Geotechnical Model Tests on Bearing Capacity of Shallow Foundation in Partial Gravity

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Abstract. From a viewpoint of the geotechnical engineering, predictions of lunar soil behavior are of fundamental importance in evaluating the reliability and feasibility of lunar surface operations. As a first step for the investigation of soil collapse problems in lunar surface environment, model tests on bearing capacity of a shallow foundation in reduced gravity conditions were performed. The model tests were conducted in an aircraft cabin. The air craft flies in parabolic arcs to generate partial gravity conditions during drives. A series of loading tests was carried out to investigate the effect of gravity on bearing capacity of dense sand under the plane strain condition. Figure 1 shows the model test apparatus used in this study. Two kind of air-dried sands; the Japanese lunar soil simulant and Toyoura sand were used. The lunar soil simulant is an artificial soil produced to imitate actual lunar soil characteristics including chemical composition, density, particle distribution, and shear strength (Kanamori, 1998; Kobayashi, 2006). On the other hand, the Toyoura sand is widely used as a standard sand in geotechnical study in Japan. The model sands were compacted in a soil box (W:400, H:160, D:50 mm) by a vibrator to give the relative density of 90 %. A model footing (Breadth, B = 20 mm, base: rough) made of aluminum was penetrated to the model ground surface with constant loading rate of 3.0 mm/s. The loading tests were conducted under the different gravity conditions from 0 to 2g.

![CAD image](image1.png) ![Experimental rack](image2.png)

FIG. 1. Model test apparatus

Figure 2 shows examples of test results of load-settlement relationships. When paying attention to first peak values, the values of the lunar simulant are greater than those of Toyoura sand, suggesting that the shear strength of the lunar soil is greater than sandy soil of Earth when the soil is densely packed. Regarding the behavior of post-peaks,
the more drastic drops are seen in case of the lunar simulant compared to the case of Toyoura sand, indicating that the lunar simulant exhibits brittleness.

Figure 3 shows the relationships between gravity, \( g \) and ultimate bearing capacity (the first peak of base contact pressure), \( q_u \). It can be seen that the gravity is reflected in \( q_u \) of Toyoura sand, while the lunar simulant seems to have less effect of gravity when the gravity is smaller than \( 1g \). This result indicates that the cohesive component of the lunar simulant, rather than frictional component, greatly contributes to the bearing capacities.

Figure 4 shows the relationships between gravity and coefficient of subgrade reaction, \( k_s \). It can be seen that \( k_s \) of the lunar simulant is larger than that of Toyoura sand, and the effect of the gravity on \( k_s \) of lunar simulant is comparatively small. These results indicate that bearing characteristics of lunar surface will be firm even in reduced gravity environment, however, on the contrary, it becomes difficult to carry out earthmoving operations including soil cuttings and soil preparations when the lunar soil is densely packed.

Form a theoretical consideration, it appeared that the effect of gravity on the bearing capacity become insignificant when the gravity and footing breadth is comparatively small or the soil has a large cohesion. Furthermore, it turned out that the classical bearing capacity theory extremely overestimate the ultimate bearing capacities because dimensionless parameters, \( \rho gB/c \) given by this experimental condition is too small. Hereafter, the authors intend to develop a theoretical framework for a precise prediction of bearing capacity on lunar surface.

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PRINCIPAL AUTHOR'S BIO (~50 WORDS)

Taizo Kobayashi is a research associate of Department of Civil Engineering at Kyushu University, Japan. His research interests are in geotechnical engineering, principally in the development of in-situ testing devices, design of foundations and mechanics for soil-machine interactions (Terramechanics).