

Deformation and Breakage of Particles of Cement-Treat Granulate Soil

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1. Introduction

Cement-Treat Granulate Soil (CTGS) has been developed recently by mixing dredged clay with appropriate amount of cement and polymer. Having relatively high particle strength and benefits of granular material, CTGS has been expected to be applied to reclamation or backfill material. Dong et al. (2009) has concluded that the CTGS particles are crushable and deformable under imposed pressure and the deformation and/or crushing of the particles is a key factor influencing on the triaxial stress-strain behaviours of CTGS. Study on the deformation and breakage of CTGS particles is thus a necessary in order to have a full understanding the mechanical behaviors of this material.

2. Intrinsic structure of CTGS particles.

The Kawasaki clay, normal Portland cement and Aquuna (partially neutralized polyacrylic acid) polymer were selected to produce CTGS. The detailed production method and material can be found in Takahashi et al. (2009) and Dong et al. (2009). This paper deals with two types of CTGS with mixing proportion of the cement and the polymer to wet weight of the clay as following: (1) C_1 type: 5 % cement and 0.1 % polymer; (2) C_2 type: 15% cement and 0.3% polymer to the wet weight of clay.

Table 1. Material properties

Properties	C_1	C_2
Particle density ρ_s (g/cm ³)	2.69	2.71
Water content, w (%)	44.82	39.2
pH	10.64	11.34
d_{60} (mm)	4.98	3.4
d_{10} (mm)	1.56	1.2
e_{max}	3.35	2.98
e_{min}	2.44	2.23

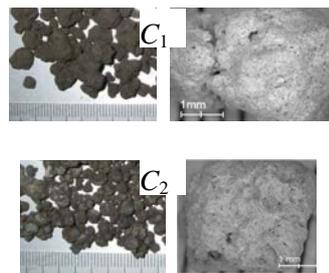


Fig. 1 GCTS and its microscopic photos

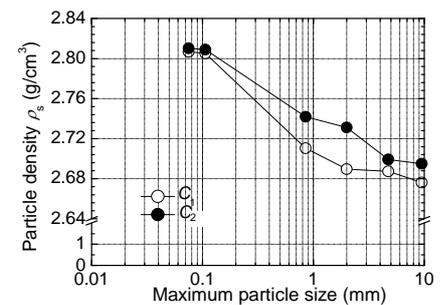


Fig.2 Variation of the particle density with maximum particle size of samples.

The particles and corresponding microscopic photos of C_1 and C_2 are shown in Fig.1. It can be seen that some hollows is clearly observed on the surface of CTGS particles. A decreasing rate of particle density to maximum particle size of samples in both C_1 and C_2 is found as shown in Fig.2. Therefore, there is a possibility of existence of inter-closed voids, into which water could not penetrate. It is supposed that CTGS particles consist of particle-matrix, inter-closed voids and inter-open voids. Assume that inter-closed voids are fully vanished at CTGS particles smaller than 0.075 mm and water can not absolutely penetrate into it, volume of the inter-closed voids can be calculated from the variation of particle density. In this regard, ratio of volume of inter-closed voids to volume of particle-matrix is 4.7 % on average in case of C_1 and that amount in case of C_2 is 4.3 %.

3. X-ray Computer Topography (CT) Scanner Test associated with CD triaxial tests

In order to investigate the deformation and/or crushing of CTGS particles, CD Triaxial tests associated with X-ray CT scanner tests (Kikuchi et al., 2008) on C_1 and C_2 specimens were performed. The methodology of this test is that CT image is numerically quantified as a numerical number and proportional to the material density. The darker region represents for the lower density material and the brighter region reveals the higher density material, so that the grey level of CT image of specimen can be used to evaluate the distribution of material density within the specimen. In this study, two cases of CD tests were carried out on specimens of C_1 ($D_r = 6.9\%$) and C_2 ($D_r = 7.1\%$) having 5 cm in diameter and

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10 cm in height. After consolidated under confining pressure of 200 kPa, specimens were sheared at strain rate of 0.1% /min. Figure 3 shows the deviatoric stress versus the axial strain of specimens. The reduction of the deviatoric stress at some strain levels was because of the stress relaxation as the X-ray scanner test conducting. Figure 4 shows the middle cross-section of specimens. It can be seen that brighter colour region reveals size and shape of CTGS particles, and darker colour region represents voids between particles, from which the shape and trajectories of some typical particles during testing can be recognized. It is observed that the trajectories of particles are almost in vertical direction that indicates relatively small lateral movement of particles. The alteration of cross-section area of particles could be therefore used as a quantitative parameter to evaluate the particles deformation during the test.

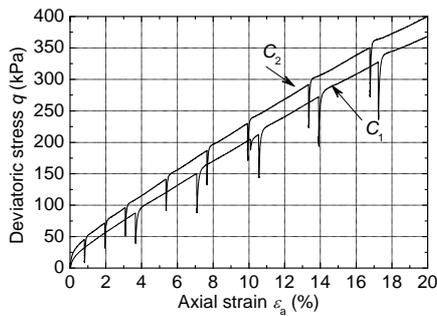


Fig.3: Deviatoric stress versus axial strain.

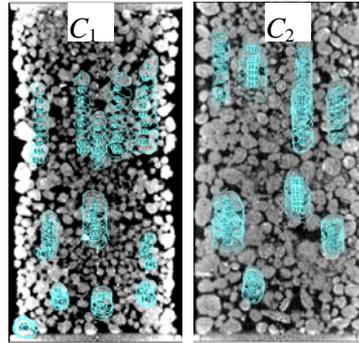


Fig. 4: The middle cross-sections of specimens with trajectory of particles

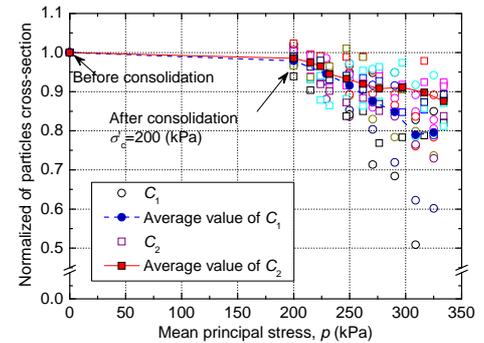


Fig. 5: Normalized of particles cross-section at the middle cross-section of specimens

Normalized cross-section area of some selected particles versus mean principal stress, where the X-ray scanner test was performed, is shown in Fig. 5. The average value of normalized cross-section at each stress level is calculated and also depicted in Fig.5. It can be seen that particle sizes were not significantly changed during consolidation, until $p = 200$ kPa. Therefore primary deformation of specimens could be dominantly induced by the rearrangement of particles. When shearing starts, the normalized cross-section was gradually or dramatically reduced in some particles at the later stage of shearing. The observed change in the cross-section area of particles reveals that deformation and crushing of particles is about 20% in C_1 case and 11% in case of C_2 on the average when tests finished. In addition, the difference of the deviatoric stress (Fig.3) is observed in early stage of shearing, and then inclinations of stress-strain curves are relatively similar. On the other hand, the reduction of cross-section area of particles appears in the later stage of shearing. The influences of stiffness of CTGS particles may appear in the volume change of specimens during shearing

4. Conclusions

CTGS has a high porosity that consists of not only connected voids between particles but also inter-open voids and inter-closed voids within particles. The deformation and crushing of particle bodies during triaxial shearing were visually observed based on X-ray CT images. It could be demonstrated that the deformation of GCTS specimens is induced by both rearrangement of particles, and deformation and crushing of particles. The larger average value of normalized cross-section of C_2 than that of C_1 during shearing indicates that stiffness of C_2 particles is larger than the one of C_1 particles.

Acknowledgement

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