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Soil liquefaction: how the granular medium evolves, macroscale and microscale study

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During earthquakes, certain soils may loose their ability to support shear and liquefy. This effect can cause buildings to sink into the soil. As a first step we aim to understand the behaviour of an object sinking into liquefied granular media: can we predict the velocity of sinking and the final depth of intrusion if it exists?
We run numerical simulations and laboratory experiments to study the behaviour of a model system, namely the mechanics of an intruder (sphere) initially placed bove a shaken model soil, modelled as (saturated or dry) granular medium, shaken by horizontal movements at a controlled frequency. The simulations are done with frictional elastic granular 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) slow liquefaction, (2) fast liquefaction, (3) convection. The peak ground acceleration (PGA) is the decisive parameter. The final depth of intrusion depends on isostasy, and on the severity of shaking. It can be entirely determined by isostasy, when the shaking entirely unjams the edium and suppresses the average friction around the intruder. For moderate haking, the liquefaction is absent, or partial, and the sinking is subisostatic. The initial penetration velocity of the sphere is often sufficient to determine which of the three behaviours takes place in the experiment. We show that the macroscopic response of the medium, once classified in the right regime, can be collapsed on a master curve, with a reduced depth as function of reduced time. The non-dimensionalisation is done using an immersed volume determined by isostasy, and a time determined by the imposed frequency.

As a second step we study the response of the granular medium, how it evolves during liquefaction. With numerical simulations we study the velocity field and find a phase difference between the intruder velocity and the surrounding medium. In complementary 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 may explain how the object penetrates into the granular medium. From the velocity field computed during numerical simulations, we also compute an excitation parameter which gives us comprehension on the strain along the vertical axis.