Effect of failure mode on extensive strength of fiber-reinforced sand under triaxial shearing condition

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1. Introduction

Reinforcing of soils using natural or synthetic fibers is one of the alternative solutions for improving the stability of soils. However, unlike compressive strength, extensive behavior and strength is not clearly influenced by content of fibers (Chen, 2010; Diambra et al., 2010; Mandolini et al., 2019). The objective of the present study is to clarify the reasons why the extensive strength is less influenced by the fiber-contents, as fiber is a tension resisting element, than the compressive strength. For this purpose, the failure modes of unreinforced and reinforced specimens are focused on and compared through both compression and extension triaxial tests with different confining pressures. The effect of the failure mode on the extensive strength and behavior of fiber-reinforced sand are discussed and some limitations in extension experiments of the currently available experimental techniques are explored.

2. Literature reviews

From most of the previous studies, the effect of fibers on the compressive strength is significantly high (Diambra et al., 2010; Mandolini et al., 2019), whereas the fiber inclusions have almost no effect for tensile strength increasing (Chen, 2010; Diambra et al., 2010; Mandolini et al., 2019). Fig.1 shows triaxial test results from Diambra et al., (2010); and Mandolini et al., (2019). Most of studies have not been focused on the failure mode that influences the shear behavior and strength.

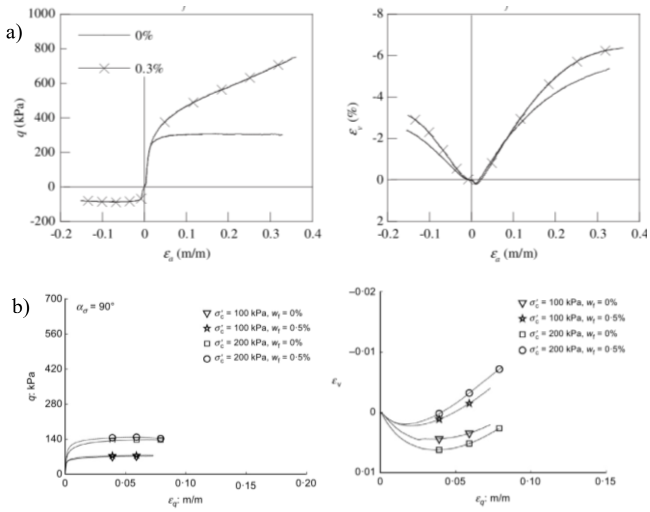

Fig.1. Expermental results from a) Diambra et al., (2010) and b) Mandolini et al., (2019)

2. Materials and Methods

Toyoura sand is used for all experiments. Polyvinyl alcohol (PVA) fibers with 12mm length and 0.03mm diameter is used as a reinforcing material (Table 1). Three different fiber-mixture ratios of 0.0%, 0.2% and 0.4% are adopted to obtain correlation of fiber-reinforcement for both compression and extension experiments. All samples are prepared in dry condition with relative densities of 80%. The consolidated drained triaxial experiments are conducted under 200kPa confining pressure in compression and 300kPa - for extension. All specimens are sheared up to 20 % in compression and approximately 15 % in extension experiments.

Table 1 Properties of the PVA fibers.

Length (mm)	Diameter (mm)	Specific gravity	Tensile strength (MPa)	Young's modulus (GPa)	Elongation at break (%)
12-15	0.04	1.3	1560	41	6.5

3. Test results and discussion

Fig.2 shows triaxial compression test results. The values of deviator stresses of fiber-reinforced specimens are 127% (0.2% fiber) and 164% (0.4% fiber) of unreinforced one at 20% axial strain. The reinforced specimens exhibited smaller volumetric change than unreinforced sand. Fig.3 represents triaxial extension test results. All results were given in a couple of series. Initial tensile strength is higher with the fiber content increment, and peak value of deviator stress reaches at lower axial strain than compression test. However, post-peak strength of fiber-reinforced specimens is ambiguous and have approximately same values of deviator stress at 20% of axial strain. The tensile strength is almost the same regardless of the presence of fibers. The fiber-reinforced specimens experience smaller dilation at the end of test, despite higher volumetric change at the initial stage of shearing.

Fig.4 shows the failure modes of the fiber-reinforced specimens in compression tests. They look like lantern and deformations occur through the entire height of specimens. On the other hand, the failure modes of fiber-reinforced specimens for triaxial extension test are totally different from unreinforced one in Fig.5. The shear zone is transferred to the bottom of the specimen as the fiber content increased. The failure mode is clearly observed with shrinking in the bottom part of specimens, leaving without deformation top part of the sample. It should not be regarded as an element test.

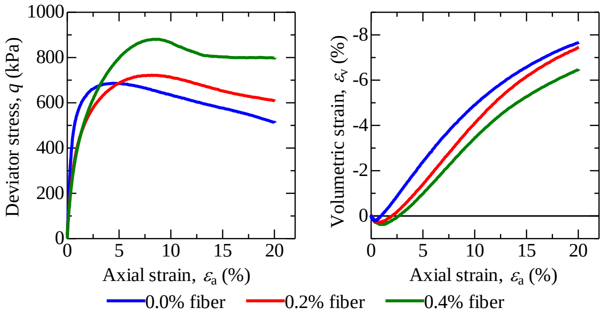

Fig.2 Consolidated drained triaxial compression test results performed under 200kPa confining pressure

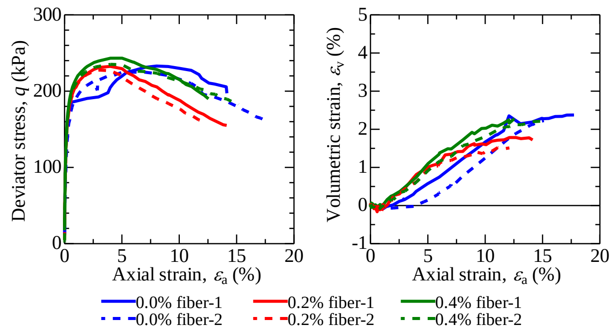

Fig.3 Consolidated drained triaxial extension test results performed under 300kPa confining pressure

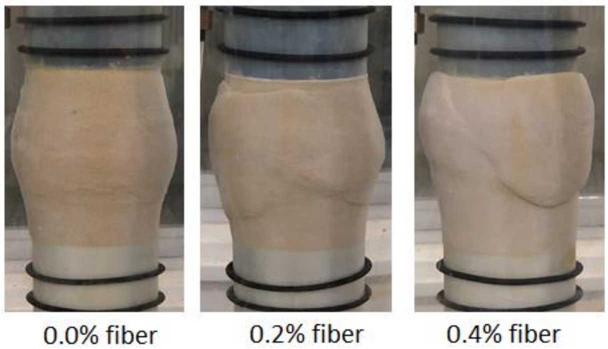

Fig.4 Failure modes of unreinforced and reinforced specimens under loading condition (p'_0=200kPa)

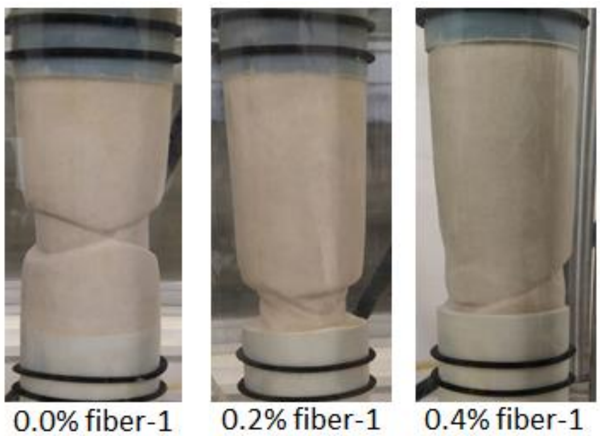

Fig.5 Failure modes of unreinforced and reinforced specimens under unloading condition (p'_0=300kPa)

4. Conclusions

According to the experimental results and discussion, the followings are main conclusions:

1) The compression behavior is significantly influenced by the fiber content, whereas for extension tests the effect of fibers is negligible.
2) In case of compression test, the specimen not locally but entirely deform and fail for considered fiber contents. As for extension test, the unreinforced specimen exhibit double "necking" shear zone in the central part of specimen, while the reinforced specimens experience transferred shear bend to the lower part of specimens.
3) According to the experimental results and their repeatability, a triaxial extension test is not regarded as element test, and it may not be enough to accurately assess the tensile strength of fiber-reinforced specimen.

References

Chen, C. (2010). Triaxial compression and extension for fiber-reinforced silty sand. GeoShanghai International Conference 2010. Ground Improvement and Geosynthetics ASCE, 367-376.

Diambra, A., Ibraim, E., Muir Wood, D., Russell, A.R. (2010). Fibre reinforced sands: experiments and modelling. Geotext. Geomembranes 28 (3), 238-250

Mandolini, A., Diambra, A., & Ibraim, E. (2019). Strength anisotropy of fibre-reinforced sands under multiaxial loading. Géotechnique 69 (3), 203-216.