers was investigated by researchers in last few years and results showed that mixing fibers with granular soils improved liquefaction resistance and shear modulus of the soils.

Material and Method

Soil reinforcement with fibers has some advantages compared to traditional soil reinforcement techniques. For example; mixing fibers with the soils is relatively easy with current soil mixing techniques and if homogeneous mixing is achieved, the fibers provide isotropic strength gain in the soil [3].

Although there are various investigations about strength and deformation characteristics of fiber-reinforcement soils under static loads, the studies on under cyclic loading are very limited in the literature.

In order to understand the liquefaction behavior of fiber reinforced soil, a series of ring-shear tests and a series of cyclic triaxial tests have been carried out on soil samples with different fiber content and sand density.

Literature Review

Vercueil et al., [4] performed an experimental study (cyclic triaxial tests) of the liquefaction resistance of Hostun sand reinforced with geosynthetics. The results showed that the liquefaction resistance considerably decreases with fiber addition.

Bhandari and Han [5] carried out studies on the behavior of the geotextile and the soil under a cyclic wheel load using discrete element method. They reported that the geotextile has a major effect on the degree of interaction between the geotextile and the soil.

Altun et al. [6] conducted several stress-controlled cyclic torsional shear tests to investigate the effect of geosynthetics in increasing the resistance to liquefaction of Toyoura sand. The results showed that the liquefaction resistance of sand deposits can be remarkably improved by geosynthetic reinforcement.

Maher and Woods [7] studied the dynamic response (i.e.,shear modulus and damping) of sand reinforced with randomly distributed fibers using resonant-column and torsional shear tests. They reported that the addition of fibers enhances the dynamic modulus of cohesionless soils.

Ibraim et al. [8] investigated the static liquefaction behavior of fine sand reinforced with discrete crimped polypropylene fibers in both triaxial compression and triaxial extension tests. They found that the presence of fibers diminishes the potential of liquefaction.

Chen and Loehr [9] studied the behavior of fiber reinforced soil in the triaxial experimental setup under with and without drainage. They found that the soil strengths of the fiber-reinforced specimens under drained conditions exceeds the respective values of the same specimens under undrained conditions at low deformation levels.

Results and Discussion

The studies on the behavior of soils reinforced with randomly distributed elements under cyclic loading is very limited in the literature since the studies are about the strength properties of fiber reinforced soils. Investigators noted that that the number of cycles causing liquefaction increased with an increase in fiber ratio and CSR values increased with the increase of fiber length. Since, application of dynamic triaxial and torsional shear tests are significantly difficult, a regression analysis were performed in the current study by using the results of the previous studies. A sample of the used data is depicted in Table 1.

Table 1. A summary of the results derived from previous studies

Fiber Percent (%)	Dr (%)	Fiber Length (mm)	CSR
1	30	6	0.336
0.5	30	6	0.288
0.25	30	6	0.244
0	30	6	0.221
1	30	12	0.351
0.5	30	12	0.296
0.25	30	12	0.266
0	30	12	0.221
1	50	6	0.399
0.5	50	6	0.323
0.25	50	6	0.264
0	50	6	0.316
1	50	12	0.409
0.5	50	12	0.344
0.25	50	12	0.335
0	50	12	0.316

Based on the multiple variate regression analyses, the following equation was obtained.

$$CSR = a + bF_p + cD_r + d\left(F_p/D_r\right) + e(exp(F_p{}^3 D_r{}^3) \quad (1)$$

In this equation, CSR represents the Cyclic Stress Ratio whereas F_p, and D_r denotes fiber percent and soil relative density, respectively. The constant parameters of *a, b, c, d* and *e* will be taken as: 0.5481, 0.2832, 0.2328, -0.04756, -0.4001, respectively. The graphical representation of the multivariate regression analysis was shown in Fig.1. The coefficient of determination is found as 0.90 for the suggested formula.

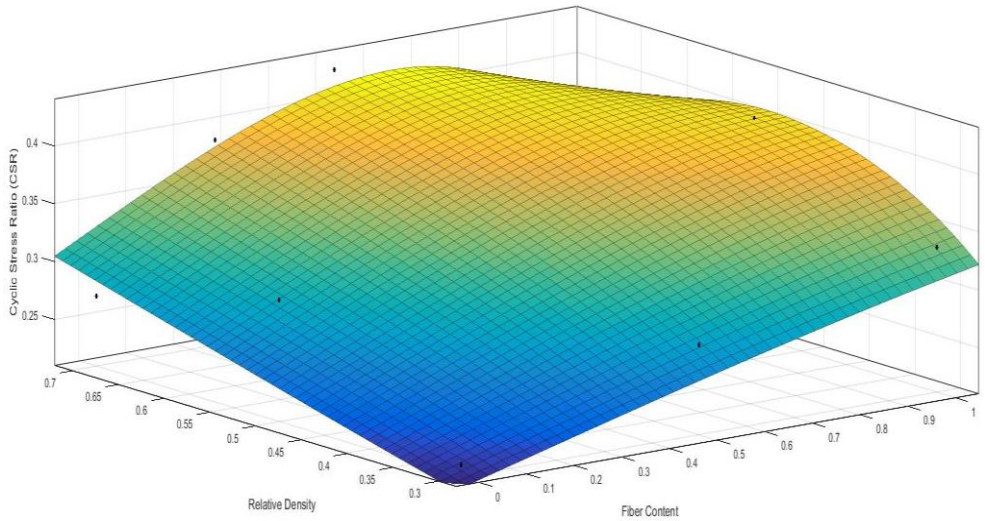

Figure 1. Graphical depiction of the multivariate nonlinear regression modeling results

Conclusion

Fiber reinforcement is an efficient method in limiting or even preventing the occurrence of the lateral movement of the sandy soils due to liquefaction. The presence of fibers affects the behavior of sand in cyclic compression by increasing the cyclic strength therefore liquefaction hazards or deformations appear to diminish. The cyclic test results showed that the addition of randomly distributed polypropylene fibers increases significantly the liquefaction resistance of sands at low relative densities. Since, application of dynamic triaxial and torsional shear tests are significantly difficult, a regression analysis were performed in the current study by using the results of the previous studies. The obtained formula is able to capture the effect of fiber percentage and relative density of the cohesionless soil on the cyclic stress ratio values with a good agreement (R^2=0,90).

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