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FE-ANALYSIS OF GRANULAR MATERIALS BASED ON X-RAY CT DATA

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In geotechnical engineering, understanding the mechanisms of deformation and failure of granular materials is essential. In particular, strain localization is a phenomenon commonly observed in granular materials and it is a key issue to understand the stability of soils or the interaction between soils and structures. The mechanical properties of the granular materials depend on the micro-scale condition such as shape of particle, its density and structure. For detailed analysis, not only macro but also micro-scale condition plays an important role. However its analysis method which can consider the micro-scale condition is not developed enough.

In experimental studies, quantitative evaluation of deformation and failure behaviors from micro- to macro-scale can be achieved through full-field measurements of displacement and strain fields in soil specimens under loads. X-ray Computed Tomography (CT) is a visualization tool that allows observation of the internal 3D structure of materials and has been applied to study deformation of geomaterials in the last two decades (i.e. Desures et al 1996). An object of this research is to develop the evaluation method of the micro-scale condition of granular material from X-ray CT data for numerical analysis. Digital Image Correlation (DIC) which is a powerful tool in experimental mechanics was investigated. DIC can provide full-field measurements of kinematics and strains at the surface of or within an object during its deformation (Hall 2006). The combination of both methods provides a quantitative evaluation of 3D deformation process of granular materials. In present study, in-situ (loading and X-ray scanning at the same time) triaxial compression test on sand was performed and sand grains were visualized independently.

Firstly, localized behavior of granular materials is revealed by X-ray CT and digital image correlation. Fig. 1 presents mechanical responses observed in the triaxial compression test. The result shows typical stress-strain curve of dense sand having clear peak and softening then reach to residual stress. The specimen shows volumetric expansion from the beginning of the axial loading. Vertical cross section of the specimen before and after loading is shown in Fig. 2. 3D volumetric digital image correlation was applied to the series of 3D images recorded through the triaxial compression. Fig. 3 shows displacement and shear strain field over vertical cut of the specimen. The localized deformation can be evaluated from these results. This information is valuable for analysis of granular materials.

For numerical analysis of the granular materials, the distinct element method (DEM) has been widely used. However, input parameters to specify the characteristics of the spring (i.e., the interaction between particles) cannot be determined systematically. In this paper, the authors proposed a FE-analysis method based on X-ray CT data for granular materials. The FE-analysis is implemented with particle discretization, both mesh size and geometry is determined from X-ray CT data. The numerical simulation method of failure behavior, namely PDFEM, is used (Hori et al 2005). PDFEM solves a boundary value problem by applying particle discretization to a displacement field; domain is decomposed into a set of Voronoi blocks and the non-overlapping characteristic functions for the Voronoi blocks are used to discretize the displacement function (Fig 4). In this research, a series of analysis result for sand is discussed. Laboratory test results and simulation results are compared, and validation of the proposed is discussed. Utilizing micro-data is strongly impressed.

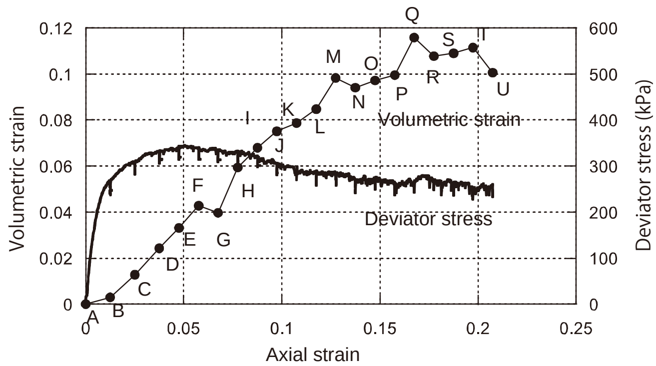

Fig.1 Mechanical response

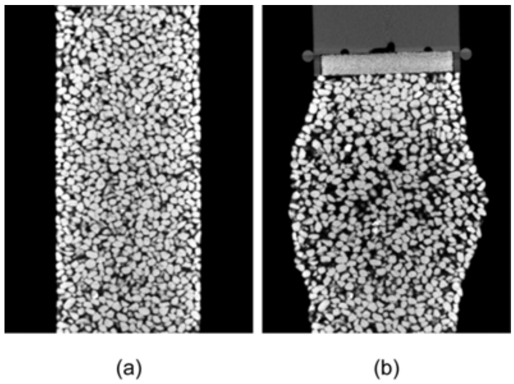

Fig.2 Vertical cross secton of the speciment at (a) initial and (b) after loading

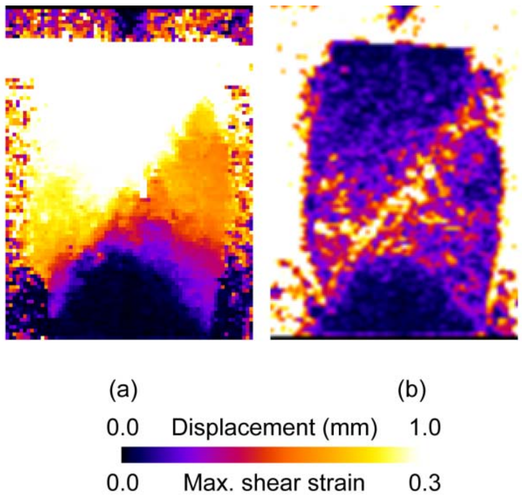

Fig. 3 Distribution of (a) magnitude of displacement and (b) max. shear strain

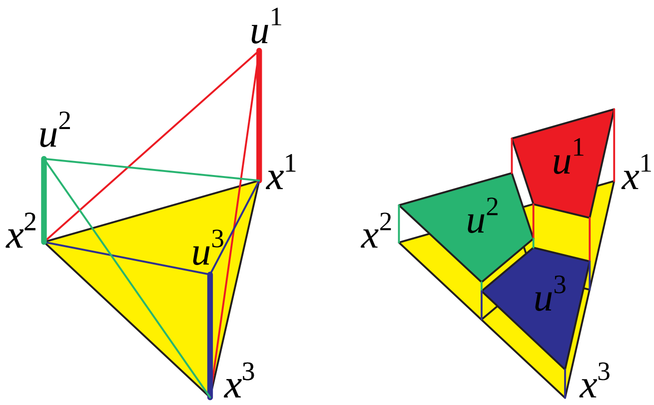

Fig. 4 Comparison of discretization for (a) ordinary FEM and (b) FEM-β

REFERENCES

[1] Hori,M, Oguni,K, Sakaguchi,H: Proposal of FEM implemented with particle discretization for analysis of failure phenomena, J. Mech. Phys. Solids, 53, 681–703, 2005.

[2] Desrues, J., Chambon, R., Mokuni, M., Mazerolle, F.: Void ratio evolution inside shear bands in triaxial sand specimens studied by computed tomography, Géotechnique 46 (3). 529-546, 1996.

[3] Hall, S.A.: A methodology for 7D warping and deformation monitoring using time-lapse seismic data, Geophysics, 71 (4). O21-O31, 2006.