Rheological behaviour of geopolymers
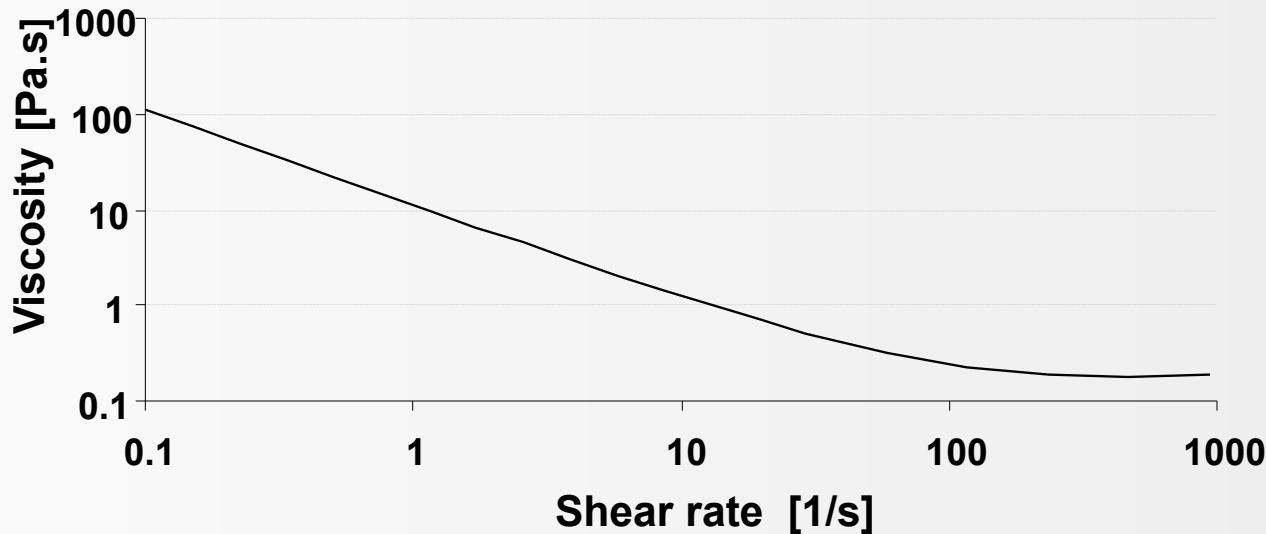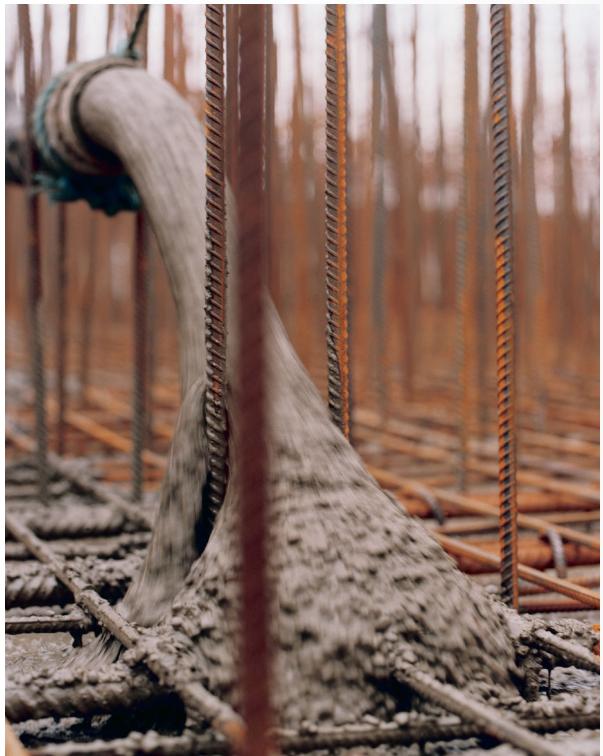
Geopolymer camp – July 2012

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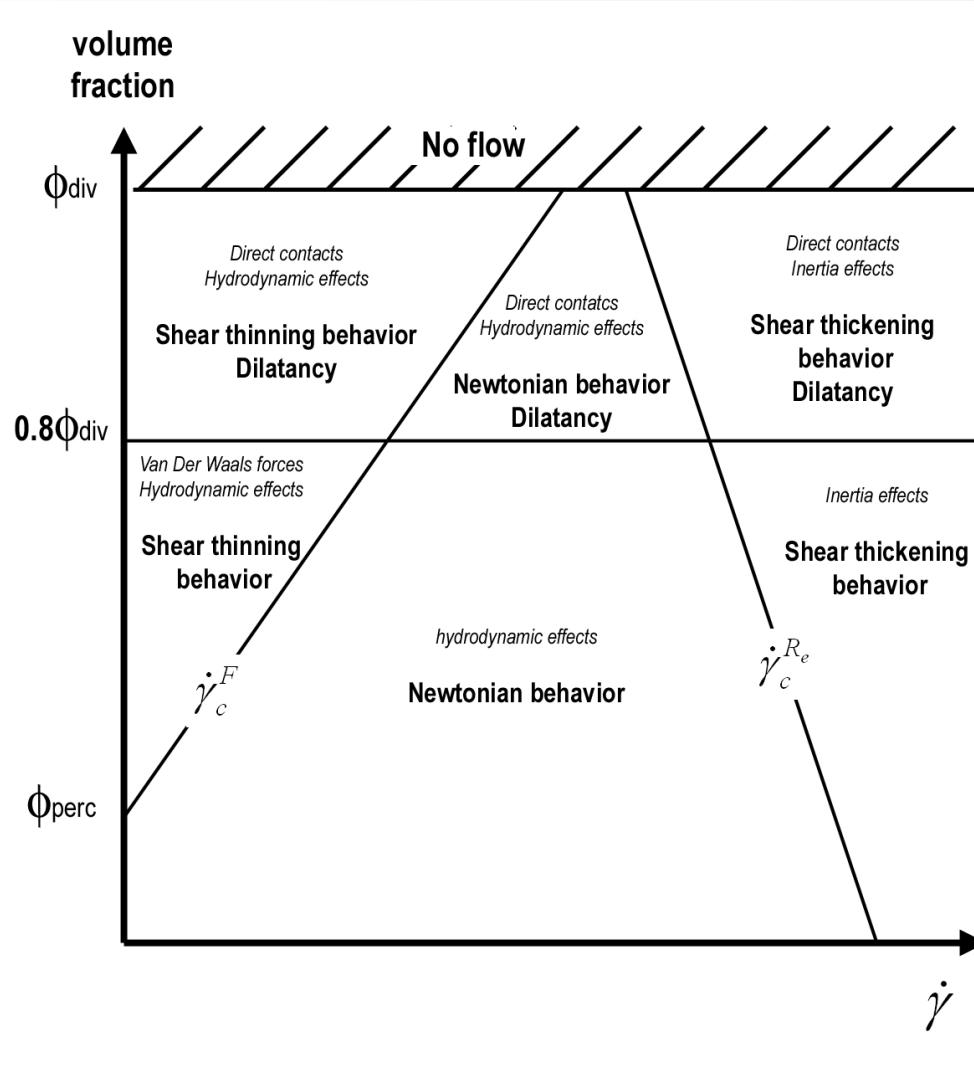
Rheological behaviour of cement
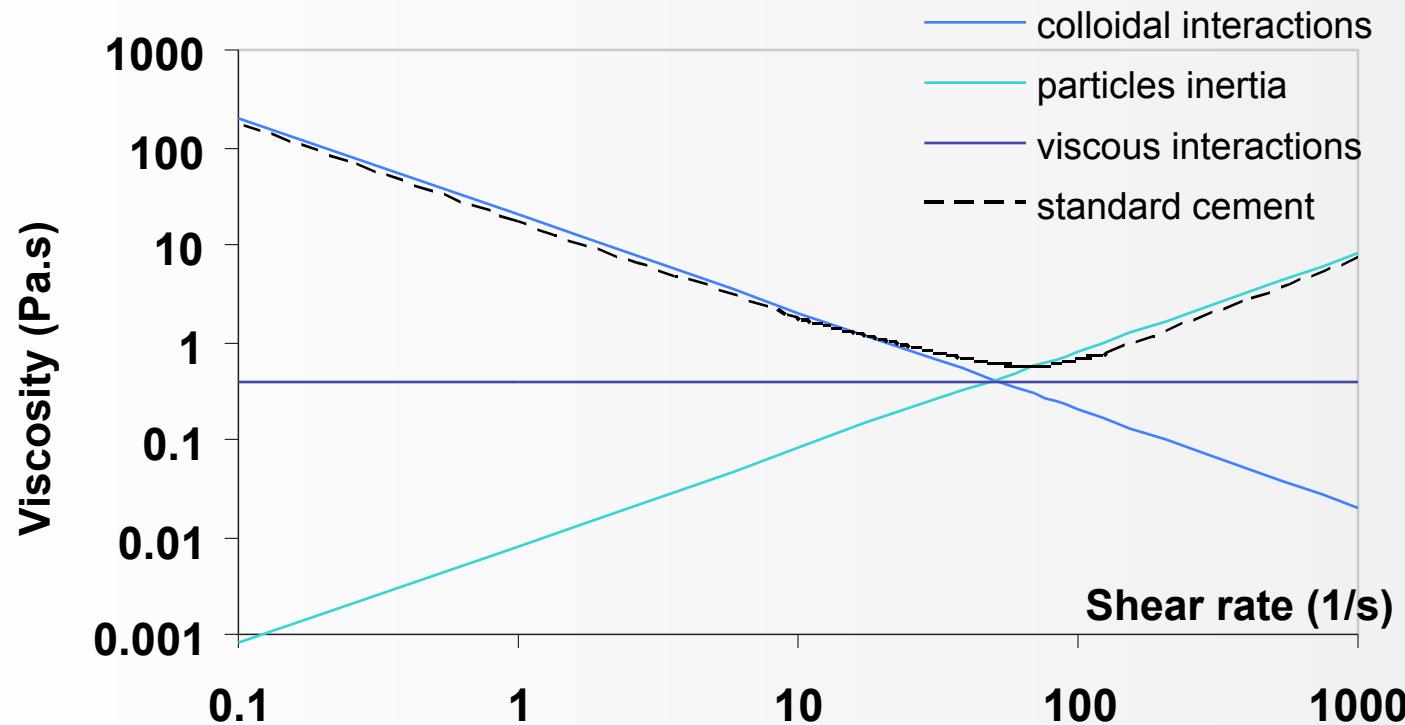
**Yield stress fluid with viscosity**

Cement suspensions

[1] N.Roussel et al. Cement and Concrete research 40 (2010) 77-84
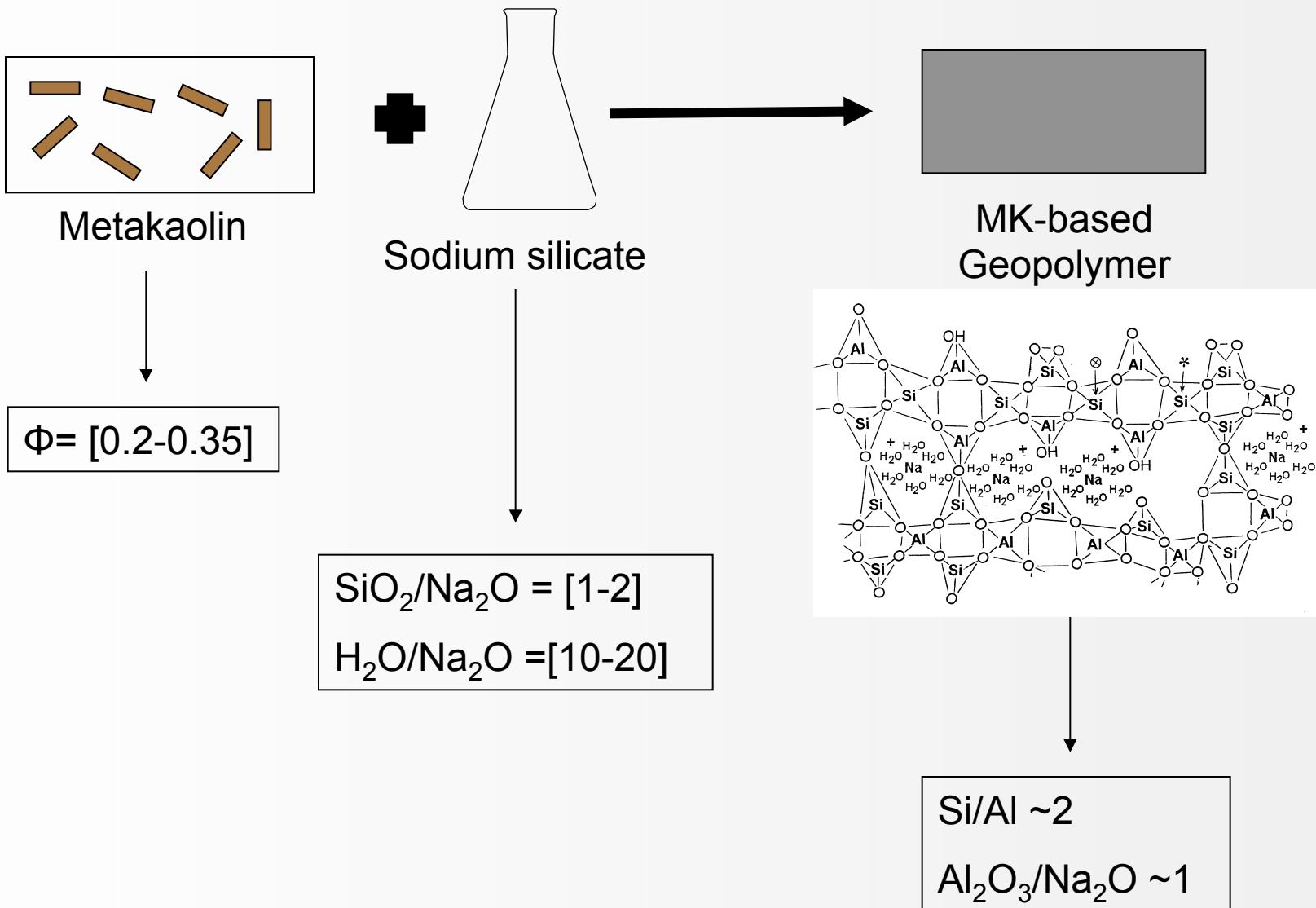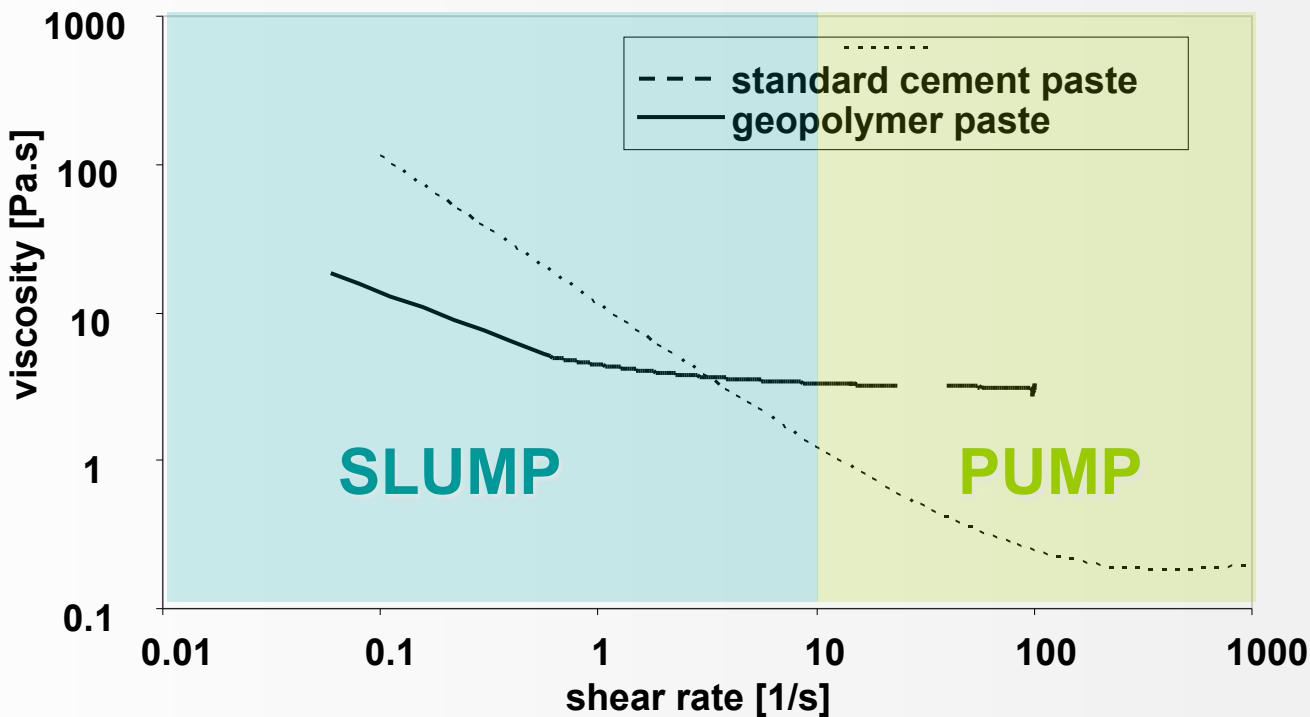
- Colloidal interactions ➔ $f\left(1/\dot{\gamma}\right)$

- Viscous interactions ➔ independant of $\dot{\gamma}$

  What about geopolymer?

- Inertial interactions ➔ $f\left(\dot{\gamma}\right)$

Metakaolin

Sodium silicate

MK-based
Geopolymer

$\Phi = [0.2\text{-}0.35]$

$SiO_2/Na_2O = [1\text{-}2]$

$H_2O/Na_2O = [10\text{-}20]$

Si/Al ~2

Al_2O_3/Na_2O ~1
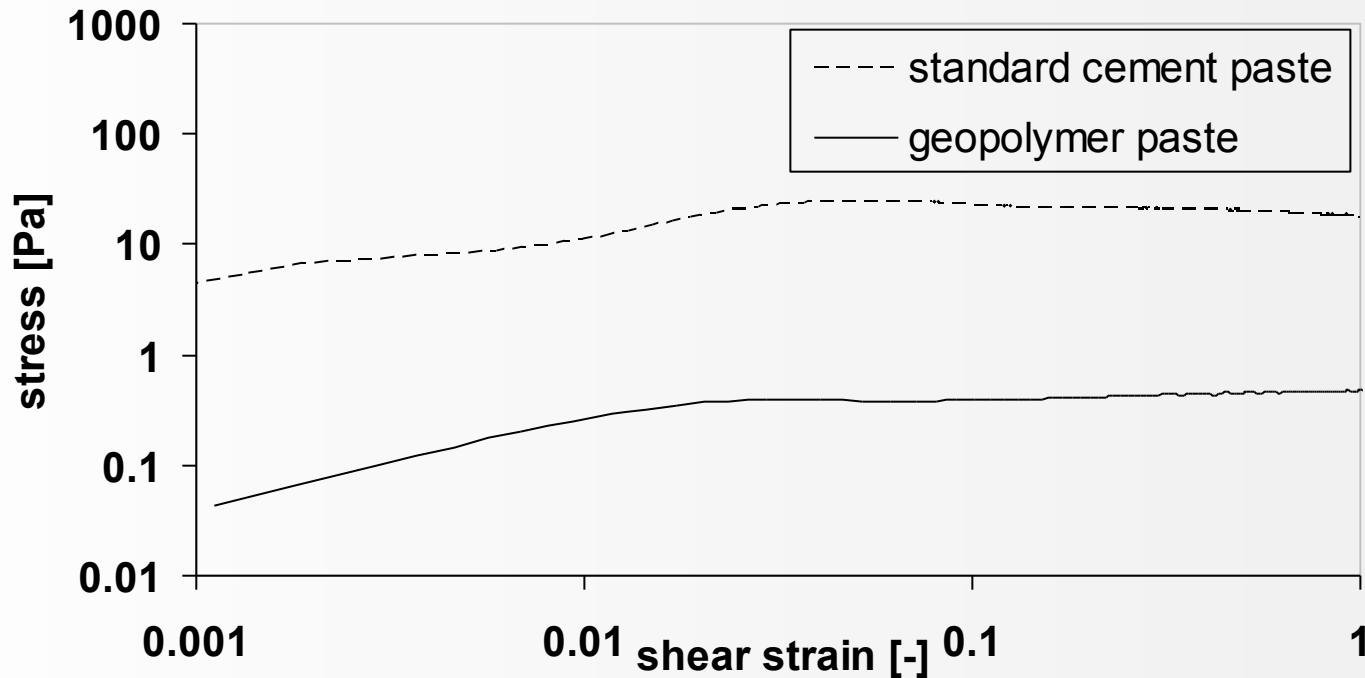
Geopolymer's rheological behaviour

- In general, for standard MK-based geopolymer
    - Low colloidal contribution
    - High viscous contribution
    - No thickening
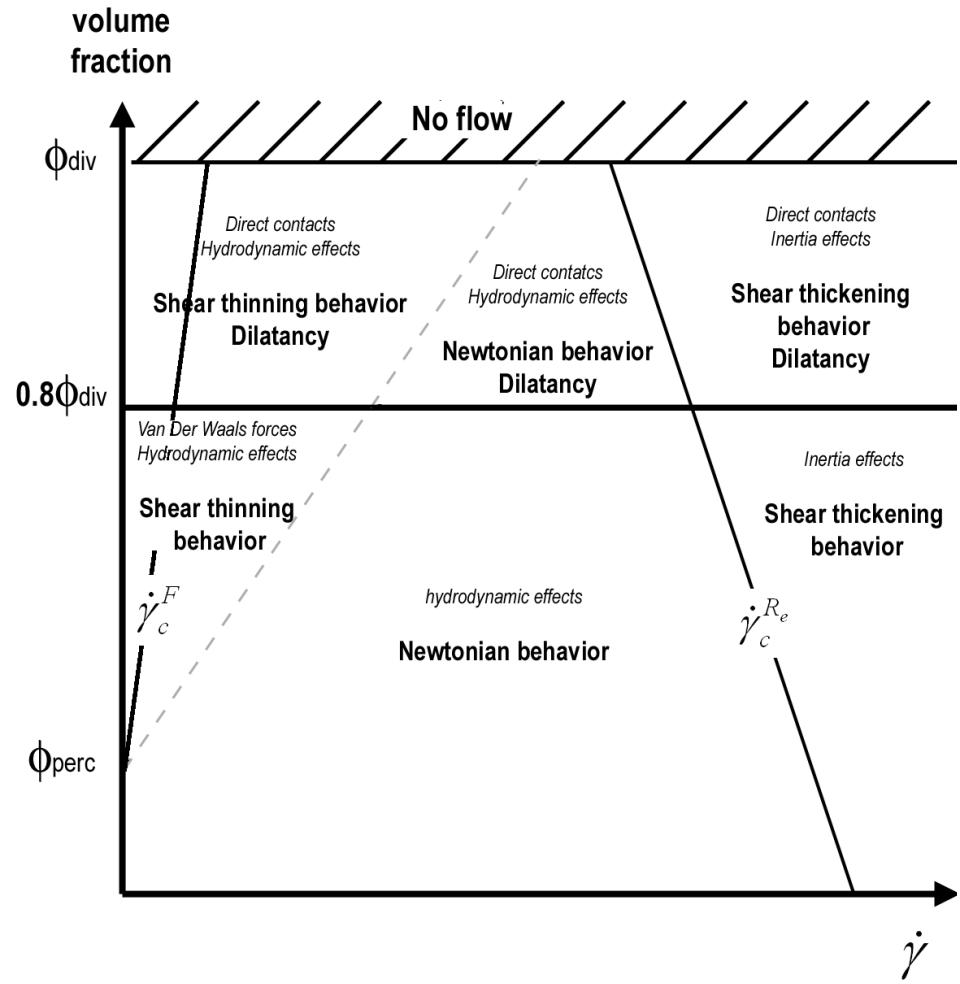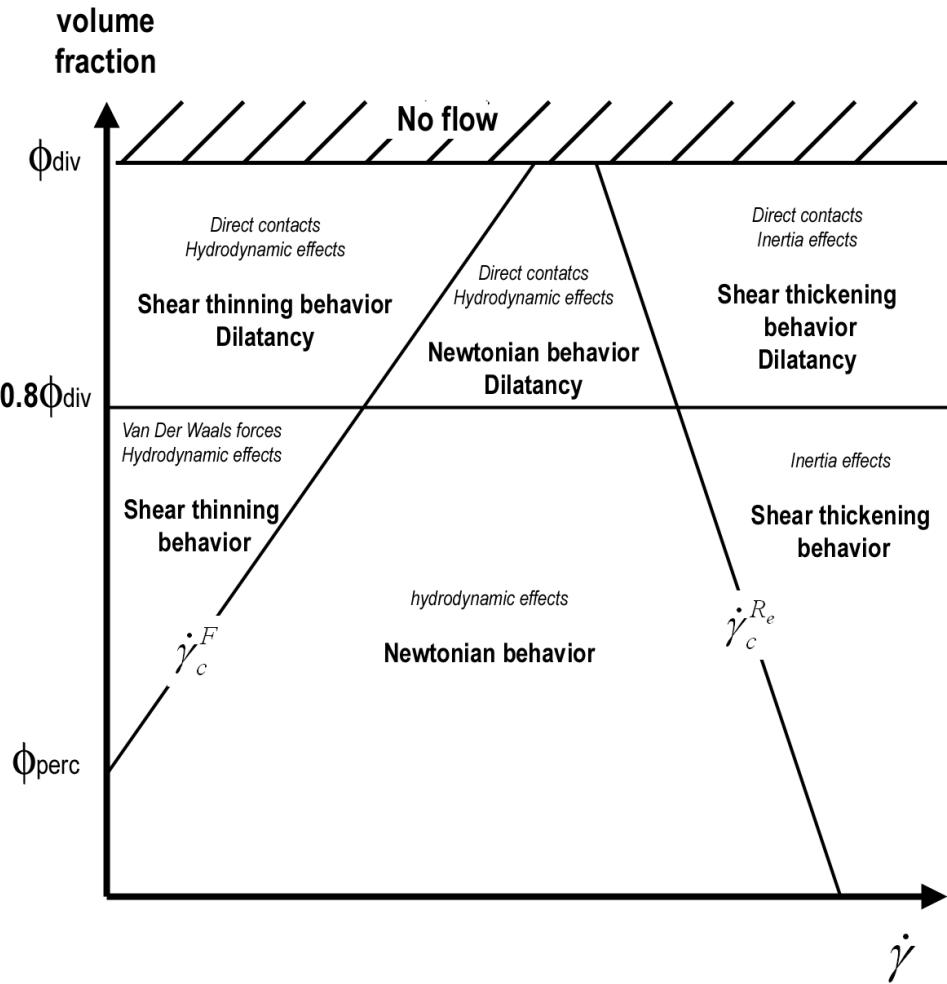
• In cement suspensions,

• Colloidal interactions due to Van der Waals forces

•In geopolymer suspension,

• Low colloidal interactions, low Van der Waals forces [2] [3]

[2] A. Favier et al. *submitted* (2012)

[3] L.T.Drzal J. Colloid Interface Sci., 93 (1982), 126-138

Left diagram (Geopolymer):

volume fraction

ϕ_{div}

No flow

Direct contacts
Hydrodynamic effects

Shear thinning behavior Dilatancy

Direct contatcs
Hydrodynamic effects

Newtonian behavior Dilatancy

Direct contacts
Inertia effects

Shear thickening behavior Dilatancy

$0.8\phi_{div}$

Van Der Waals forces
Hydrodynamic effects

Shear thinning behavior

Inertia effects

Shear thickening behavior

$\dot{\gamma}_c^F$

hydrodynamic effects

Newtonian behavior

$\dot{\gamma}_c^{R_e}$

ϕ_{perc}

$\dot{\gamma}$

Geopolymer

Right diagram (Cement):

volume fraction

ϕ_{div}

No flow

Direct contacts
Hydrodynamic effects

Shear thinning behavior Dilatancy

Direct contatcs
Hydrodynamic effects

Newtonian behavior Dilatancy

Direct contacts
Inertia effects

Shear thickening behavior Dilatancy

$0.8\phi_{div}$

Van Der Waals forces
Hydrodynamic effects

Shear thinning behavior

Inertia effects

Shear thickening behavior

$\dot{\gamma}_c^F$

hydrodynamic effects

Newtonian behavior

$\dot{\gamma}_c^{R_e}$

ϕ_{perc}

$\dot{\gamma}$

Cement

Viscous contribution
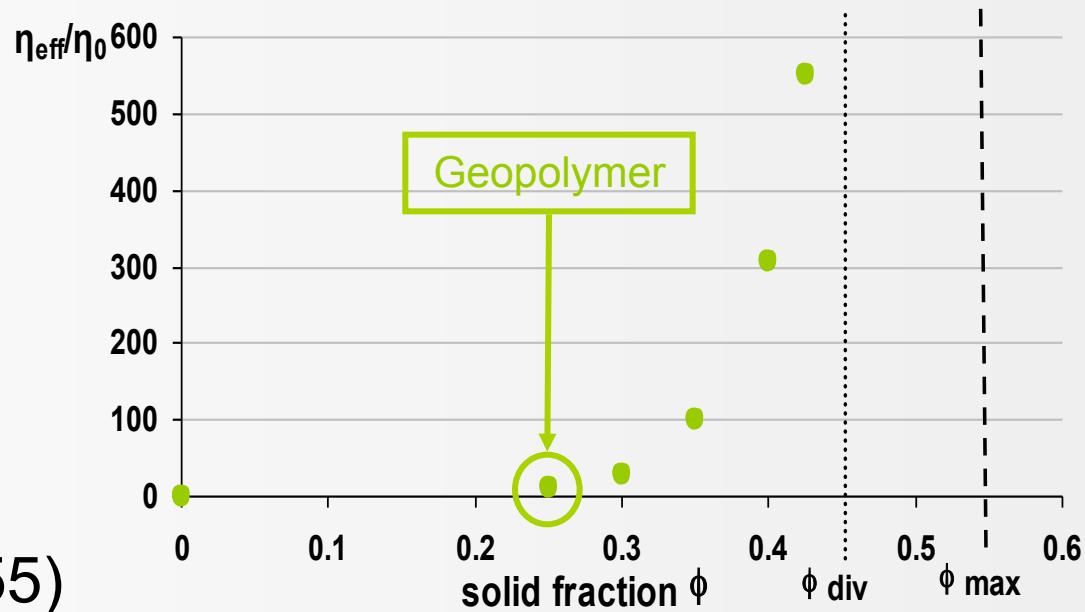
$$\eta = \eta_0 \times f\left(\frac{\phi}{\phi_{\max}} \right)$$

- cement ➔ low η_0

- geopolymer ➔ high η_0
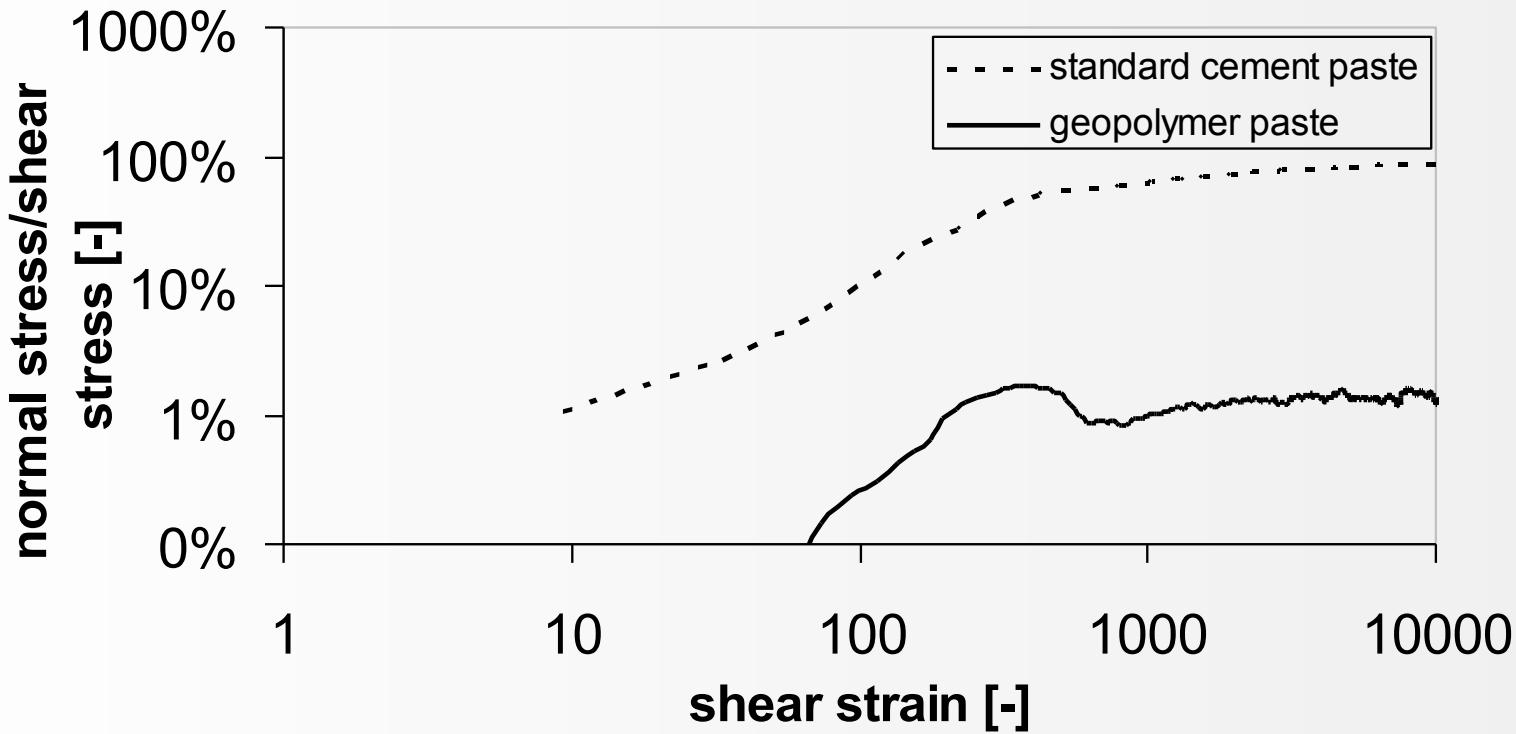
Solid fraction contribution

- cement

➔ high ϕ (0.6) and ϕ_{max} (0.9)

- geopolymer

➔ low ϕ (0.25) and ϕ_{max} (0.55)
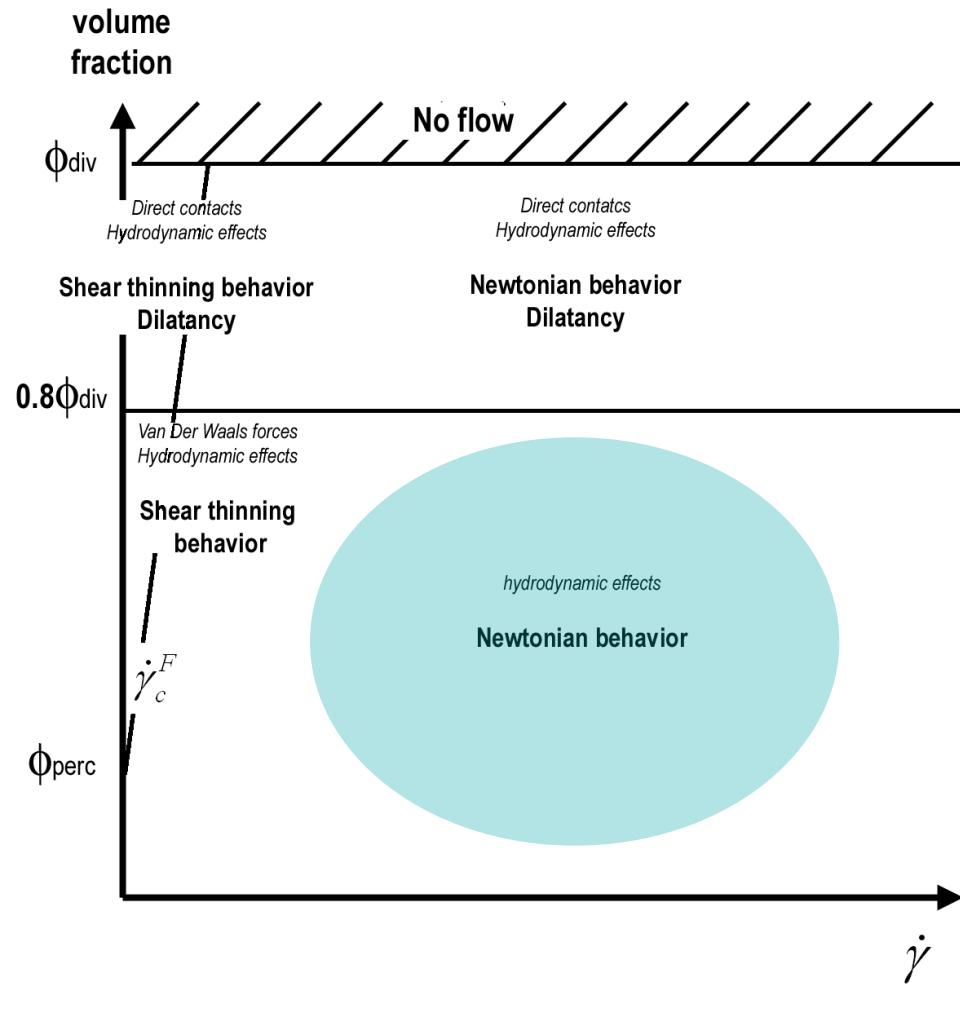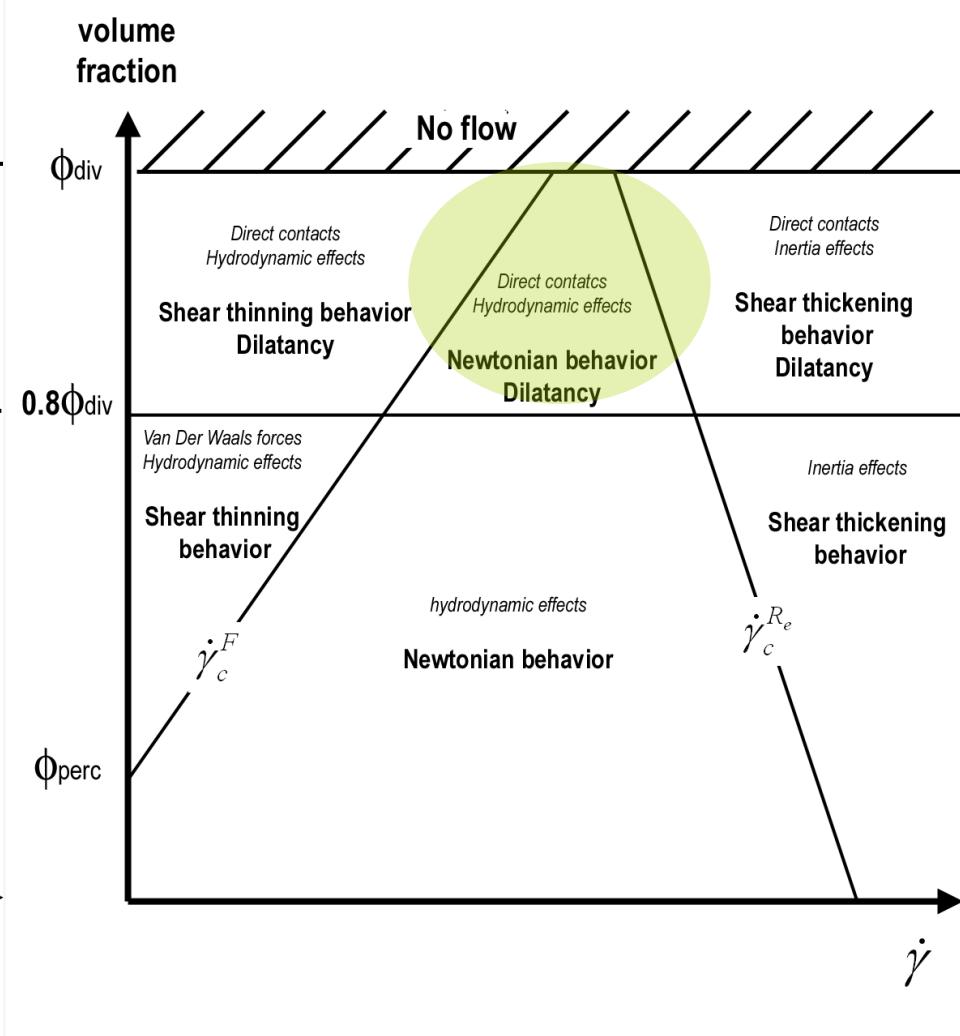
In geopolymer suspension,

- ϕ/ϕ_{max} is low and weak normal force

➔ no thickening

Geopolymer diagram (left):

volume fraction

ϕ_{div}

No flow

Direct contacts
Hydrodynamic effects

Direct contatcs
Hydrodynamic effects

**Shear thinning behavior
Dilatancy**

**Newtonian behavior
Dilatancy**

$0.8\phi_{div}$

Van Der Waals forces
Hydrodynamic effects

**Shear thinning
behavior**

hydrodynamic effects

Newtonian behavior

$\dot{\gamma}_c^F$

ϕ_{perc}

$\dot{\gamma}$

Geopolymer

Cement diagram (right):

volume fraction

ϕ_{div}

No flow

Direct contacts
Hydrodynamic effects

Direct contatcs
Hydrodynamic effects

Direct contacts
Inertia effects

**Shear thinning behavior
Dilatancy**

**Newtonian behavior
Dilatancy**

**Shear thickening
behavior
Dilatancy**

$0.8\phi_{div}$

Van Der Waals forces
Hydrodynamic effects

Inertia effects

**Shear thinning
behavior**

hydrodynamic effects

Newtonian behavior

**Shear thickening
behavior**

$\dot{\gamma}_c^F$

$\dot{\gamma}_c^{R_e}$

ϕ_{perc}

$\dot{\gamma}$

Cement

Perspectives: rheological improvements

- Modifying solution viscosity
- Slowing down reaction

Adding delay
admixtures (borate)

Adding polymer with
high molar weight