D201

The effect of particle shape on the shear behavior: Results of tests on rice particles and implication for high-mobility of rock avalanche

○Shengshan WU, Gonghui WANG

1. Introduction

Rock avalanches are a common geological disaster caused by the sudden failure of large-volume rocks that slide a long distance at an extremely fast velocity (Hungr et al., 2014; Legros, 2002). Rock avalanches are more mobile than normal landslides, travel faster and farther, and cause more great damage (Delaney & Evans, 2015; Mitchell et al., 2020). From the data on rock avalanches, the apparent friction coefficient of rock avalanches is ultra-low if the volume is larger (Lucas et al., 2014). Many studies were conducted to investigate the reasons for the ultra-low shear strength of the sliding mass from rock avalanches, in order to reveal the movement mechanism of rock avalanches.

Recently, some field evidence indicated that rock fragmentation can occur throughout the runout (Davies et al., 1999). The phenomenon of inverse grading is a typical feature of rock fragmentation. During the transfer process, rocks become particles of various sizes and shapes (Wang et al., 2017). Previous experimental studies showed that particle shape significantly affects the shear strength (Altuhafi et al. 2016; Rousé et al. 2008) and other mechanical behavior of the granular materials. Nevertheless, less evidence had been obtained. To improve our understanding of the effect of particle shape on shear strength and to reveal the motion mechanism of particles with different shapes, we conducted a series of ring shear tests on granular materials with different sharps.

2. Materials and Methods

In this study, two types of rice with different particle shapes were used as experimental samples: Thai long-grain white rice (RT) and Japanese rice with short grains (RJ) as shown in Fig. 1. Ring shear tests by using DPRI-5 were performed on these samples under natural dry conditions to compare their shear behaviors at continuous shear rates. To avoid the effect of possible particle breakage on the shear behavior, some tests were performed under lower normal stress conditions. In all the tests, we used stress ratio (μ = monitored shar resistance against normal stress) as a common index to compare the results.

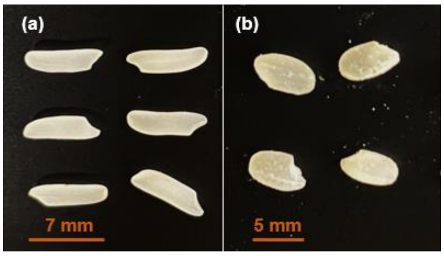

Fig. 1. Images of the tested samples. (a) Thai long-grain white rice, and (b) Rice from Japan.

3. Results

Figs. 2-3 example the results of ring shear tests under relatively lower normal stress (43 kPa for RT and 42 kPa for RJ). As shown in Fig. 2, RT was sheared at various shear velocities from 0.02 cm/s to 10 cm/s. During the total shear process, an obvious stick-slip phenomenon occurred as the shear velocity is lower (< 0.5 cm/s in this test), and μ_{max} reached about 1.3. The stick-slip phenomenon became not clear as shear velocity increased (> 0.5 cm/s). With increasing shear velocity, μ also decreased to about 0.3, presenting the exitance of the typical shear rate effect.

Fig. 3 presents the results of a test on RJ under normal stress of 42 kPa. The stick-slip phenomenon also occurred at lower shear velocity (< 0.2 cm/s), and then gradually disappeared with the increase of shear velocity. However, μ_{max} reached about 0.7, which is smaller than that of the test on RT. Similarly, the shear rate effect is clear. The μ reached about 0.4 when the shear velocity was 10 cm/s.

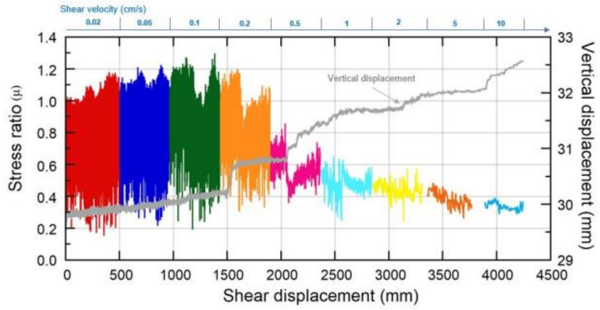

Fig. 2 Stress ratio of RT at different shear rates under normal stress of 43 kPa.

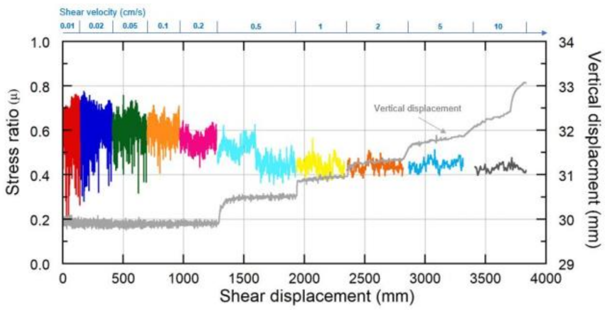

Fig. 3. Stress ratio of RJ at different shear rates under normal stress of 42 kPa.

4. Summary

In the shear velocity range of this research, the average stress ratio at each shear velocity is shown in Fig.4. From our experimental results, it can be found that when shearing at low velocity, the stress ratio vibration amplitude in the tests on RT (with longer grains) is stronger than that in the tests on RJ (with shorter grains). Further, the μ of RT is lower than that of RJ under higher shear rates (5~10 cm/s). Based on the results of tests on different types of rice shown in this study and other results of our tests on sandy materials, we concluded that the particle shape of the granular materials can greatly affect its friction strength, and inferred that the different shear behavior may result from the different shear mechanisms, such as laminar and turbulent shears occurring with the shear zones of granular materials. The Thai rice with longer grains may facilitate the directional alignment of particles and then the formation of laminar shearing, while the Japanese rice with short grains may facilitate the formation of turbulent shearing. Concerning this inference, further study will be needed and is also underway.

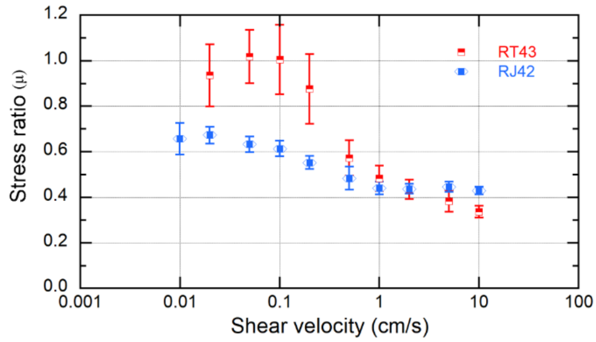

Fig. 4. The average stress ratio of RT and RJ at different shear velocities.

5. References

Altuhafi, F. N., Coop, M. R., & Georgiannou, V. N. (2016). Effect of particle shape on the mechanical behavior of natural sands. Journal of Geotechnical and Geoenvironmental Engineering, 142(12), 04016071.

Davies, T. R., & McSaveney, M. J. (1999). Runout of dry granular avalanches. Canadian Geotechnical Journal, 36(2), 313–320.

Hungr, O., Leroueil, S., & Picarelli, L. (2014). The Varnes classification of landslide types, an update. Landslides, 11(2), 167-194.

Legros, F. (2002). The mobility of long-runout landslides. Engineering Geology, 63(3–4), 301–331.

Lucas, A., Mangeney, A., & Ampuero, J. P. (2014). Frictional velocity-weakening in landslides on Earth and on other planetary bodies. Nature communications, 5(1), 1-9.

Rousé, P. C., Fannin, R. J., & Shuttle, D. A. (2008). Influence of roundness on the void ratio and strength of uniform sand. Geotechnique, 58(3), 227-231.

Wang, Y. F., Dong, J. J., & Cheng, Q. G. (2017). Velocity-dependent frictional weakening of large rock avalanche basal facies: Implications for rock avalanche hypermobility? Journal of Geophysical Research: Solid Earth, 122(3), 1648–1676