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EXPERIMENTAL ANALYSIS OF FAILURE OF CEMENT TREATED SOIL USING X-RAY TOMOGRAPHY

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Summary: In order to evaluate the mechanical behavior of cement-treated soil, a series of triaxial loading test was performed. The internal behavior of cement-treated soils was visualized by x-ray tomography and mechanical behaviour was evaluated by digital image correlation technique. It is found that the failure mode of cement-treated soil depends on the confining pressure and the number of the crack increase and progression of the crack becomes complex with increase of confining pressure.

1. INTRODUCTION

In geotechnical engineering, a soft foundation is often stabilized by mixing cement with soil. The mechanical properties of the cement-treated soil depend on the amount of cement mixed with the soil. In the previous research, it is reported that the brittle behavior under tensile load is necessary to considered in a design of soil structures [1]. The purpose of this study is to reveal the confining pressure dependency on tensile strength of cement-treated soil by observation of change of internal structure during loading. X-ray tomography is utilized for quantitative evaluation of failure process of cement-treated soil under triaxial tension test.

2. EXPERIMENTAL METHOD

The undrained triaxial tensile test was performed on prismatic specimen in this study under three different confining pressure. The test apparatus was specially designed for X-ray tomography, and it was mounted on the rotation table of the scanner. A universal joint was installed between a loading ram and a cap to reduce the effect of eccentric load or bending. Both ends of the specimen were fixed with cap and pedestal by plaster. In this work, a microfocus X-ray scanner located at the Port and Airport Research Institute, Japan was employed to acquire 3D volume images of the triaxial specimens. In-situ triaxial tension tests, where scanning and loading occur simultaneously, were performed on a series of cement-treated soil specimens under undrained condition.

As a loading procedure, isotropic load was applied as a consolidation and then undrained tensile loading was applied. The strain rate of 10^{-1} %/min for loading was kept constant. The specimens were scanned during the process of tensile tests to obtain full 3D volumes. The scans were conducted at different strain level (e.g. initial state, after peak stress, residual state).

The cement-treated soil tested in this study was made of two different material such as Kibushi Clay with 135 % of water contents and Portland cement. Composition of the cement was adjusted to obtain the unconfined compression strength of 110 kPa. The specimen was cured for 7 days using a split mold.

3. RESULTS

Figure 1 (a) shows the mechanical response from three triaxial tensile tests under different confining pressure. Clear peak stress and strain softening can be observed in all tests. The reduction of deviator stress after the peak is large as when confining pressure is small.

X-ray tomography scan was conducted for the triaxial tensile test with 0. 49, 196 kPa of confining pressure. Figure 1 (b), (c), and (d) show the vertical cross-sections of tested specimens under 0 kPa, 49 kPa, and 196 kPa of confinement, respectively. The clear crack observed in Fig 1 (b) and (c). This crack appear just after the peak stress

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(ε_a=-1.0%) and it can be observed at the lower part of the specimen. The deformation due to the progress of axial strain cannot be seen in either of the cross-section with 0kPa and 49 kPa of confinement. It can be also seen that the outline of the specimen is constricted.
Figure 1 (d) shows the vertical and horizontal cross-sections of the specimen tested under 196 kPa of confinement. The crack appears at the bottom of the specimen. The difference from other cases is that a number of small cracks are generated with the progress of axial strain. The boundary shape of the specimen around cracks is constricted and the length of the specimen, calculated from the cross-sections, was reduced by 74% with respect to the initial. The local failure of the specimen may be derived from the partial reduction of the stiffness of the sample caused by small cracks concentrated in a narrow area. At the constricted area, the frictional resistance is produced by disturbance of the soil structure.
From above observation and discussion, the tensile failure mode of cement-treated soil depends on the confining pressure and the number of the crack increase and progression of the crack becomes complex with increase of confining pressure. This feature suggests that the tension strength can be modelled as *c* material under low confinement and *φ* material under high confinement. In order to develop the numerical simulation method of cement-treated soil, the confining pressure dependency have to be incorporated into a mechanical model.

References

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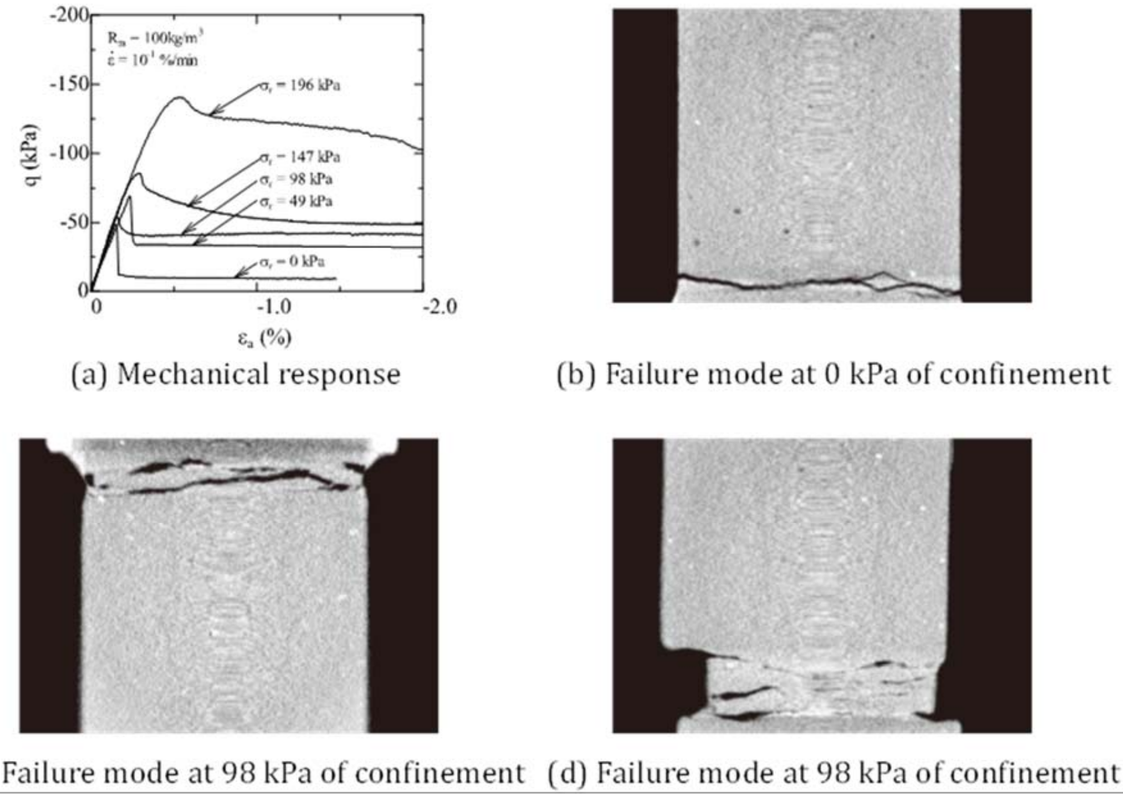

Figure 1: Experimental results of triaxial tension test on cement-treated soil (a) mechanical response, (b)-(d) vertical cross section of the specimen at 0 , 49, and 196 kPa of confining pressure, respectively.