D09

Frictional Instability of Locally Sheared Granular Materials: Does it Depend on Particle Size?

○Yao JIANG, Gonghui WANG, Toshitaka KAMAI

1. Introduction

Granular frictional instability is intrinsic to many geophysical processes, ranging from landslides to earthquake rupture on gouge-filled faults. Field observations support that the progressive maturation of these catastrophic events may undergo diverse styles of movement, such as slow, stable creep, periodicity of stick-slip or accelerative sliding; laboratory experiments also manifest that the granular frictional properties are strongly dependent on the sliding rate and state variables (Marone, 1998; Scholz, 2002; Anthony and Marone, 2005; Johnson et al., 2008; McLaskey et al., 2012). However, the effect of particle characteristics on grain-scale shear deformation of granular assemblies is still poorly understood. In the present research, we report on laboratory experiments designed to examine the frictional instability with particular emphasis on the influence of shear velocity and particle size in locally sheared granular materials, which attempts to improve the understanding of physical processes and failure mechanisms for such kind of large mobilization phenomena in rapid landslides.

2. Methods

We conducted a series of laboratory experiments on granular analogues composed of spherical glass beads in a ring shear configuration under conditions of room temperature and atmospheric humidity. Experiments with three kinds of uniform particle sizes (i.e., 1.0-1.41mm, 2.0-2.5mm and 4.7-5.3mm) were carried out under shearing velocity from 0.005 to 50 mm/s and constant vertical stress of 200 kPa, where breakage and comminution of grains were not considered.

Additionally, in order to investigate how the micro-slip instabilities nucleate, propagate and catastrophically fail, we employed acoustic emission (AE) method to capture the release of high frequency elastic energy generated by abrupt perturbations of internal forces among granular assemblies. A high frequency AE transducer (in the range of 100 kHz to 1 MHz) was installed near the shear plane during tests such that the resultant elastic waves can be recorded.

3. Results

One selected result is shown in Fig.1 to identify the dependence of particle size on the friction strength and instability. Figs.1a-d suggest that the frictional instabilities are associated with the AE waveforms for different particle sizes, respectively.

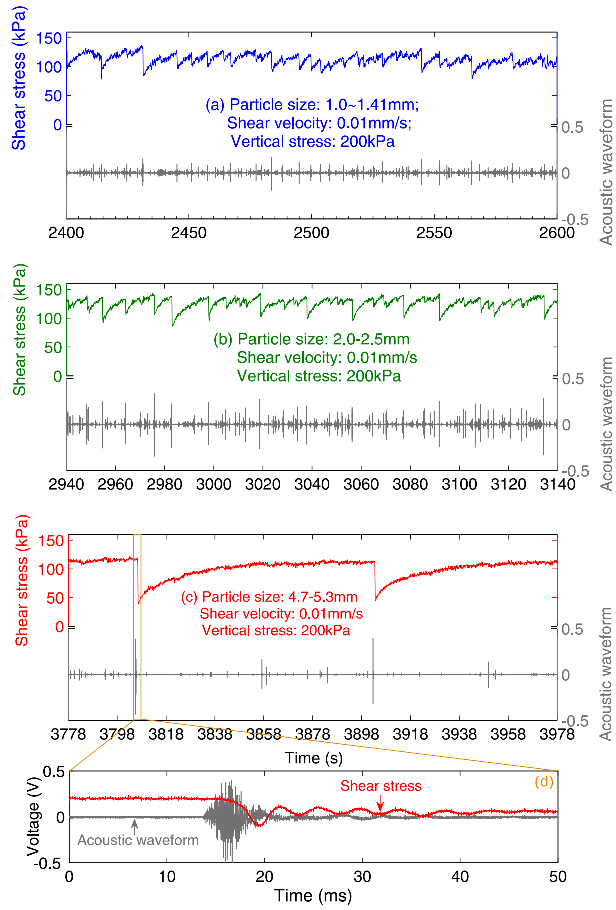

Fig. 1 Frictional properties and the measured AE waveforms for different particle sizes.

We find that the dynamical shear resistance drops will show larger, but the frequency of such kind of catastrophic frictional instability will lower with increasing the particle size. Importantly, the occurrence rate of generated AE events decreases, but the amplitude of AE waveforms increases with increasing the particle size. In particular, as illustrated in Fig.1d, we observed ultrasonic precursors well before dynamic failures occurred among granular materials.

4. Conclusions

Our results highlight the links among granular material properties, mechanical conditions and characteristics of generated AEs. The most important finding of this study is the presence of ultrasonic precursors prior to the shear failure of granular materials. The frictional properties of granular materials are entwined with the particle properties and mechanical conditions, and the generated AEs also exhibit different characteristics. Herewith, as future directions, we will concentrate on analyzing the characteristics of AE events, and endeavor to provide a new insight into the physical processes and better understand the failure mechanisms for such kind of catastrophic phenomena in rapid landslides.

Acknowledgments The first author would like to extend his sincerest gratitude to Dr. Issei DOI for his helpful discussions and invaluable suggestions.

5. References

Anthony, J.L. and C. Marone (2005). Influence of particle characteristics on granular friction. Journal of Geophysical Research: Solid Earth, 110(B8): B08409.

Johnson, P. A., H. Savage, M. Knuth, J. Gomberg, and C. Marone (2008), Effects of acoustic waves on stick-slip in granular media and implications for earthquakes, Nature, 451, 57-60.

Marone, C. (1998), The effect of loading rate on static friction and the rate of fault healing during the earthquake cycle, Nature, 391, 69-72.

McLaskey, G. C., A. M. Thomas, S. D. Glaser, and R. M. Nadeau (2012), Fault healing promotes high-frequency earthquakes in laboratory experiments and on natural faults, Nature, 491, 101-104.

Scholz, C. H. (2002), The Mechanics of Earthquakes and Faulting, Cambridge Univ. Press, New York.