University of Colorado Boulder

Water Energy Nexus IRT

2018 Seed Grant Final Report

Title: Fracking soils: towards an engineered delivery method for environmental remediation and soil modification

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Research Objective(s): The remediation of contaminated sites characterized by fine-grained soils is often hampered by the extremely slow rate of fluid flow and the project is often time consuming and costly. We propose to adapt fracking which has been matured for more than 50 years in the field of oil and gas industry to augment environmental remediation and soil modification in large volumes of fine-grained, uncemented or weakly cemented shallow deposits. The goal of this proposal is to conduct numerical studies to prove this concept.

Research Activities/Methodology: We hypothesize that controlled injection of engineered fluid together with granules (i.e. proppants) will create lenses of high permeability channels in the subsurface to enhance the accessibility of treatment fluid to the target soils. The main methodology adopted in this study is the coupled Computational Fluid Dynamics and Discrete Element Method (CFD-DEM) conducted to investigate the possibility of fracking a weakly cement granular reservoir by adjusting the fluid and packing parameters.

Results: The first step is to recreate successfully the coupling between fluid flow and grain interaction in a tight geometry. This is verified by simulating the soil boiling problem and validated by simulating the sedimentation problem of a single sphere. Then we create a planar geometry representing a borehole in a large subsurface domain. The first series of investigation focuses on finding a set of viscosity and injection rate to create fingers (which are precursors of localized flow channels) in cohesionless soils. This attempt is unsuccessful (Fig. 1 top). Then we moved on to try fluid injection in lightly cemented soils. It is found that fingers or fracture-like patterns is only possible for soils with some level of cohesion (Fig. 1 bottom).

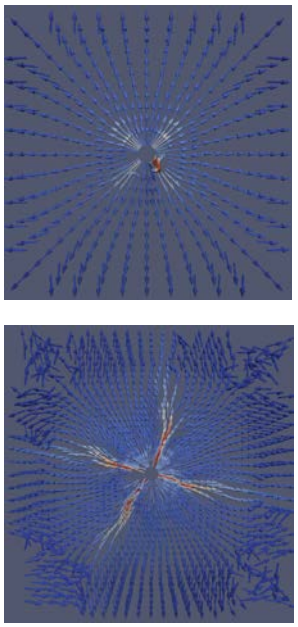

Figure 1: Fluid velocity for simulations with (top) cohesionless and (bottom) cohesive soils.

Accomplishments: The validation portion of CFD-DEM method has been published a few days ago in the following paper:
Hu, Z., Zhang, Y., & Yang, Z. (2019) Suffusion-induced deformation and microstructural change of granular soils: a coupled CFD–DEM study. Acta Geotechnica, available online DOI: https://doi.org/10.1007/s11440-019-00789-8.

Conclusions/Next Steps: This study concludes that granular fingering of fracking is unlikely to happen in saturated cohesionless soils like sand or silts. However, for clayey soils or silt-clay mixtures, fracking is possible and it worth to investigate further the controlling parameters of this process. The follow up research includes further understanding of the mechanisms of fingering/ fracturing in soils, and what parameters controls the optimum surface area/volume ratio. We also need to develop an experimental device to pair with CFD-DEM simulations. Proposal wise, the PI plan to submit a regular proposal to the ECI program under NSF CMMI with the same title: “Fracking soils: towards an engineered delivery method for environmental remediation and soil modification”.