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Analysis of physical clogging of granular materials submitted to internal fluid flow for civil engineering applications

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Subject:

When a porous granular material is subjected to fluid flow, deposition of solid particles inside the porous space can be observed. Particle can be already present in the flowing fluid or eroded from the solid matrix. This deposition phenomenon inside the porous material is widely encountered in civil engineering applications and its consequences in terms of filtration and clogging phenomena are often responsible of important problems [1].
For example, structures composed of cohesionless granular material with internal fluid flow (such as embankments, dams or dikes) can be subjected to internal erosion [2, 3, 4] by suffusion, which is characterized by a relatively slow migration of the finest particles. Nevertheless, during this erosion process, filtration and clogging of eroded particles may initiate another erosion phase which is characterized by a higher kinetic [4]. At the end, complete structure failure can be the consequence of this erosion process. Nevertheless, this faster erosion phase can lead to a lack of time to take the necessary measures to ensure the structure sustainability.

The objective of this thesis project is to deepen the understanding of the relevant parameters allowing the characterization of the phenomenon of granular filtration of a fluid loaded with inert particles until the appearance of jamming and clogging phenomena applied to the cited application. Nevertheless, since water flow through soils (and associated clogging) is widely encountered during civil engineering applications as infiltration (surface infiltration basins) [1, 5] or injection operations (injection of water during oil pumping)[1, 6], the applications of this work will not be limited.

This study will follow the initiating work carried out by J. Fan during his PhD (CSC 2014) [7], where deposition of relatively small suspended particles has been investigated at initial stage of filtration process with a coupling between Lattice Boltzmann and Discrete element methods [2, 8]. The developed code has been validated and new results were obtained to better understand filtration in porous media [8, 9, 10]. In this PhD work, particle accumulation inside porous space will be considered to analyze the influence of porosity evolution on fluid flow preferential paths that in turn influences particle transport and deposition. More specifically, compared

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to previous work, this study will not be limited to initial stage. It will be extended to higher suspended particle concentrations in order to be more relevant in the analysis and understanding of the phenomenon of deposition and clogging in the above-mentioned applications. Influence of porous microstructure, flow properties and suspended particle concentration will be investigated through numerical simulations performed at the pore scale.
The final objective is to completely characterized the particle deposition rate (in terms of fluid flow properties, granular material properties, transported particles properties) at the micro-scale in order to develop an upscaled model, including the particle deposition kinetics, to describe filtration phenomena and its consequences at larger scale.
This PhD work will be mainly carried out via numerical simulations, but some experiments can be considered within the framework of this project. It will be supervised by M. Hellou (Professor) and F. Lominé (assistant Prof.).

Keywords:

porous media; granular media; fluid flow; clogging; filtration; lattice Boltzmann method (LBM); permeability;

Scientific skills:

- Civil engineering and/or granular material physics
- Fluid mechanics.
- Transport in porous media
- Skills in computer programming (C++, matlab, python, etc) and/or in numerical methods to simulate fluids and/or granular materials would be appreciated

Expected collaborations:

- BRGM, French geological survey, France
- Shandong University, Jinan, China
- OSUR, Geosciences, Rennes, France

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