Soil Liquefaction Without Pressurization: A Simple Mechanism.

Numerical And Experimental Study, Consequences On The Range Of Field Earthquake-Triggered Events

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ABSTRACT

During earthquakes, certain soils can loose their ability to support shear and liquefy. This effect can cause buildings to sink into the soil. We aim to understand the behavior of object sinking into liquefied granular media : can we foresee the velocity of sinking and the final depth of driving in if it exists ? We run numerical simulations and laboratory experiments to study the behavior of a model system, namely the mechanics of an intruder above a shaken model soil, a sphere lying on the top of a (saturated or dry) granular medium shaken by horizontal movements at controlled frequency. The simulations are done with frictional elastic molecular dynamics models. The experiments are monitored using optical data and accelerometers.

Simulations and experiments show that the sphere displays three different ways to enter the granular medium : (1) rigid motion without deformations, (2) liquefaction, (3) convection. The peak ground acceleration (PGA) is the decisive parameter. The final depth of driving in depends on isostasy, and on the severity of shaking.

It can be entirely determined by isostasy, when the shaking entirely unjams the medium and suppresses the average friction around the intruder. For moderate shaking, the liquefaction is absent, or partial, and the sinking is subisostatic. The initial velocity of driving in of the sphere is often sufficient to determine in which of the three behavior the experiment takes place.

We show that the macroscopic response of the medium, once identified in the right regime, can be collapsed on a master curve, with a reduced depth as function of a reduced time. The adimensionalisation is done using an immersed volume determined by isostasy, and a time determined by the imposed frequency.

We also show that the liquefaction effect is maximum when the water table reaches the surface of the granular medium and when the PGA allows the small particles to slide the one on each other but is not strong enough to allow the intruder object to slide on small particles.

We next study the response of a dry granular medium, and how it evolves during liquefaction.

With numerical simulations we study the velocity field and a phase difference between the intruder velocity and the surrounding medium. On the other side with laboratory experiments we compare the accelerometric signals between one accelerometer fixed on the moving box

and one accelerometer inside the sphere. We find again a phase difference which can explain how the object can enter the granular medium. From the velocity field computed during numerical simulation, we can compute an excitation parameter allowing to understand vertical motion (Sanchez-Colina et al., 2014). Eventually the shape of the object has also a real effect, as shown in recent studies (Brzinski et al., 2013). Our experiments shows that cylinders lying on the granular medium are more stable under horizontal shaking than the same cylinder attached to a ring below burried into the medium as buildings foundations. We are currently modelizing this observation with numerical simulations.

Eventually, we show how the derived criteria for liquefaction can render for the field occurences.

References

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T. A. Brzinski III, P. Mayor, and D. J. Durian*, Phys. Rev. Lett.* 111, 168002 (2013)