Modeling the Rheological Properties of Concrete

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**Input**
- Cement Paste
  - Viscosity
  - Yield stress
- Aggregates
  - grading
  - concentration

**Prediction**

**Output**
Mortar/concrete
- Viscosity
- Yield stress
Viscosity vs. Solid Concentration

- Mortars w/o HRWRA
- Concretes w/o HRWRA
- Mortars with HRWRA
- Concretes with HRWRA
- Intermediate concretes
- Concretes w/ SF
- Model
What is Concrete?

• Aggregates: 1 - 20 mm
• Sand: 0.5 - 1 mm
• Fine fillers: < 5 µm
• Cement: 1-100 µm
• Water
• Chemical admixtures
Divide and Conquer

- Cement Paste: Water + Cement Particles + Admixtures + …
- Mortar: Cement + Sand
- Concrete: Mortar + Aggregate
Dissipative-Particle-Dynamics

- Mesoscopic particles represent clusters of molecules.
- Interactions conserve mass and momentum, isotropic and Galilean invariant produce hydrodynamic behavior consistent with Navier-Stokes equations.
- Molecular Dynamics: Brownian motion + velocity dependent dissipation.
Dissipative Particle Dynamics

\[ p'_i = p_i + \sum \Omega_{ij} \mathbf{e}_{ij} \]

\[ r'_i = r_i + \frac{\delta t}{m_i} \mathbf{p}'_i \]

\[ \Omega_{ij} = W(|\mathbf{r}_i - \mathbf{r}_j|) \left\{ \Pi_{ij} - \omega (\mathbf{p}_i - \mathbf{p}_j) \cdot \mathbf{e}_{ij} \right\} \]
Suspension of spherical aggregates
Tracking of particle motion
Relative viscosity vs. packing fraction

de Kruif, van Lersel, Vrij, Russel
Tumbling of an aggregate under shear

Jeffrey’s tumble
Ellipsoidal aggregates under shear
High solid fraction suspension under shear
Flow under gravity between rebars
Future Work

• Larger particle size distribution
• Add inter-particle interactions
• Model flow in more complex geometries
• Flow around rebars
• Multiphase flow