# Modeling the Rheological Properties of Concrete

Nicos Martys

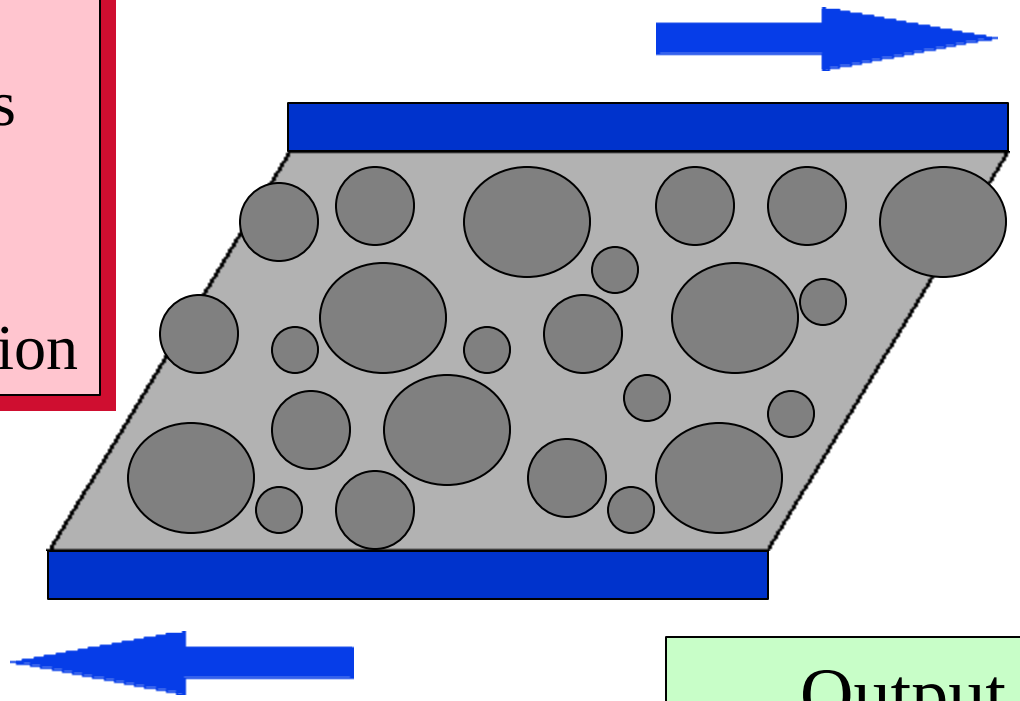
James Sims

NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

# Prediction

**Input**

- Cement Paste
  - –Viscosity
  - –Yield stress
- Aggregates
  - – grading
  - – concentration

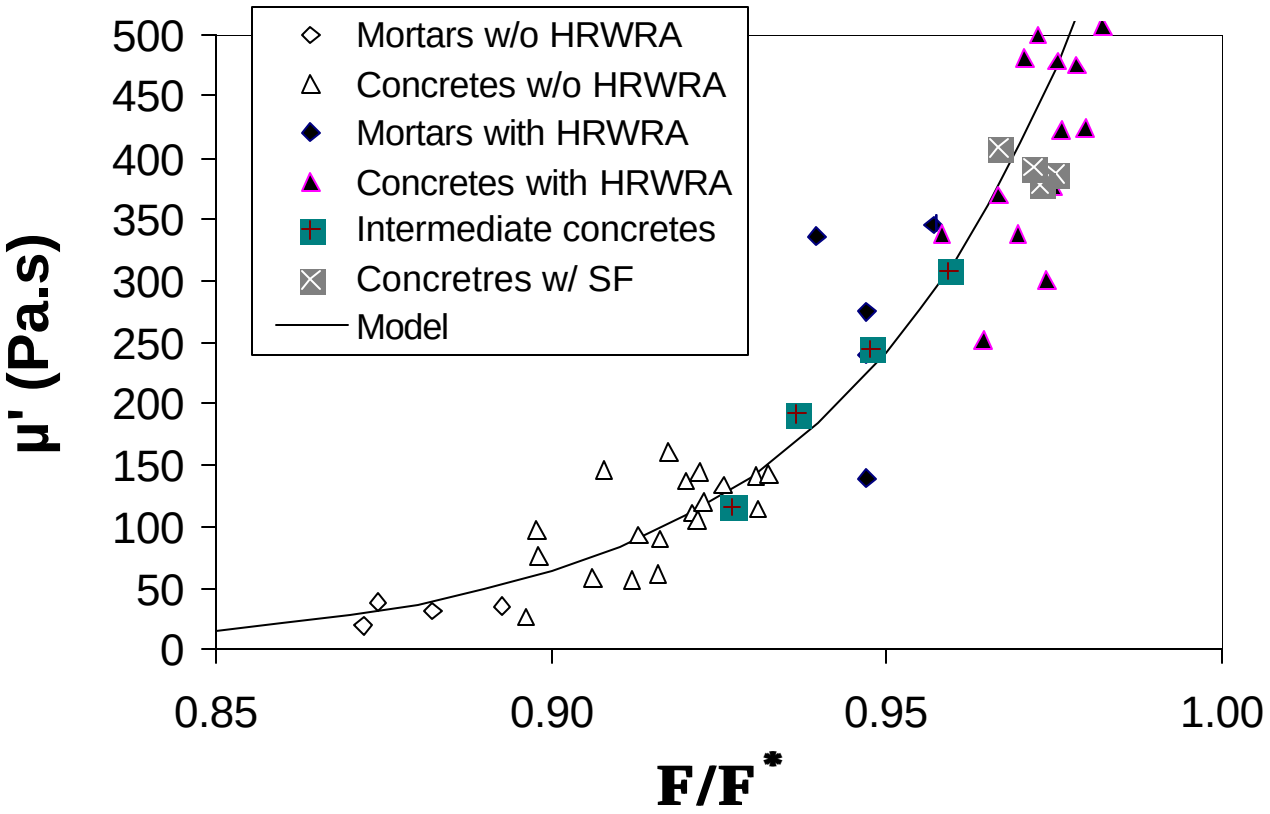


Output

Mortar/concrete

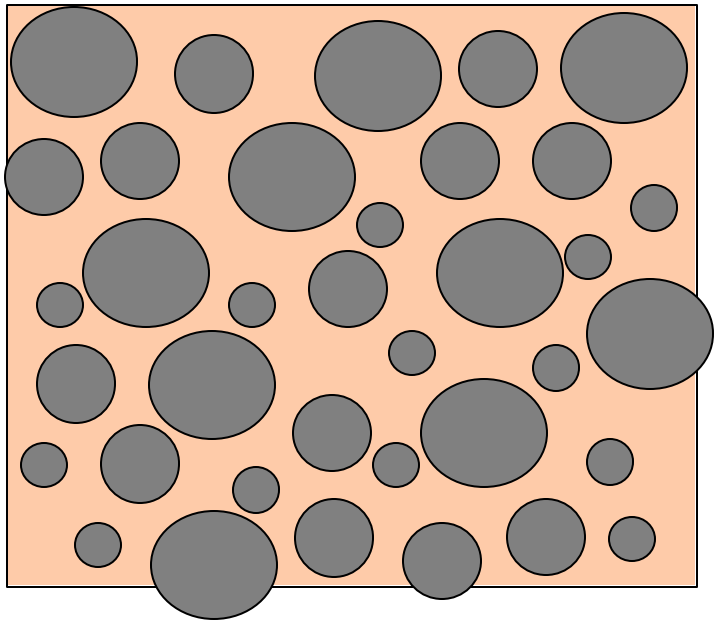
- Viscosity
- Yield stress

# Viscosity vs. Solid Concentration



# What is Concrete?

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



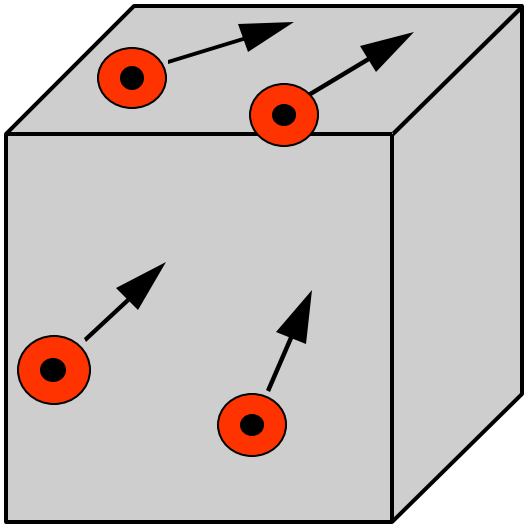
# Divide and Conquer

- 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

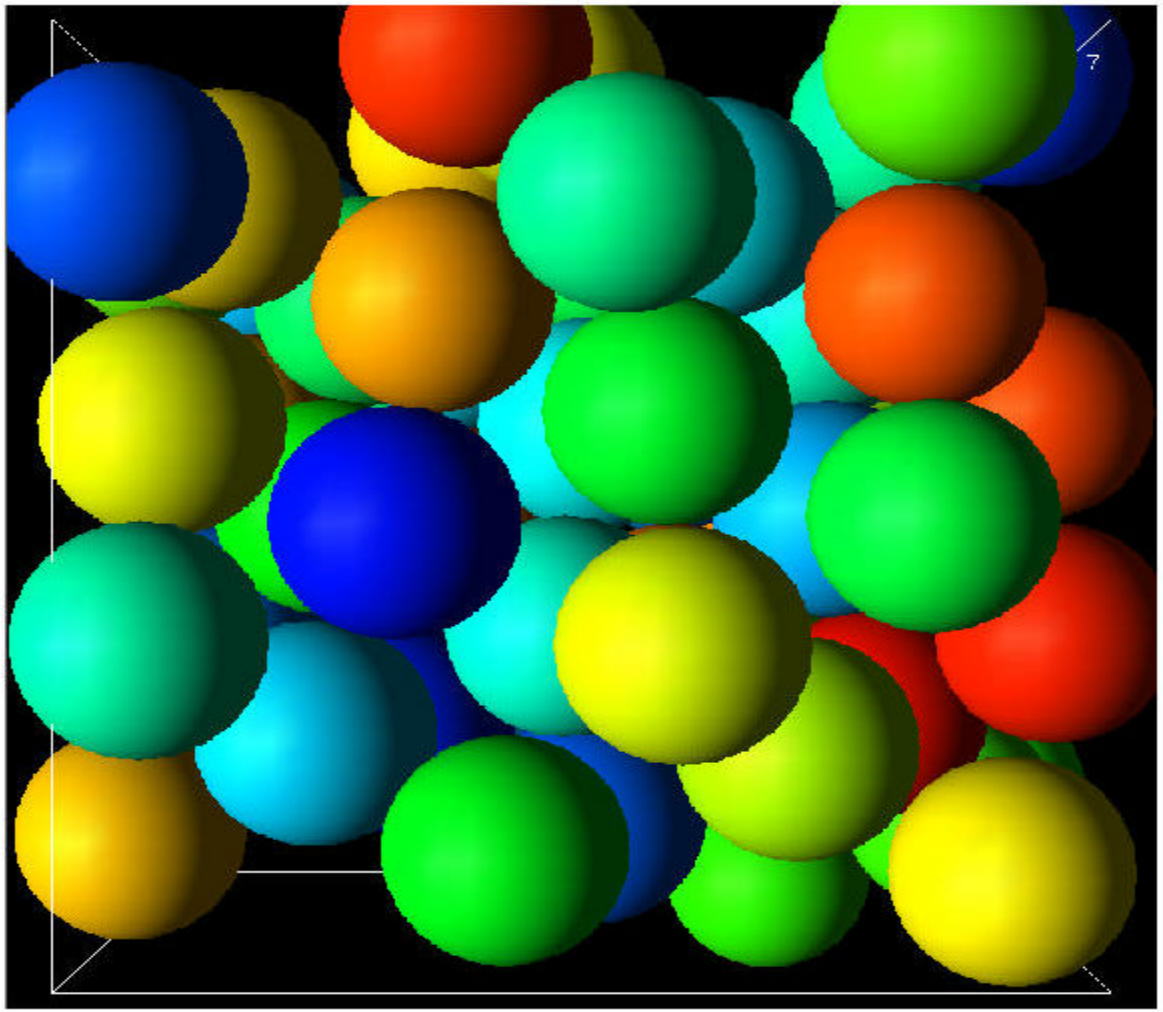


$$\vec{p}_i' = \vec{p}_i + \sum \Omega_{ij} \vec{e}_{ij}$$

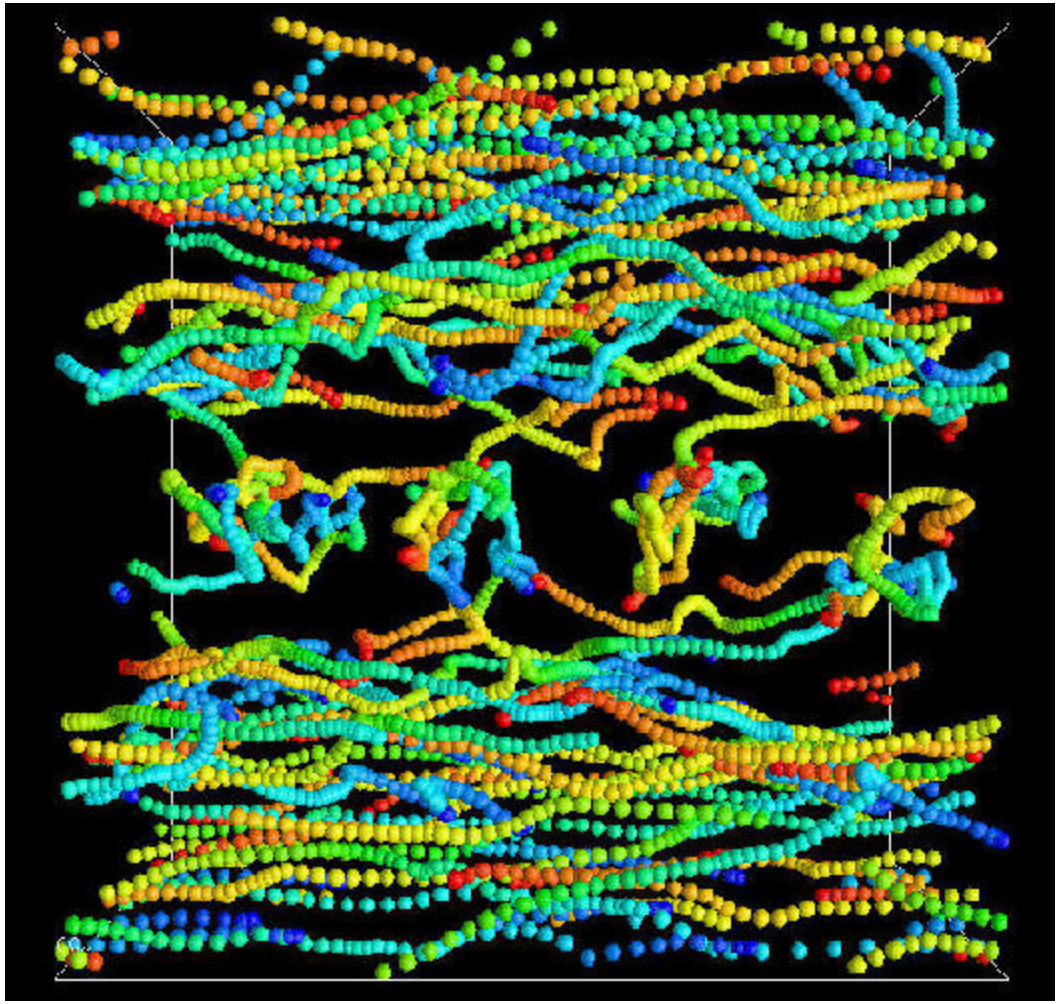
$$\vec{r}_i' = \vec{r}_i + \frac{dt}{m_i} \vec{p}_i'$$

$$\Omega_{ij} = W(\left|\vec{r}_i - \vec{r}_j\right|)\{\Pi_{ij} - w(\vec{p}_i - \vec{p}_j) \cdot \vec{e}_{ij}\}$$

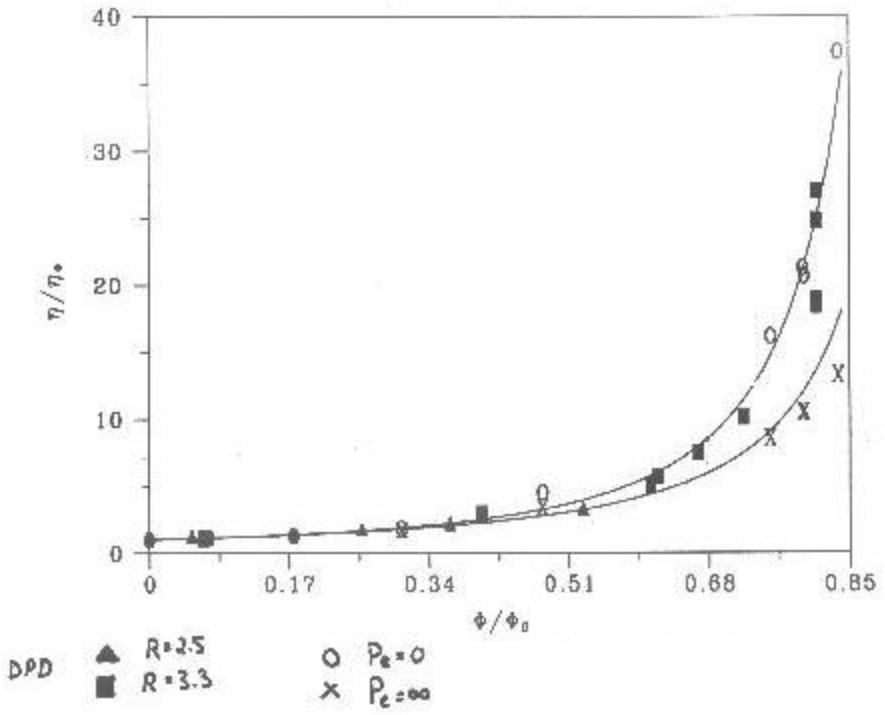
# Suspension of spherical aggregates



# Tracking of particle motion

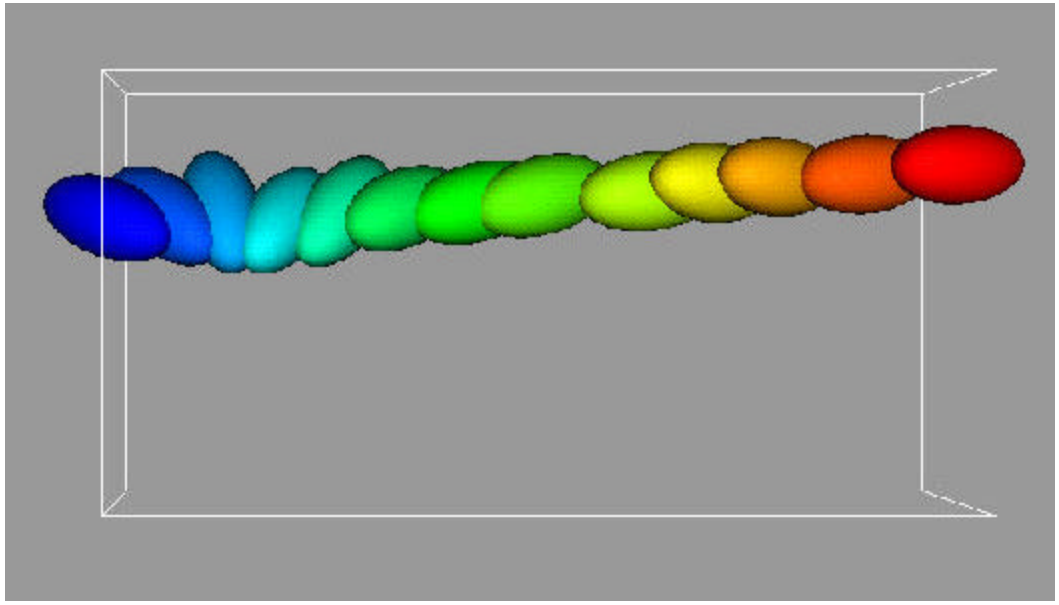


# Relative viscosity vs. packing fraction



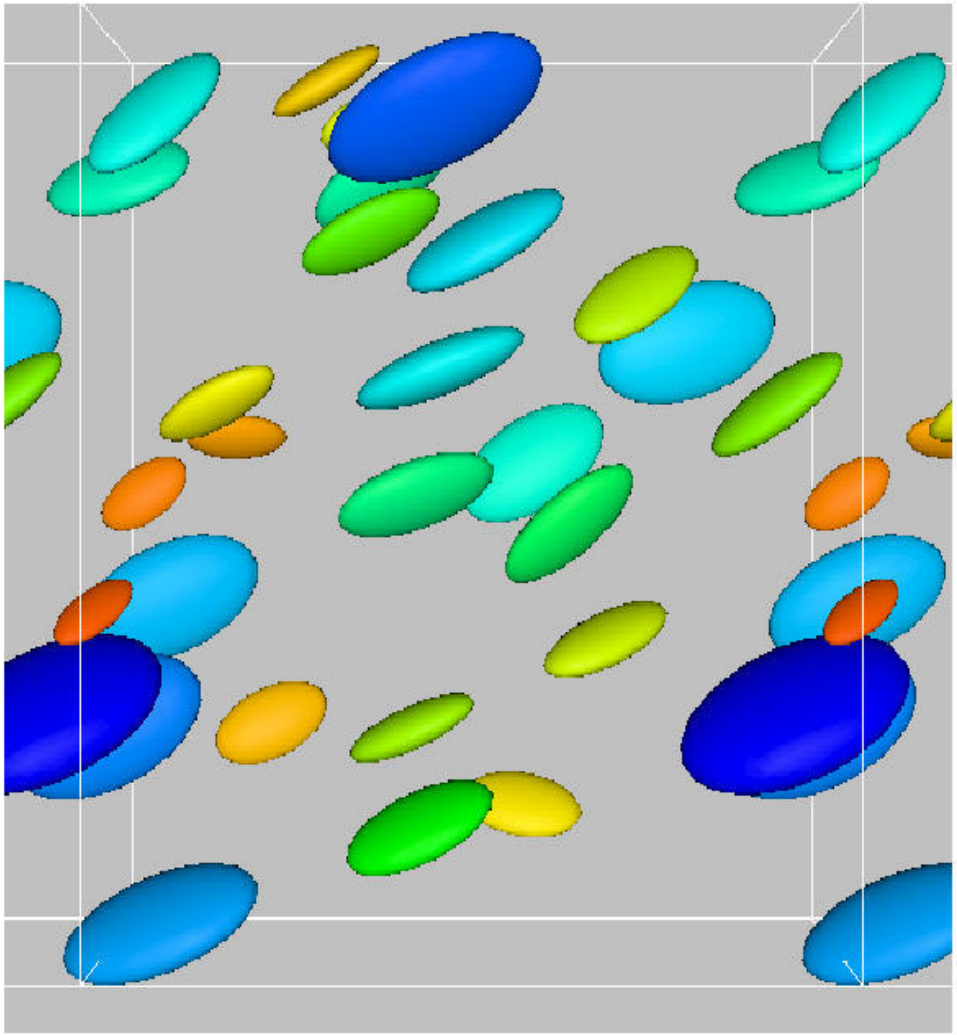

de Kruif, van Lersel, Vrij, Russel

# Tumbling of an aggregate under shear

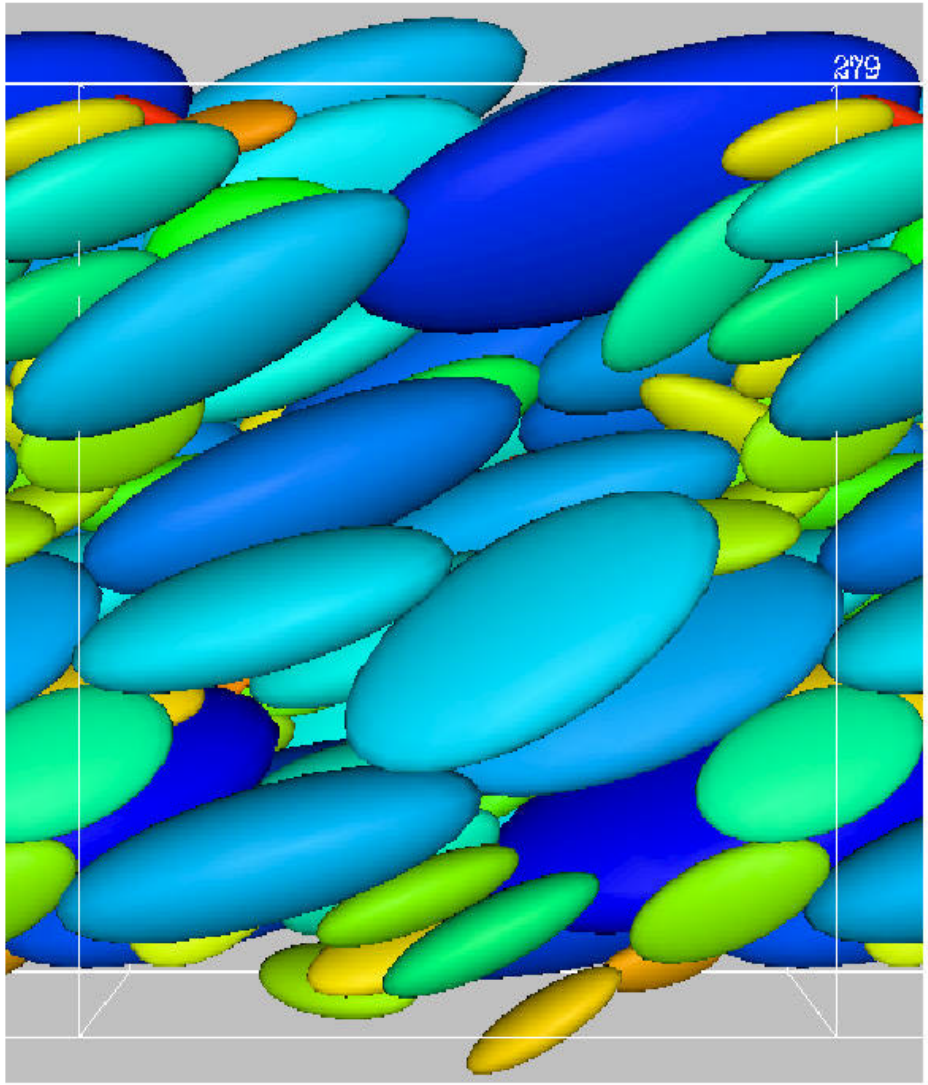


Jeffrey's tumble

# Ellipsoidal aggregates under shear

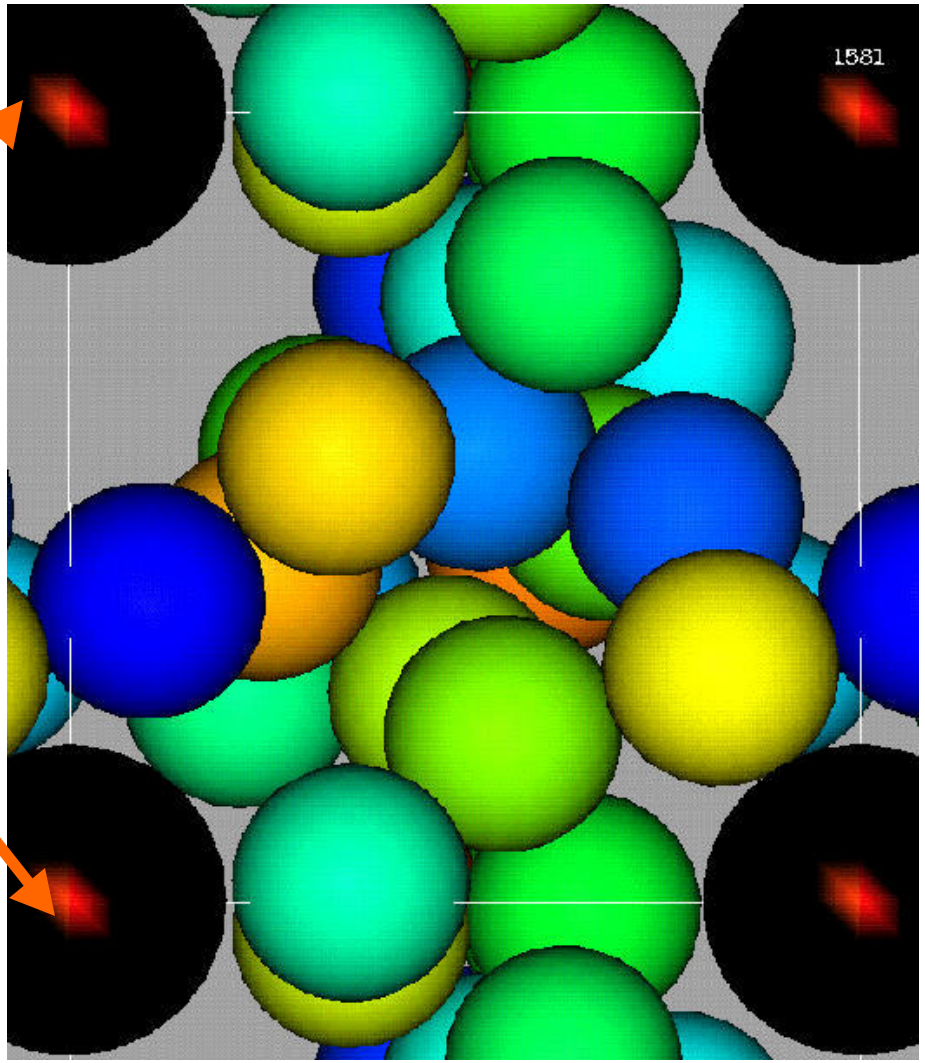


# High solid fraction suspension under shear



# Flow under gravity between rebars

Rebars



# Future Work

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