THE STIFFENING PROPERTIES OF SHORT FIBER-REINFORCED SANDS WITH SEVERAL RELATIVE DENSITIES

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1. INTRODUCTION

Reinforcement of soils using tension resisting elements is an actual and alternative solution for ground improvement and stabilization issues both for engineering and economic purposes. It is well-known that discrete flexible fibers act like plant roots and give the possibility to increase the strength and stability of soils. Prevalence of effectiveness of soil reinforcement with fibers started almost 15 years ago. However, there are not enough studies for describing the effect of fibers on soil behaviour and techniques of application of fiber-reinforcement in practice.

This study was targeted on obtaining the behaviour of fiber-reinforcement of sandy materials with different relative densities and find out a more suitable method for specimens' preparation with the vision of future application on construction site.

Photo 1. Polypropylene fibers used in this study

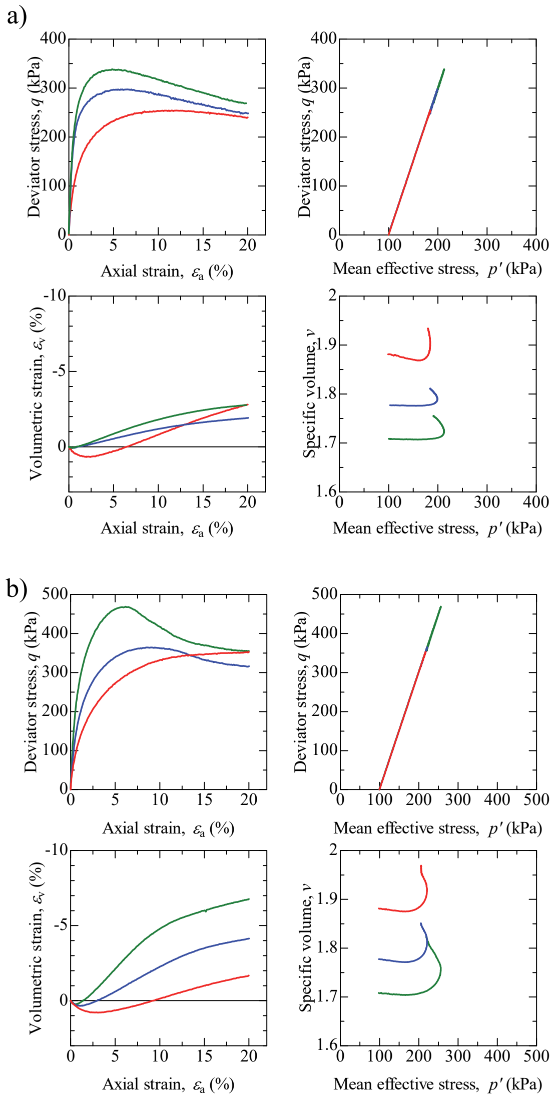
2. MATERIALS AND SAMPLE PREPARATION

Toyoura sand with main properties as maximum void ratio e_{max}=0.985, minimum void ratio e_{min}=0.639, specific density ρ_s=2.646 g/cm^3, while discrete flexible polypropylene fibers with the length l_f=12-15mm, the diameter d_f=0.03mm, the density of fiber d_f=1.30g/cm^3 were used for experimental tests. Photo 1 shows a real image of polypropylene fibers with an approximate length of 13 mm.

The samples were prepared in 4 different ways: a) manual mixing in dry condition; b) manual mixing with 10% moisture content; c) automatic mixing in dry condition and d) automatic mixing with 10% moisture content. In the case of a lower percentage of fibers (0.2% and 0.4%) the manual mixing in dry condition makes the specimen homogeneous according to visual observation and test results, however, increasing the percentage of fiber content (1%), the specimen needs to be prepared with automatic mixing and moisture content 10% in order to prevent fiber sand segregation. The cylindrical specimens of 100 mm height and 50 mm diameter were used for triaxial tests. Tamping technique (Diambra et al., 2010) was used for fabrication procedures with a random distribution (Ibraim et al., 2012) of fibers through the whole specimen.

Four fibers content ratio were used to obtain the tendency for fiber-reinforcement: 0%, 0.2%, 0.4% and 1%. The average concentration of fibers (w_f) is defined as the ratio of the weight of fiber (W_f) and the dry weight of sand (W_s) (weight ratio).

$$w_f = \frac{W_f}{W_s} * 100\%$$



3. EXPERIMENTAL TESTING PROGRAM

Laboratory specimens were prepared with relative density (D_r) values of 30%, 60% and 80% in order to investigate the behaviour of loose, medium dense and very dense sands, respectively. The specimens are sheared at 100kPa confining pressure.

The relative density of fiber-reinforced sand is defined according to the following principles for calculation of voids

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ratio (e) for definite density (Eldesouky et al., 2016):

- Principle 1: Fibers are part of the voids: $e_o = \frac{Vv+Vf}{Vs}$
- Principle 2: Fibers are part of solids: $e_o = \frac{Vv}{Vs+Vf}$

According to the above principles, relative density (D_r) equals:

$D_r = \frac{e_{max}-e_0}{e_{max}-e_{min}}$, where e_{max} and e_{min} are maximum and minimum voids ratio, respectively. In this study, principle 1 was adopted to define relative density.

Figure 1 shows the results of drained triaxial compression tests for three different relative densities 30%, 60% and 80%. Figure.1a) illustrates a typical unreinforced sand behaviour in triaxial compression with reaching residual deviator stress q=250kPa. Figure.1b) represents the results of sand reinforced with 0.2% fibers. In deviator stress – axial strain curves it is clearly seen that the fiber inclusion made peak strength more pronounced with an obvious change from peak to post-peak strength at final residual strength q=300kPa. Furthermore, in volumetric strain – axial strain curves it can be noticed higher dilatancy ratio (volumetric change almost doubled). Figure.1c) shows the results of 0.4% fiber reinforced sand with approximately same hardening and softening behaviours (peak and post-peak strength) as for 0.2% fiber reinforced sand. The same tendency was continued with increasing the percentage of fiber content to 0.4% with residual deviator stress q=350kPa (ε_a-q curves) and increased volumetric change (ε_a-ε_v curves). However, in the case of 1% fiber reinforced sand, failure characteristics become more complicated both in stress path and dilatancy changes, which can be observed in Fig.1d). In the deviator stress-axial strain curve, the specimen of 80% relative density has an obvious peak strength with a quick change to post-peak strength with residual deviator stress q=500kPa. In addition, the initial stiffness of specimen with Dr=80% is lower than that with relative density Dr=60%. This probably happened due to the interaction between sand particles and fibers with less connected with each other. Moreover, the dilation ratio decreased as can be seen in ε_a-ε_v curves. Decreasing of volumetric change happened according to the preparation issues and concentration of fibers in definite places, which led to non-uniform deformation and different failure mode compared to sand without fiber and 0.2%, 0.4% fiber-reinforced sand.

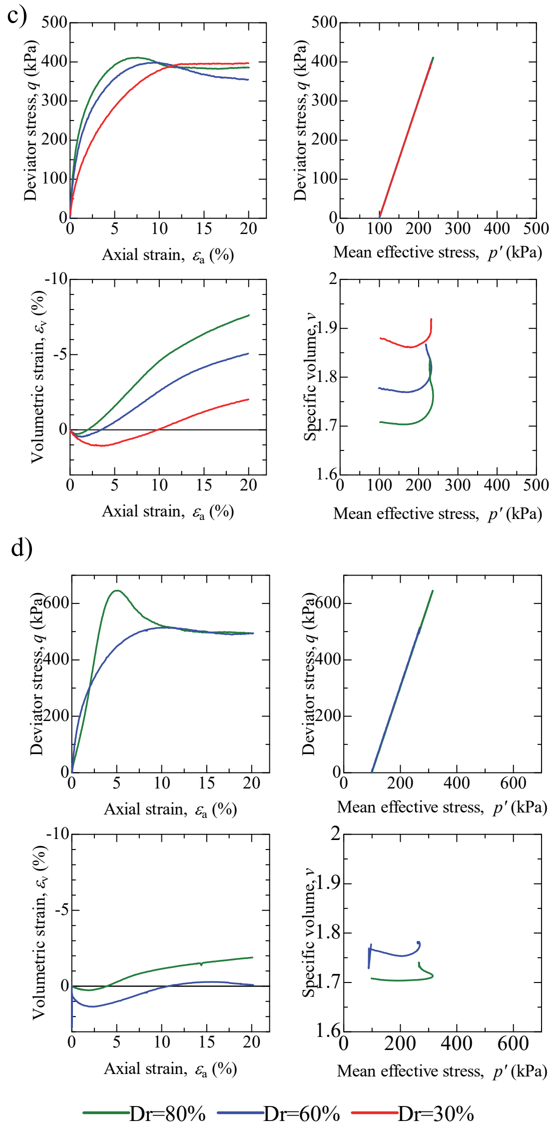

Figure 1. Drained triaxial compression test results: a) sand without fibers; b) sand reinforced with 0.2% fibers; c) sand reinforced with 0.4% fibers and d) sand reinforced with 1% fibers

4. CONCLUSION

According to the experimental results of drained triaxial compression tests, it was obtained the tendency for the residual strength and the volumetric change characteristics, a selected method for preparation and fabrication:

- Residual deviator stress is almost unique independent of relative density for each sand specimen: sand without fiber – q=250kPa; sand with 0.2%fiber – q=300kPa; sand with 0.4%fiber – q=350kPa and sand with 1%fiber – q=500kPa.
- The dilatancy ratio increases with increasing the fiber content ratio, except 1% of fiber content (due to the preparation issues with concentrated distribution of fibers).

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