論文の内容の要旨
Thesis Summary

論文題目　EXPERIMENTAL STUDY ON PARTICLE BREAKAGE UNDER HIGH PRESSURE
Title of Dissertation　（砂粒子の破砕に関する高圧せん断実験）

氏名　余 方威
Name of Author

Granular materials are comprised of particles which would be crushed under high pressure when the energy imposed on soil particle exceeds its strength. With the increasing height of dam and the high-rise building supported by piles, the force exerted on the soil particles at the bottom of high dam or surrounding the tip of piles results in particle breakage. The weathering or freezing and thawing working on particles for a long time can lead to particle breakage as well. Particle breakage changes the natural grading of soil which affects the soil behavior. In addition, particle breakage challenges the classical soil mechanics which assumes that the soil particle cannot be broken during loading and the deformation of soil just results from the change of void among soil particles and the particle movement that is governed by the theory of friction and slippage of soil particles. To investigate particle breakage in soil behavior becomes a very significant research topic in geotechnical engineering.

For investigating particle breakage in soil behavior, triaxial tests were conducted on high-pressure triaxial apparatus with maximum 3MPa confining pressure.

Ⅰ Study on the characteristics of particle breakage

The characteristics of particle breakage were investigated by triaxial tests under different influence factors to clarify the evolution of particle breakage in identifying the change of grain size distribution curves during shearing. The triaxial tests were conducted to the different designated axial strain levels from 0% to 20% by a 5% increment for detecting the different extents of particle breakage by measuring the grain size distribution curves in sieving the specimens at different designated axial strains, which were quantified by relative breakage proposed by Hardin in 1985 as a single parameter to describe the extent of particle breakage by the difference of grain size distribution curves before and after loading.

Particle breakage was found to increase with increasing axial strain and confining pressure. Slight particle breakage during isotropic consolidation was caused as well. More substantial particle breakage was caused in denser sample. More substantial

particle breakage was induced in CD tests than that in CU tests. According to the same mean effective stress to be reached after consolidation, anisotropic consolidation was revealed to result in more particle breakage than isotropic consolidation but during shearing higher confining pressure after isotropic consolidation (σ_c=2.0MPa K_0=1.0) has more influence on particle breakage than that after anisotropic consolidation (σ_c=1.5MPa K_0=0.5). Unloading-Reloading process during shearing was found to lead to particle crushing. Particle crushing was found to increase with increasing cycle numbers of cyclic loading. A hyperbolic model was established to assess Relative Breakage by plastic work per unit volume. More substantial particle crushing was revealed in Coral sand No.3 than that in Silica sand No.5. In addition, particle breakage of Coral sand No.3 was investigated as well in microscopic views on particles during shearing in intuitionistic observation.

Ⅱ Study on the influence of particle breakage on soil behavior

A series of triaxial tests were run on dense specimens under 3MPa confining pressure to the different designated axial strain from 10% to 50% by a 10% increment for Silica sand No.5 but from 10% to 40% by a 10% increment for Coral sand No.3 for producing the crushed materials, which can be called pre-crushed sand subsequently. The material of specimens after shearing was kept in oven to dry and the grain size distribution curves were obtained by sieve analysis in describing the change of grading of original sand after shearing. The grain size distribution curves were quantified by relative breakage to assess the amount of particle breakage. The pre-crushed sand and original sand were employed to rebuild new specimens for new triaxial tests under same initial conditions to investigate the influence of particle breakage on soil behavior in comparison with the results from pre-crushed sand and original sand.

Particle breakage was also found to increase with increasing axial strain and the slight particle breakage still can be caused during isotropic consolidation. Particle breakage in shear band was found to be slightly more substantial than that outside shear band. Under isotropic consolidation on pre-crushed sands, particle breakage was found to result in more volumetric contractancy with larger residual volumetric change after unloading, which can be regarded as a plastic deformation or subsidence at ground surface in reality. By triaxial test on pre-crushed and original sand under various confining pressures, particle breakage was found to deteriorate stress-stress curve in reduction of peak strength. Particle breakage resulted in loss of dilatancy behavior in increase of more contranctacny of soil. Particle breakage resulted in more substantial development and slower dissipation of excess pore water pressure with higher residual excess pore water pressure in pre-crushed sands. Particle breakage was found to change the stress path in reduction of strength. Particle breakage resulted in reduction of the friction angle and the deformation modulus substantially.

Ⅲ Study on the influence of particle breakage on critical state line

The influence of particle breakage on locations of critical state points was investigated as well in triaxial tests on original sand and pre-crushed sands.

It was found that the initial Critical State Line (CSL) from original sand has nonlinear characteristics with a marked yield stress around 0.7MPa and CSL before yield stress can be regarded as a linear line being parallel with the NCL on the loosest state. After yield stress, both high pressure and particle breakage have a complex influence effect on CSL during first shearing on original sand. It was found that particle breakage resulted in reduction of dilatancy & strength and intensification of contractancy of soil, which have a significant effect on CSL. It was found that the locations of the critical state points on original sand in CD test under 0.2MPa and 0.5MPa confining pressures were far away from the CSL, which was caused by effect of initial state of the test. In comparison with the locations of critical state points on pre-crushed sands and original sand in CD tests, critical state points moved downwards in e-logp′ plane with the increase of particle breakage but in q-p′ plane they are almost on the CSL linear fitting line. The locations of critical state points on pre-crushed sands in CU tests were found to move to left away in reduction of mean effective stress in e-logp′ plane but in q-p′ plane the critical state points over CSL moved towards the lower left to approach the CSL. With increasing mean effective stress, critical state points at same amount of pre-crushed particle breakage were found to move towards CSL in e-logp′ plane. Considering the locations of all critical state points from original sand and pre-crushed sand, it can be concluded that the locations of critical state points moved to lower left in e-logp′ plane in complex translation and rotation and developed to be nonlinear in increase of M=q/p′ in q-p′ plane with increasing particle breakage.

Ⅰ-Ⅱ: On Silica sand No.5 and Coral sand No.3

Ⅲ: On Silica sand No.5