Comparison of X-ray CT results with DEM simulation of direct shear behavior on sand and tire chips

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Introduction

In recent years, the attention has been growing on using tire products as materials in geotechnical engineering in particular. However, the mechanical properties of tire chips have not been clarified yet.

The authors have investigated shear behavior of sand and tire chips using Industrial X-ray CT[1].

In this study, Discrete Element Method (DEM) simulation of direct shear test is conducted for the case of sand and tire chips. And then, the results of X-ray CT and DEM simulations are compared in both cases.

Direct shear test with X-ray CT scanning

Direct shear tests were conducted in this paper with a circular shear box (80mm diameter). The properties of the materials are listed as follows:

(1) Silica sand: average grain size=2.0mm, soil particle density = 2.64 g/cm^3;

(2) Tire chips: average grain size=2.0mm, soil particle density = 1.15 g/cm^3.

In the test, after making each specimen, a series of CT scanning were conducted for the soil box at the initial state and for shear displacement of 2.6mm (around the peak for sand), 5.3mm (after peak) and 8.0mm (end of the test). Then, Particle Image Velocimetry (PIV) technique was used to calculate displacements and strains from the CT images.

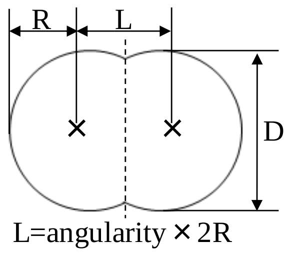

Figure 1. Particle clump used in DEM simulation

Table 1. Properties of particle

	sand	tire chips
particle density(g/cm^3)	2.65	1.15
particle clump	angularity:0.9	angularity:0(sphere)
clump diameter(mm)	1.95	2.46

Outline of numerical simulation

The DEM used here is based on the molecular dynamics[2], and the software used here is called SDEC[3]. In these simulations, spherical particles were used to model tire chips whereas non-spherical particles called clumps were used for the case of sand. A particle clump used in DEM simulations is shown in Fig. 1. Table 1 shows properties of particles for both cases.

The simulation model of direct shear test is shown in Fig. 2. The width (20mm) of the shear box used in the simulations is smaller than the actual shear box, in order to limit the number of particles and so the calculation time. Therefore, the void ratio when beginning of shearing was set at 0.59 in the case of sand and 0.55 in the case of tire chips, these values are the same as in the experiments.

Simulations of direct shear test

Table 2 shows the mechanical parameters in this simulation. The value of these parameters gave a reproduction

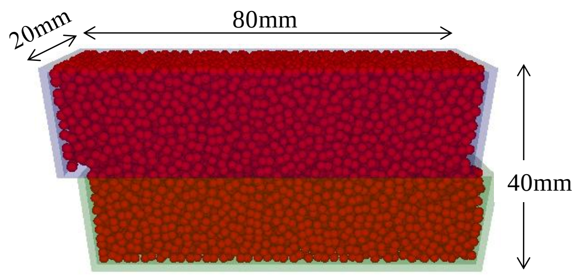

Figure 2. Simulation model used for direct shear test

Table 2. Mechanical parameters

	sand	tire chips
friction angle(deg)	40	15
nomal stiffness parameter(N/m^2)	2.24×10^8	9.0×10^6
ratio of tangental stiffness to nomal stiffness	0.1	0.75

of the shear behavior consistent with the results of experiment, and Fig. 4 shows the comparison of both results. For the case of sand, it can be seen from Fig. 4(a) that the results obtained with DEM simulation is very similar to the experiment value. However, as far as the dilatancy behavior is concerned (Fig. 4(b)), there are some difference between two results, so that the modeling of sand in DEM needs some improvements. Besides, for the case of tire chips, the experiment result was analyzed well by DEM simulation, and it can be said that elastic bodies such as tire chips can be analyzed in DEM simulations, even if this method assumes the particle to be a rigid bodies.

Figures 5 and 6 show the distributions of shear stains obtained from PIV and DEM. These strains were obtained using the changes of the shape of each small area in the materials due to shearing. For the results of PIV, the area of high shear strain first appears around the corner at the boundary of two boxes for both cases at the beginning of shearing. And this trend of shear strain distribution is close to the results of DEM simulations.

Conclusions

In this paper, the results of X-ray CT and DEM simulations were compared for sand and tire chips. As a result, it can be confirmed that the results of X-ray CT is close to the results of DEM. For the future, DEM simulation of direct shear test is going to be conducted for the case of mixed sand with tire chips.

Acknowledgment

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References

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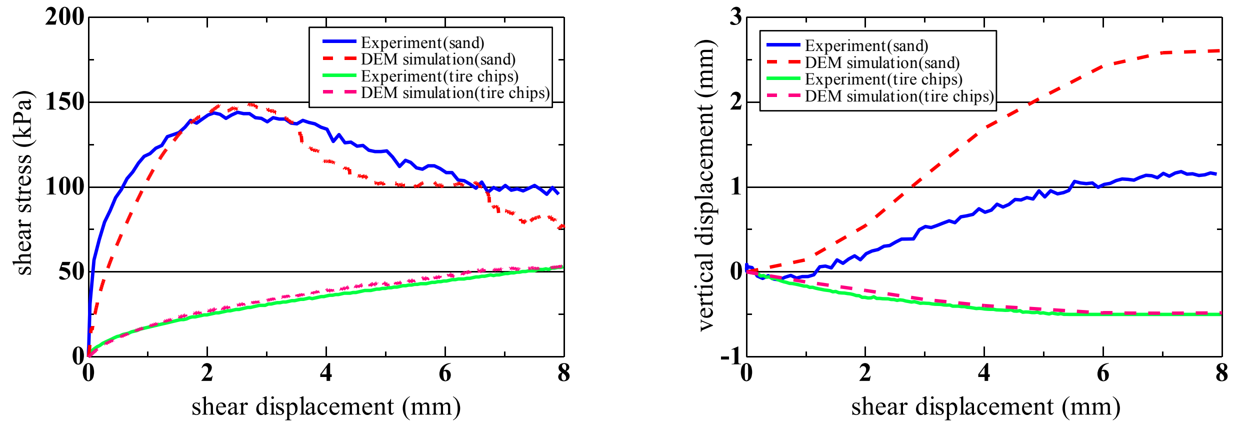

(a) shear stress-shear displacement relationship (b) vertical displacement-shear displacement relationship

Figure 4. The simulation and experimental results of direct shear test

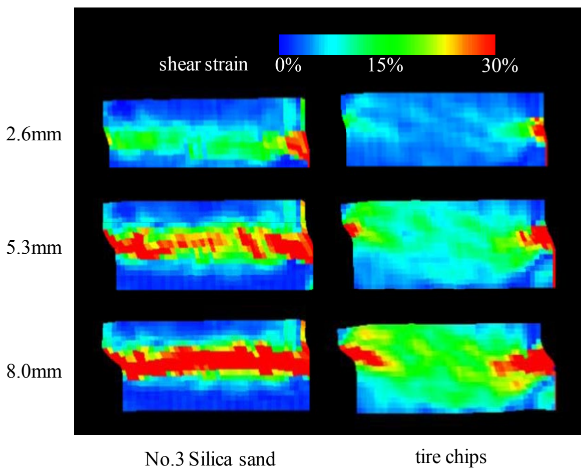

Figure 5. Shear strain distribution from PIV

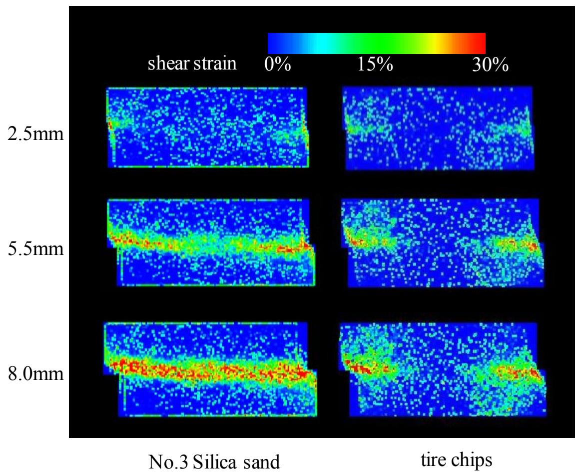

Figure 6. Shear strain distribution from DEM