INFLUENCE OF GRAIN SIZE DISTRIBUTION ON THE SHEAR BEHAVIOR OF GRANULAR MATERIALS

○ Ogbonnaya IGWE, Kyoji SASSA, and Hiroshi FUKUOKA
(Disaster Prevention Research Institute, Kyoto University)

Soil liquefaction and its catastrophic effects are real threats to public safety. The intense mobility of liquefied soils, which scarcely permits people to evacuate, always make huge losses certain whenever liquefaction causes a slope to fail. Refined knowledge of liquefaction, the conditions fundamental to its occurrence, and the characteristics of liquefiable and potentially liquefiable soils are, therefore, invaluable assets in landslide investigation and mitigation.

To this end, four silica sand samples – well graded, intermediately graded, narrowly graded, and gap-graded – having different uniformity coefficients, were constituted to allow the investigation of the influence of particle size distribution on their mechanical behavior, so as to clarify the general and specific conditions triggering liquefaction. Using a newly developed ring shear apparatus, samples were tested under a wide range of laboratory conditions.

Results of the tests clearly indicate that, for specimens confined under a normal stress range of 100 – 374 kPa, well-graded specimens have higher values of peak resistance than the rest of the specimens. But, quite contrary to many results in literature, it was observed that the residual shear resistance of the well-graded specimens was lower than that of the intermediately graded, and narrowly graded specimens, indicating that although the well-graded specimens seem to resist static liquefaction better than the intermediately, and narrowly graded specimens under the same condition, their lower residual resistances should be a source of concern from the viewpoint of public safety because of their potential for large travel distances. Notable also were results indicating that gap-graded specimens have the lowest values of residual shear resistance than the rest of the specimens at the same state.

The high point of the present research, however, is the find that whether or not a sample liquefies seems to depend more on relative density rather than on gradation. By carefully altering the relative density of a material of any gradation at a given effective confining stress, that material could become dilative or contractive in behavior. And, in between these two extreme behaviors is a relative density at which that material will neither dilate nor contract at failure. In keeping with these kinds of behavior, the concept of "critical pore pressure: the boundary between contraction and dilation" was born. The new proposed concept is consistent with the fundamental elements of critical soil mechanics.

The present research found that there is a critical or a limit value of pore pressure, above which all the samples, regardless of grading, suffered sudden collapse and liquefaction, and below which they dilated and gained some measure of stability. This critical state is established whenever the value of excess pore water pressure at failure is equal to the corresponding value of shear resistance at failure, such that the critical failure ratio, r_c, ($r_c = \Delta\sigma'/\Delta\tau$) is unity. Although critical pore pressure, as expected, varies with normal stress, critical failure ratio must be less than one for a sample to liquefy, and more than one for a sample to dilate. The critical failure ratio represents the state at which change in effective stress at failure is equal to the corresponding change in shear resistance at failure. Careful observation revealed that how much a sample dilated was strongly affected by the difference between the value of $\Delta\sigma'/\Delta\tau$ for a sample at a given normal stress, and the critical failure ratio at that normal stress. The advantages of this new concept is that it incorporates the essential elements, and basic features of critical soil mechanics while predicting the contractive and dilative behaviors of granular materials; and can be effectively represented on the shear resistance – effective stress planes.