Evaluation of 3-D grain motion inside a granular assembly during shear deformation

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Mechanics of granular materials is used in various engineering fields such as geotechnical engineering and powder engineering. Within a quasi-static regime, a granular assembly stands against an external force by constructing a contact-force network. Therefore it is essential to study its packing structure (number of contact points, their orientation etc.) and its evolution during shear deformation. This research attempted such particle-level observation inside a triaxial specimen using micro X-ray CT system (SP-μCT) at BL20B2.

We developed a micro triaxial apparatus suitable for SP-μCT, which enables us to keep a confining pressure constant and to apply a precise axial strain to a small specimen with 3.4 mm in diameter and 10 mm in height. The material used is Toyoura sand, a standard sand commonly used for geotechnical engineering research, whose grain size ranges from 0.1 to 0.2 mm. Two types of specimen, a loose one and a dense one were tested and the stress - strain curves were obtained (Fig.1). The resultant peak axial stresses for both specimens are rather higher than those with a conventional tri-axial test whose specimen size is over 50 mm in diameter and 100mm in height. It is mainly due to the effect of relatively-thick (0.15mm) membrane wrapping the specimens.

Loading was stopped several times during the test, as it is observed in Fig.1 by the vertical stress drop, to take a series of X-ray images. Fig.2 shows the reconstructed CT images of a central vertical cross section of the dense specimen before and after loading. It can be recognized that the shear deformation is concentrated on the upper part of the specimen, accompanying a considerable dilation (volume increase). The images are clear enough to quantify each grain motion including its rotation. Such information as 3-D microscopic motion of grains in a shear zone, which has never been observed before, is quite useful for the verification of microscopic constitutive model as well as particle-level simulation.

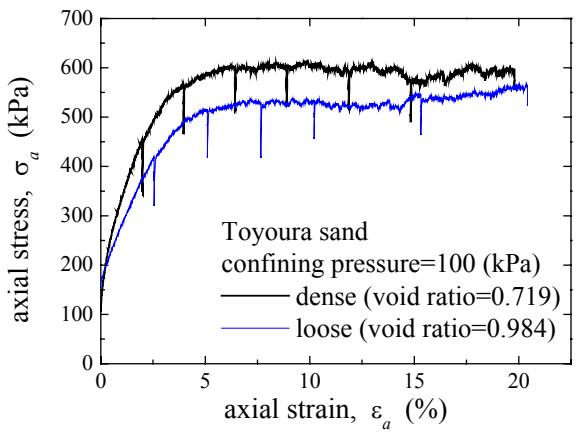

Fig.1 Stress-strain curve

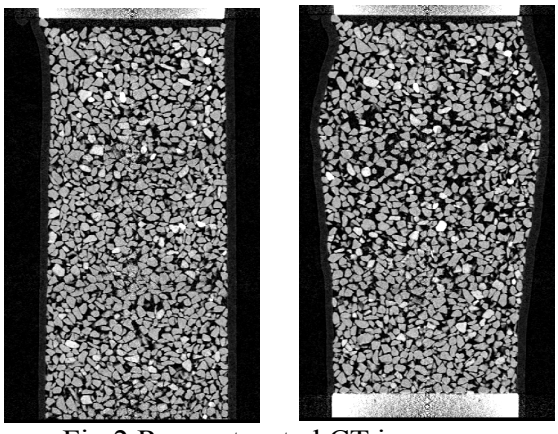

Fig.2 Reconstructed CT images. $\varepsilon_a = 0$ (left) and $\varepsilon_a = 15\%$ (right)