On the Shear Behavior of Nanomaterials and Its Implication to Landslide Hypermobility

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1. Introduction

Rock avalanches, normally characterized by large volume (> 1 million m^3), extremely high velocity and unexpected long runout (Legros, 2002), are the geological disaster caused by the sudden failure of rock slopes without warning or noticeable premonition. The destructiveness of rock avalanches could be exampled by the 1903 Frank Slide occurring in Canada, which killed 90 people and buried part of the mining town of Frank. In recent decades, great efforts had been paid to understand the rapid movement mechanism of rock avalanches. For example, the statistical data have revealed that the apparent friction coefficient of rock avalanche (μ = H/L, where H is the difference in elevation, and L is the Horizontal distance of the displaced landslide materials) depends on its volume (V) (Lucas et al., 2014), i.e., μ becomes smaller with increase of V, and smaller μ means higher mobility and longer travel distance of the displaced materials.

By now, many assumptions, such as fluidization, self-lubrication, acoustic fluidization, entrainment, dynamic fragmentation, and others, had been proposed to explain the reduced basal friction, which is thought to be the main reason for the long run-out. Although there is no conclusive one that had been accepted widely yet, due to the fact that most of them lack quantitative field or experimental evidence. Recent field observation and experimental works strongly suggest that the rock pulverization during the transportation may play a key role on the reduction of basal friction probably due to the production of nanomaterials that may works as lubricant (Han et al., 2011), or the formation of a powder layer that may works as lubricating base (Kamata et al., 2002). As the first step to unravel the possible mechanisms behind this, we conducted a series of ring shear tests on different nanomaterials at differing shear rates (from 0 ~2.3 m/s). Some preliminary results are presented in this study.

2. Materials and Methods

Nano-silica powder (NSP), American Dragon halloysite (ADH) and halloysite from New Zealand (NZH), were used in this study. The SEM and TEM photos revealed that these materials are different in size and shapes (Fig. 1).

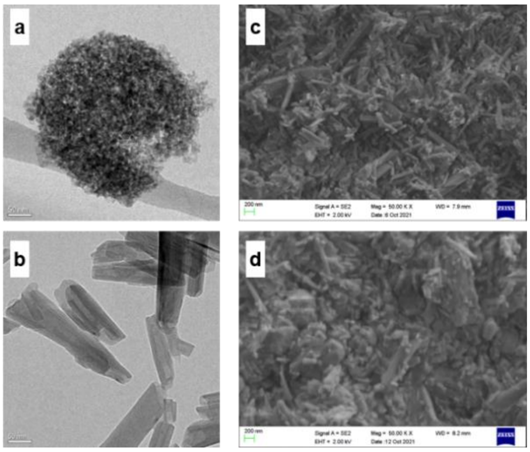

Fig. 1. Microscopic observations of test samples: TEM photos of (a) Nano-silica and (b) Dragon halloysite, respectively; SEM photos of (c) American Dragon halloysite (tubular) and (d) New Zealand halloysite (mixture of tubular and spheroids and platy).

Halloysite is a material that could be easily dehydrated, we also conducted tests on the halloysite that had been dried for 24 h under the temperature of 420℃ and 500℃, respectively. All of these tests were performed using the ring shear apparatus of DPRI-6 (with a maximum shear rate of 2.24 m/s) under dry condition. It is noted that we sheared the same sample by continuously changing the shear velocity.

3. Results

Some of the test results are exemplified in Figs. 2-4. Fig. 2 shows the time series data of shear velocity and stress ratio (λ = monitored shar resistance against normal stress) for the test on NSP. It is noticed that λ keeps approximately constant (about 0.6) during the whole shearing process, while the shear velocity is varied greatly (from zero to 2.24 m/s). Therefore, it is inferred that not all the materials in nanometers can work as lubricant to lower the λ.

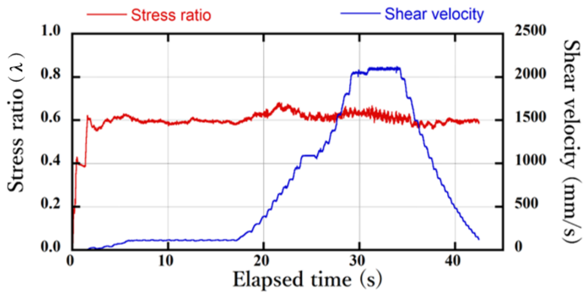

Fig. 2. Results of test on Nano-silica.

Fig. 3 presents the results of tests on ADHs that were dried under different temperatures. It could be noticed that the shear rate effect is significant, i.e., with increase of shear velocity, λ decreases in each test. However, when the shear velocity is increased to the maximum value (2.24 m/s), λ of the original sample (red line) is significantly lower than that of the dried sample (blue line). Therefore, it is inferred that during shearing dehydration might have occurred, resulting in the significant reduction of λ.

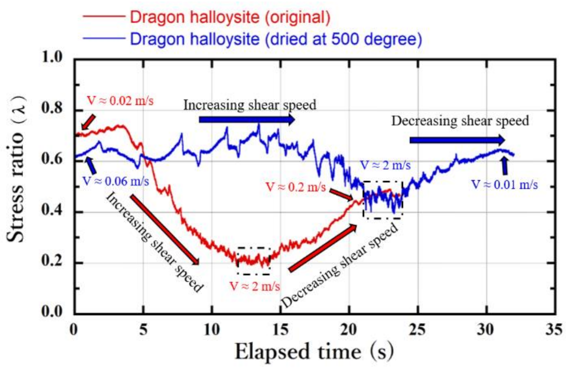

Fig. 3. Results of tests on ADHs

Fig. 4 presents the results of tests on ADH and NZH. Both samples were not dried. As shown in Fig. 4, the shear rate effect is also clear. The λ decreases with increasing shear velocity, and it is also worth noting that the λ obtained with the tubular shape sample (red line) is smaller than λ obtained with the mixed shape sample, showing the effect of grains shape on the shear behavior.

4. Summary

From our experiments data, we found that not all the nanomaterials exhibit rate effect in high-velocity shear test, they can also maintain high strength in high-speed motion (such as the results of NSP shown in Fig. 2). The shape and dehydration of materials during shearing may play key role on the mobilized friction. The shear rate effect on λ as shown in Figs. 3 and 4 may result from the changing of shear model with shear rate. It is also noted that detailed study concerning this is still on going, and we hope to reach a conclusive interpretation with more detailed evidences in near future. Examination on the effect of formation of powder layer on the shear resistance is also planned.

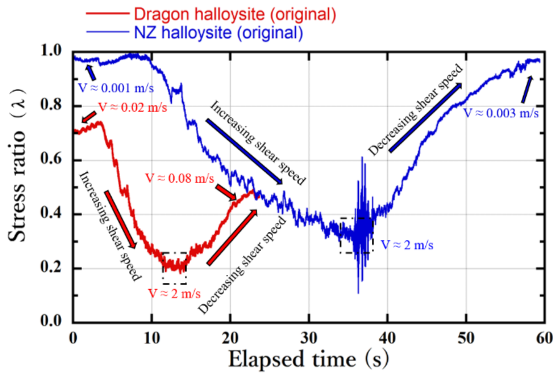

Fig. 4. Results of tests on ADH and NZH

Acknowledgments

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5. References

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