Department of Infrastructure Engineering
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Particle scale study on fluid flow and heat flow in granular materials

Introduction

The understanding of fluid flow and heat flow processes are important in a number of engineering applications such as geothermal energy, buried earth-structures, radioactive waste disposal, geological Carbon dioxide storage and hydrocarbon energy. Macro-properties, such as hydraulic and thermal conductivity, are required when studying these processes and they are controlled by the micro-structure of geomaterials. However, the micro-macro relationships are difficult to establish a priority, and existing empirical equations usually ignore the effects of microstructural features, such as particle shape and connectivity. In addition, geomaterials are usually prone to deformation (due to loading) and diagenesis (dissolution and precipitation) over time. The deformation and diagenesis will affect the microstructure and further change the transport properties.

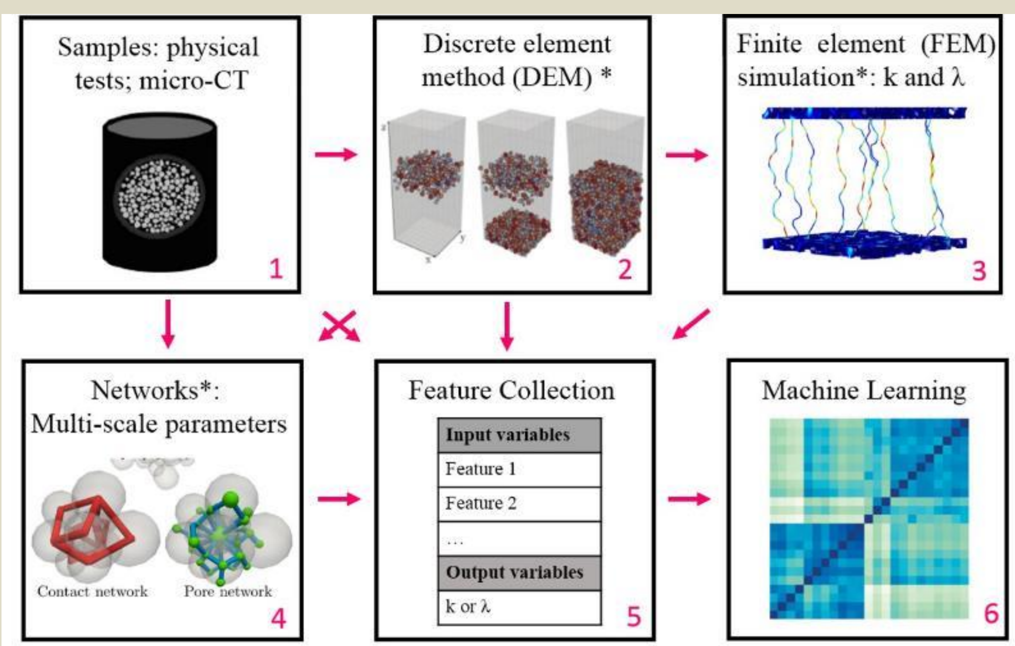
Hence, the main aim of this research is to establish new robust empirical equations which quantify the influence of multi-scale parameters extracted from the microstructure on conduction properties of granular mixtures in quasistatic state and during deformation induced by loading or diagenesis.

Research objectives

- To achieve multiscale parameters including 3D particle shape and connectivity.
- To further develop the workflow in the figure, e.g. realistic particle packings, a new thermal network.
- To find out the effects of multi-scale parameters on both fluid and heat flow simultaneously?
- To investigate the variation of microstructure and transport properties under loading and cementation processes.

Methodology

With the advent of CT image techniques, microstructures can be easily extracted. Moreover, single realistic irregular particles can be achieved from CT images and be used to generate virtual realistic irregular particle packings using discrete element method (DEM). Hydraulic conductivity (k) and thermal conductivity (λ) will be obtained by solving transport equations with Finite Element Method (FEM). Multiscale features can be collected using complex networks. After that, multiscale parameters as input variables and transport properties as output variables will be imported into machine learning techniques. Then, machine learning and statistical techniques can distinguish the most relevant and least redundant variables. Finally, this framework will achieve robust empirical equations with uncertainties and errors rigorously addressed.



Engineering applications

- In geothermal engineering, this project will guide the material selection of high-quality grout which requires high thermal conductivity and low hydraulic conductivity.
- In nuclear waste disposal engineering, this project will help in the design of engineered barrier which needs low hydraulic permeability and a self-sealing (deformation) ability.
- The results of this project will assist in predicting the macroscale behaviour of methane hydrate-bearing soils, which are sensitive to thermal, hydraulic, mechanical and chemical conditions.

*van der Linden, Narsilio and Tordesillas, 2016. Machine learning framework for analysis of transport through complex networks in porous, granular media: A focus on permeability. Physical Review E, 94(2), p.022904.

Discipline: Civil Engineering (Geotechnical)

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