CONTACT MATURING AND AGING OF SILICA SAND

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1. Background

Silica sands have been known to exhibit rate effects, but they are also known to change properties over time; in particular, the stiffness has been found to increase in time under sustained loads (aging effect). There is no consensus as to what dominant processes are responsible for these effects. A hypothesis was proposed recently [1] suggesting that the key cause of aging in silica sand is the time-dependent fracturing of asperities on grain surfaces at inter-granular contacts, referred to here as *contact maturing*. Such fracturing is consistent with the rate process concept (e.g., [2]), and it was used in simulations of contacts by the distinct element method [3].

The purpose of this research was to gain experimental evidence for contact fracturing and the resulting fatigue or contact maturing. The second goal was to explore the use of the distinct element method as a simulation tool for describing contact maturing.

2. Testing of individual inter-granular contacts

Testing of individual contacts presents challenges both due to the small size of the specimen and because of the sensitivity of the measured quantities to changes in humidity and temperature. An apparatus was constructed, Fig. 1(a), capable of measuring the time-dependent convergence of

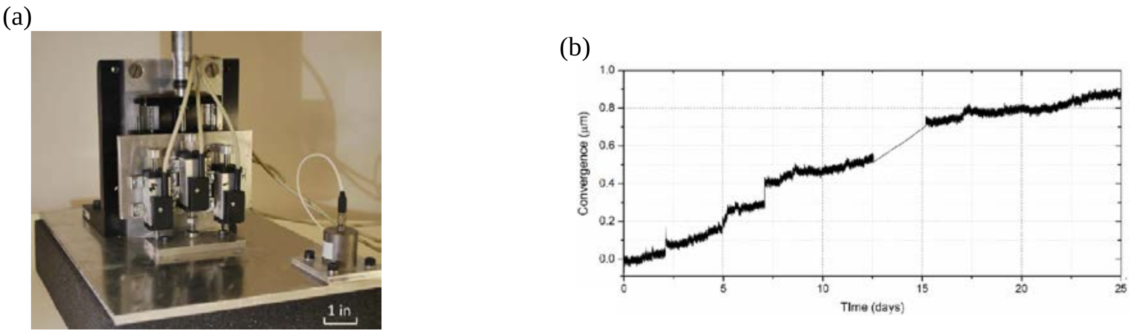

Figure 1. (a) A view of the contact testing apparatus, and (b) increase in convergence of the grain loading platens in time under sustained load of 2.4 N.

two platens transmitting the load to a single grain, while the load on the grain remains constant. This convergence (under the loads used) is attributed to the micro-fracturing process occurring on the grain surface at the two contacts of the grain with the platens. The time-dependent response of an Ottawa 20-30 grain to a load of 2.4 N is shown in Fig. 1(b). The convergence of the platens reached about 0.9 μm in 25 days (loss of data at 12.5 – 15 days was due to power supply interruption). Inspection of the grain surface by means of scanning electron microscopy revealed that, indeed, the areas of contact are characterized by micro-fracturing and resulting comminution.

3. Distinct element modeling of contacts

In order to simulate the process of contact maturing, two half-grains were modelled as assemblies of bonded particles, Fig. 2(a). A time-dependent parallel bond model was utilized [4] in order to describe the delayed fracturing leading to contact maturing. The inter-particle bonds are subjected to a contact force (with both the normal and shear components), as well as the bending moment and torsion. Once tension above a certain threshold occurs in any part of a bond, the stress corrosion process is activated, leading to deterioration (reduction in size) of the bond. Consequently, some bonds become eliminated in time, which is interpreted as the appearance of micro-cracks.

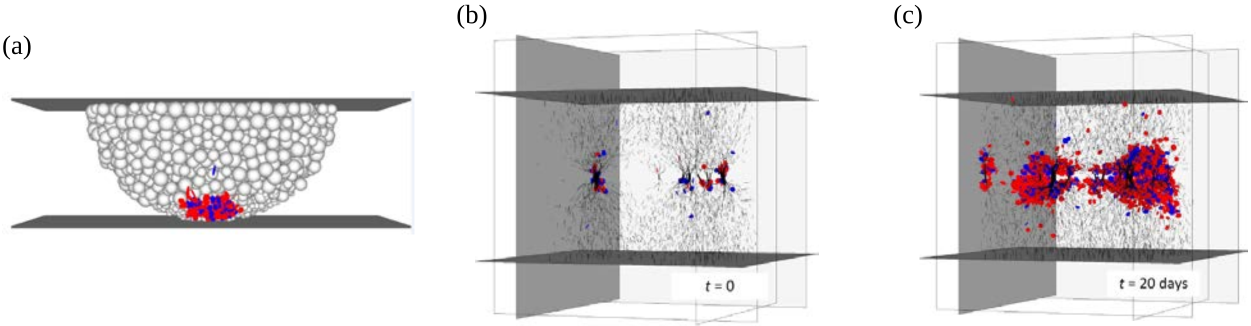

Figure 2. (a) Half-grain simulated using distinct element method, (b) force chains at the contact region and cracks immediately after application of the load (t = 0), and (c) after 20 days [3].

Results from preliminary simulations are presented in Figs. 2(b) and 2(c). This is a simulation of a contact between two silica grains (nominal contact area of 30x30 μm), subjected to a constant force of 2.4 N. Immediately after application of the load, there were 10 force chains intersecting the contact area between the two grains simulated, Fig. 2(b), and 88 bonds were fractured at that time. The respective numbers after 4 days were 18 contact points and 1804 cracks, whereas after 20 days the number of force chains intersecting the nominal contact area (or the number of contact "points") increased to 31, with 2670 cracks, Fig. 2(c).

3. Remarks

Test results revealed comminution of the material at contacts in silica sand; this causes the number of contact points at the nominal inter-granular contact to increase, leading to an increase in contact stiffness. This effect will propagate through the spatial scales, and will be seen as an increase in the macroscopic stiffness. Indeed, this can be detected as a time-dependent increase in the shear wave propagation in sand subjected to sustained loads. The experimental evidence is consistent with the contact maturing hypothesis, and the distinct element method appears to capture the essential elements of the process.

Acknowledgements

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