UC DAVIS
CENTER FOR GEOTECHNICAL MODELING

A Hypergravity Laboratory Platform to Push the Frontiers of Engineering and Science

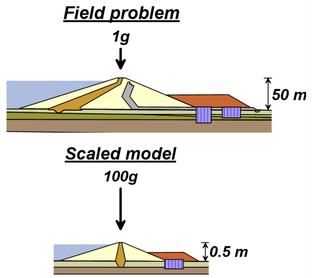
Jason DeJong, Director; Dan Wilson, Associate Director

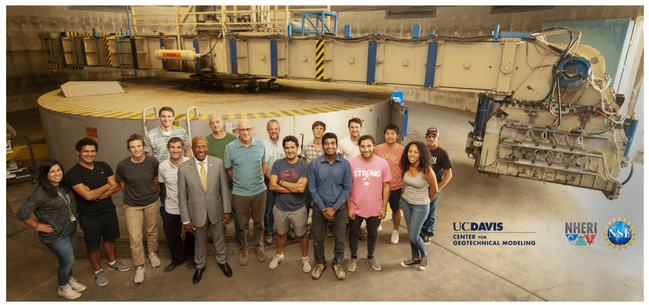
NHERI
Natural Hazards Engineering Research Infrastructure

Shared use centrifuges for research at hypergravity

Centrifuges enable the use of scale models to represent nonlinear, stress-dependent responses of soil masses. Physical models at hypergravity are often the only recourse for representing large systems such as civil infrastructure.

The national shared use 9m- and 1m-radius centrifuges at the UC Davis Center for Geotechnical Modeling (CGM) allow users to perform experiments at up to 80g of hypergravity, with scaled dimensions up to 125 m long and 50 m deep.





Above: The stress beneath a 50m-tall embankment at 1g is the same as the stress beneath a 0.5m-tall embankment at 100g, increasing similarity in behavior.

Left: The 9m machine at UC Davis is the world's largest centrifuge equipped with a shake table.

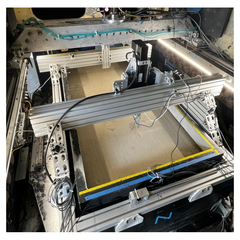
Hypergravity and civil infrastructure – a history of success

This unique environment has been used to model infrastructure systems subject to static and dynamic loads, generating data otherwise unattainable. Results include seminal contributions related to the design and performance of critical civil infrastructure such as dams, levees, tunnels, and bridges.

Operational highlights:

- Five decades as a national shared use facility
- > $100M (2023$) across ≈100 research awards
- Federal, state, local, and private sponsors

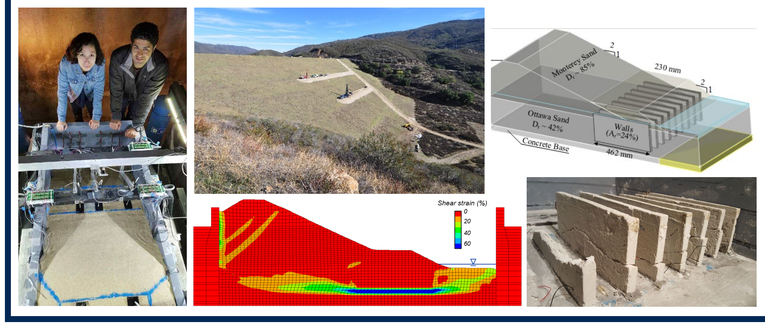

Josh Bauer/NREL

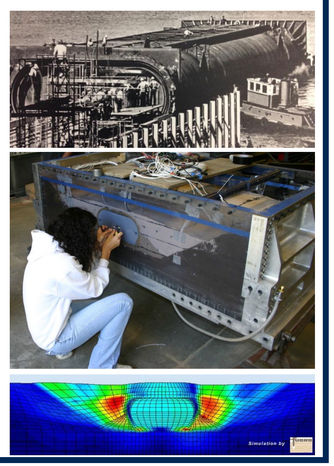


Above: Investigating novel foundations for deep water offshore wind energy.

Right: Verifying seismic risk analysis of Bay Area Rapid Transit (BART) transbay tube.

Left: Verifying design methods used to analyze novel techniques for remediating seismic liquefaction risk of embankment dams.





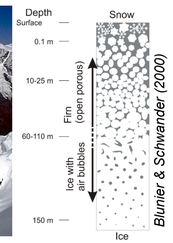
Wide ranging opportunities exist

Gravity affects many physical quantities including weight, buoyancy, convection, pressure, stress, pressure gradients, and potential energy. Being able to adjust the gravity field provides an opportunity to validate computational models more comprehensively across a range of disciplines.

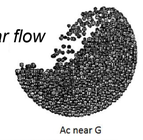
Given the success of centrifuge experiments and modeling in geotechnical engineering, the CGM has been exploring how this hypergravity experimental environment could be used more broadly across other areas of engineering and science. A recent international workshop identified opportunities that were wide-ranging, including arctic engineering, ocean currents, offshore hazards, nuclear waste disposal, combustion, flow of granular materials, and thermal convection in fluids and gasses.

Permafrost

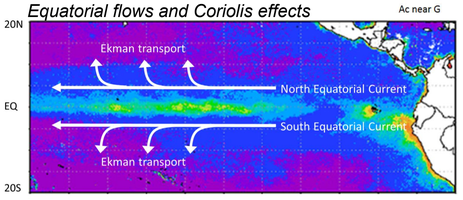

J. Merck

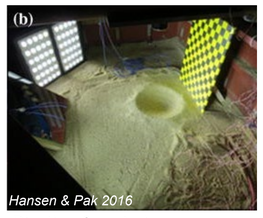


Granular flow



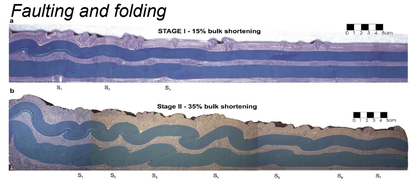
Equatorial flows and Coriolis effects



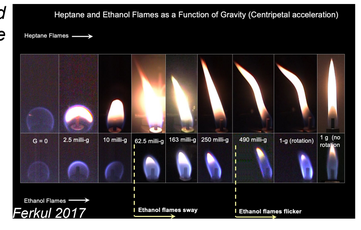


Blasting & cratering

Faulting and folding



Combustion and buoyancy of flame



The examples above show various mechanics that can be studied at hypergravity as identified at the 2020 Frontiers in Hypergravity workshop (Kutter et al. 2021). Hypergravity experiments can enable researchers to advance fundamental understanding, fill knowledge gaps, and validate advanced computational models for an array of multi-physics, nonlinear, coupled, stress- and gravity-dependent processes.

Acknowledgements

Shared-use operation of the centrifuge facility at UC Davis has been supported by NSF through NEES (CMMI 0086566, 0402490, 0927178) and NHERI (CMMI 1520581, 2037883).

https://cgm.ucdavis.edu/ cgm@ucdavis.edu