Fundamental Characterization of Microgravity Geomechanics

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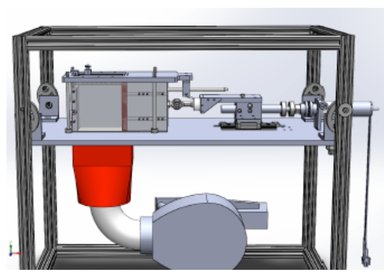
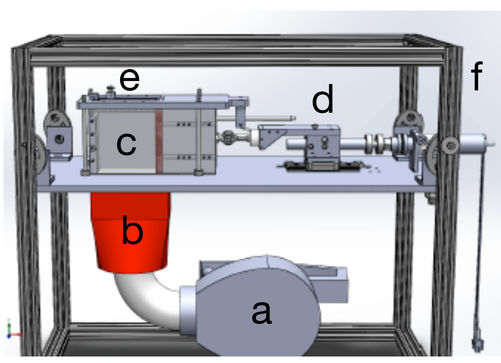
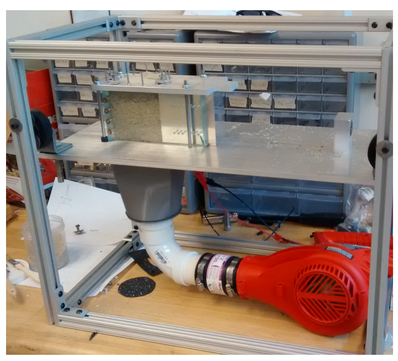
Introduction

- Objective: study the microgravity behavior of geomaterials to improve our understanding of the interactions between spacecraft and extraterrestrial soils
- Applications: rover mobility in low gravity (e.g. on Martian or Lunar soils)
- Approach: test geomaterials using novel prototype characterization device onboard a Zero Gravity Corporation research flight



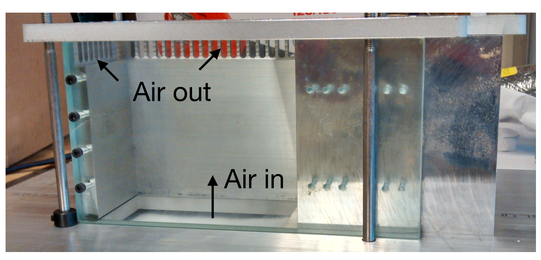
Prototype Testing Device





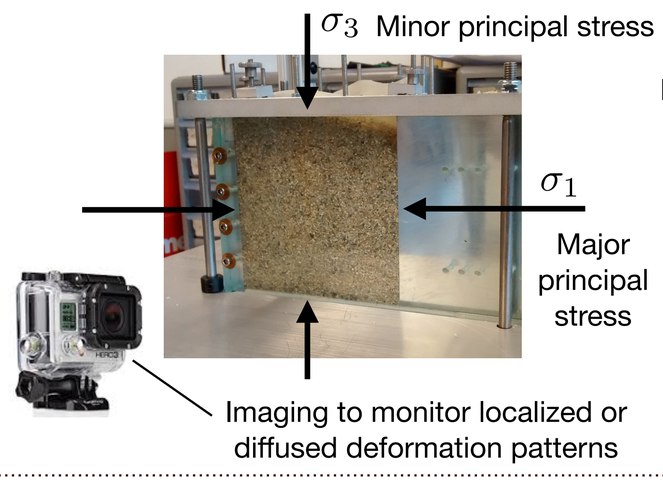
- Prototype components:

a. Air compressor for fluidization of geomaterial to prescribed relative density
b. Air inlet chamber designed to provide uniform fluidization of the sample
c. Specimen holder with inlet and outlet holes for fluidization and glass window for imaging sample during load; post-processing of images will analyze deformation



d. Loading screw attached to compression block and load cell
e. Membrane to lightly confine the sample; membrane deformation will be measured
f. Frame to mount testing device to plane floor

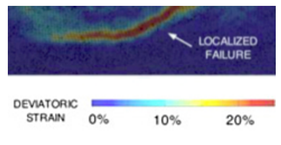
Measurements



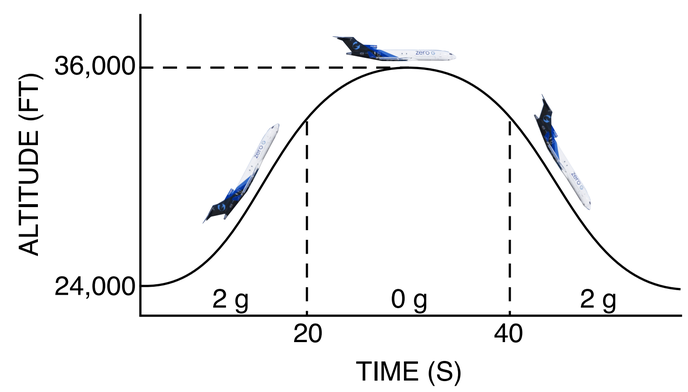
Internal friction angle (strength)

$$\phi = \phi(\sigma_1, \sigma_3)$$

Digital image correlation of images (example)



Testing Protocol

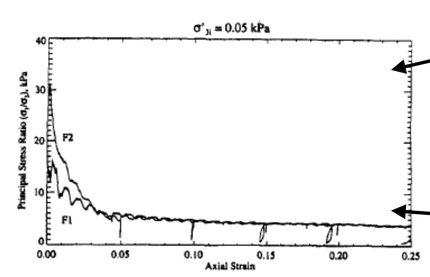


- 20s: Initiate fluidization system to calibrate packing relative density
- 28s: Begin compression test; monitor with camera
- 40s: Test finished, prepare for 2g

Microgravity Geomechanics

- Sture et al. (1998) demonstrated remarkable microgravity soil response during cyclic triaxial testing aboard the Space Shuttle
- The current work will perform real-time imaging in similar conditions to monitor the evolution of deformation during loading and failure in microgravity

Regularly spaced sets of dilation/shear bands visualized from an Epoxy-Impregnated Specimen tested aboard the Space Shuttle in Sture et al. (1998)



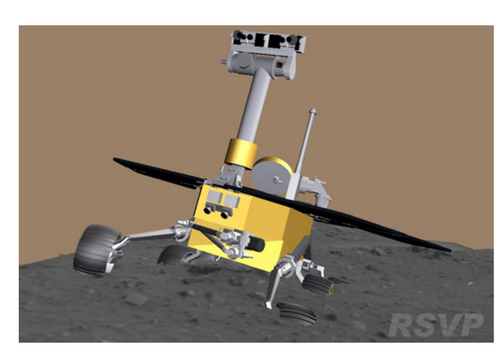
Peak and residual friction angles (70° and 37°) in microgravity much higher than observed in regular gravity (44.1° and 34°), from Sture et al. (1998)

Periodic oscillations in stress response may result from force chain failure

Sture, S., Costes, N. C., Batiste, S. N., Lankton, M. R., AlShibli, K. A., Jeremic, B., ... & Frank, M. (1998). Mechanics of granular materials at low effective stresses. *Journal of Aerospace Engineering*, *11*(3), 67-72.

Applications and Future Work

- Microgravity geomechanics will improve modeling of surface interactions with spacecraft, preventing, for instance, rover embedding and mobility challenges



Spirit Embedding Image credit: NASA/JPL-Caltech

- Improved understanding of microgravity geomechanics may also enhance preparation for future missions to other celestial bodies (e.g. moons, asteroids)
- Additional parabolic flight testing can elucidate fundamental properties of various regoliths in various low-gravity conditions

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