Consolidation and Permeability of Flocculated Kaolinite Sediment

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Objectives

The main purpose of this research was to characterize and improve understanding of the dewatering properties of kaolinite using polymer modification in gravitational and centrifugal fields. The specific objectives were as follows:

- To couple High-Resolution X-ray Micro-Tomography (HRXMT) measurements with image processing procedures and the Lattice Boltzmann Method (LBM)
- To identify operating conditions for improved consolidation of flocculated kaolinite including centrifugation

Introduction

Kaolinite (as shown below) is a major clay mineral found in oil sand tailings and organic polymers as well as centrifuge have been used to enhance the dewatering rate and sediment compaction.

Figure: SEM scan and the structure of kaolinite

Mathematical Section

Darcy's Law:

$$Q = KA\frac{h_1 - h_2}{L} \quad (1)$$

$$h_i = z_i + \frac{p_i}{\rho g} \quad (2)$$

$$\kappa = K\frac{\mu}{\rho g} \quad (3)$$

The LB method simulates the Darcy process and calculate the average flow velocity and porosity. The permeability of the porous media can then be computed using:

$$\kappa = \frac{a^2 \nu \phi \overline{U}}{\rho g} \quad (4)$$

Materials

The following materials were required to complete the research:

- Acid washed kaolinite powder (Fisher K2-500)
- SNF A-3338 polyacrylamide (PAM)

Methods

After the polymer solution is mixed with the kaolinite suspension and processed in a gravitational or centrifugal field, methods introduced by Videla et al. [2] were used to process 3D data and estimate permeability.

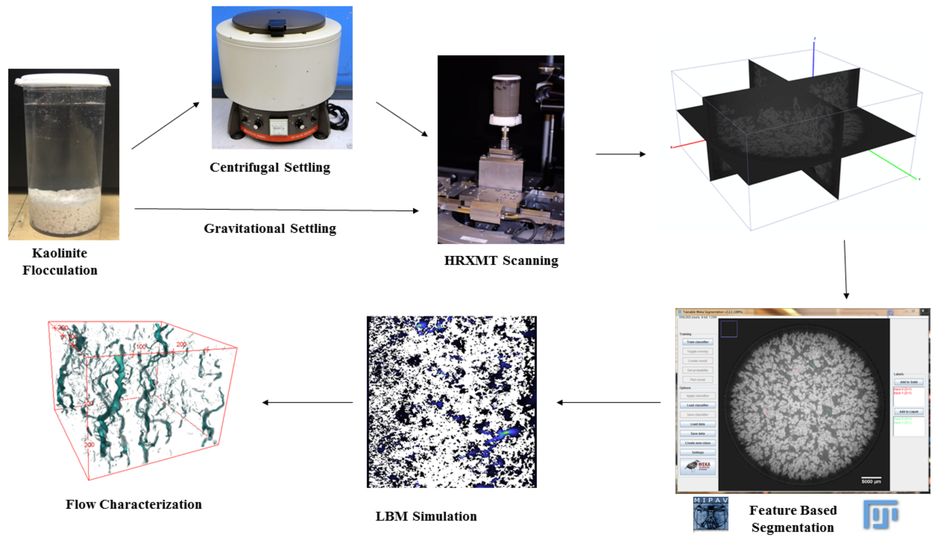

Figure: Coupling Micro-CT with LBM

Results

Centrifugal

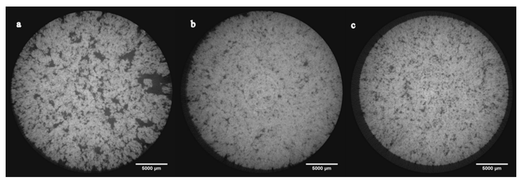

Figure: G-Factors: (a) 172 G, (b) 688 G, (c) 1547 G

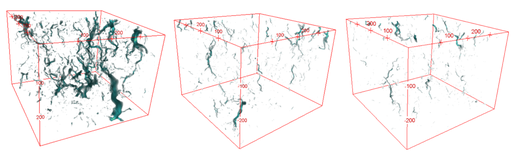

Figure: LBM-simulated velocity distribution

Table: Estimated permeability (cm^2)

G-Factor (g)	172	688	1547
Permeability (cm2)	7.26E-07	5.40E-07	5.33E-07

Gravitational

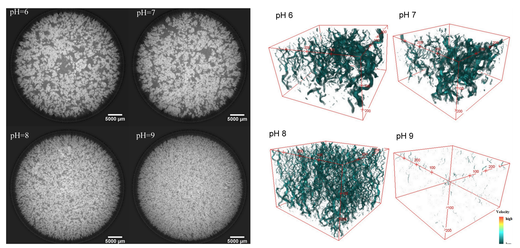

Figure: 2D slice and 3D flow velocity distribution at polymer dosage 500 g/t

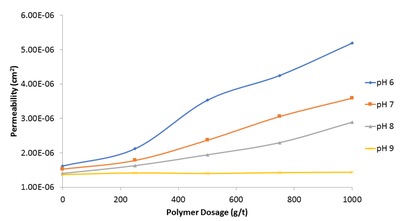

Figure: Effect of Polymer Dosage (PD) at pH = 6

Conclusion

Fundamental understanding of flocculated kaolinite sediment at the **pore scale level** is important for developing sustainable tailings management for many mineral processing operations including phosphate tailings in Florida and oil sand mature fine tailings in Alberta, Canada. **Polymer flocculation and centrifugation** can improve kaolinite sedimentation and consolidation.

Additional Information

Due to limitation of the voxel resolution used in this thesis, channels sizes that are less than 1 voxel cannot be counted which could be the main reason why permeability of flocculated kaolinite sediments measured almost the same with both no polymer addition and high suspension pH conditions.

References

[1] Sandra C Motta Cabrera, Jonathan L Bryan, Apostolos Kantzas, et al. Estimation of bitumen and solids content in fine tailings using low-field nmr technique. *Journal of Canadian Petroleum Technology*, 49(07):8–19, 2010.

[2] CL Lin, AR Videla, and Jan D Miller. Advanced three-dimensional multiphase flow simulation in porous media reconstructed from x-ray microtomography using the he–chen–zhang lattice boltzmann model. *Flow Measurement and Instrumentation*, 21(3):255–261, 2010.

Acknowledgements

I would like to acknowledge my colleagues in the lab for their help, my family for their love, affection, and continuous support.

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