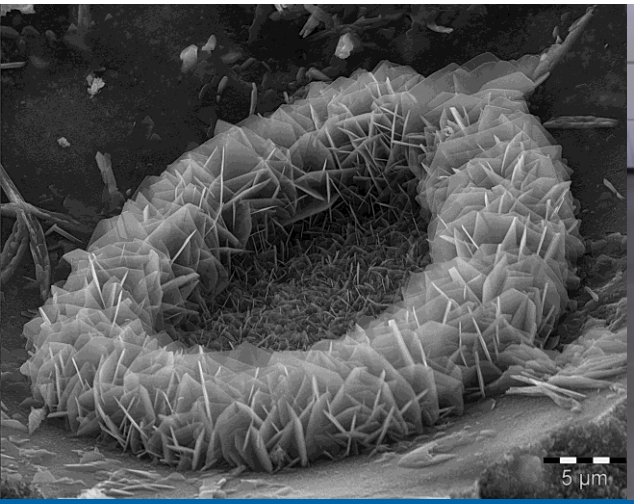
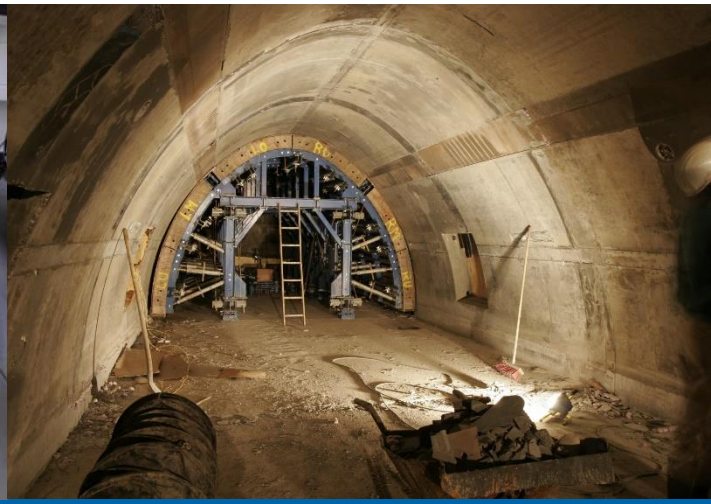
TECHNISCHE UNIVERSITÄT
BERGAKADEMIE FREIBERG
The University of Resources. Since 1765.

Professorship for construction materials
Institute of Ceramic, Glass and Construction Materials
Faculty of Mechanical, Process and Energy Engineering

宇部興産株式会社
UBE INDUSTRIES,LTD.

Influence of Pumping on Fresh Concrete Properties for SCC





Thomas A. BIER – Keisuke TAKAHASHI

Outline

- Earlier Experiences
  - Field Trials
  - Literature on Mixing
- Materials and Testing
- Macrolevel
  - Influence on rheological Properties and workability
- Microlevel
  - Hydration, Chemistry and Microstructure
- Concept and Summary
- Conclusions

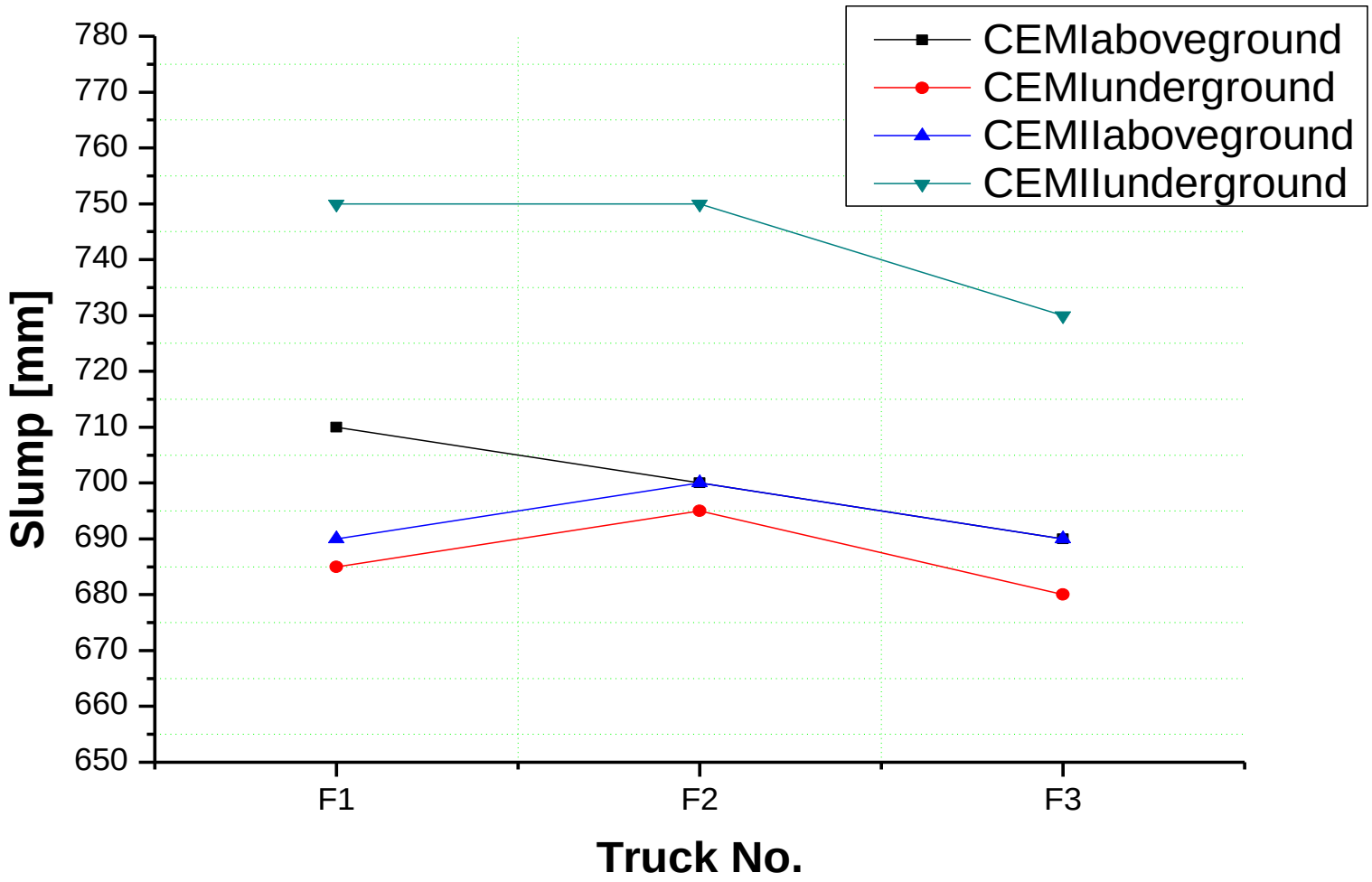
Abstract

During field trials, involving pumping of self compacting concrete, changes in rheological properties have been observed. In order to predict possible changes, studies were undertaken on self compacting mortar (SCM) where various mixing as well as pumping intensities were applied. As a result not only changes in rheological properties but also changes in hydration kinetics were observed. It has been shown that mixing and shear stress during pumping, respectively, do exhibit a pronounced influence on rheological properties of self-compacting mortars. The changes in rheological properties can be explained by the dispersion of the particles as well as an accelerated formation of pre-hydrates during early hydration.

Process Chain Underground Pumping

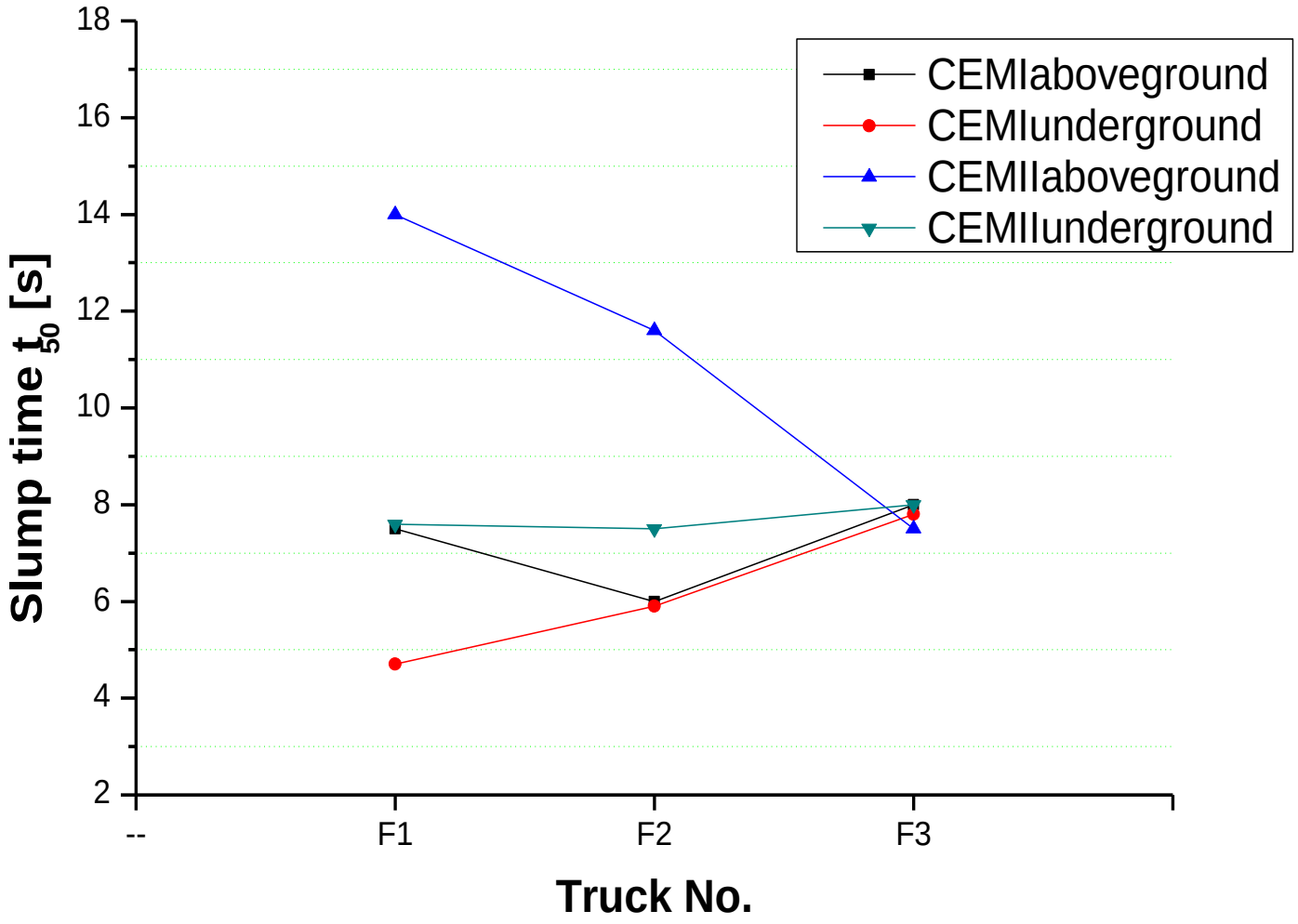
Process Chain Underground Pumping

Slump Flow Value



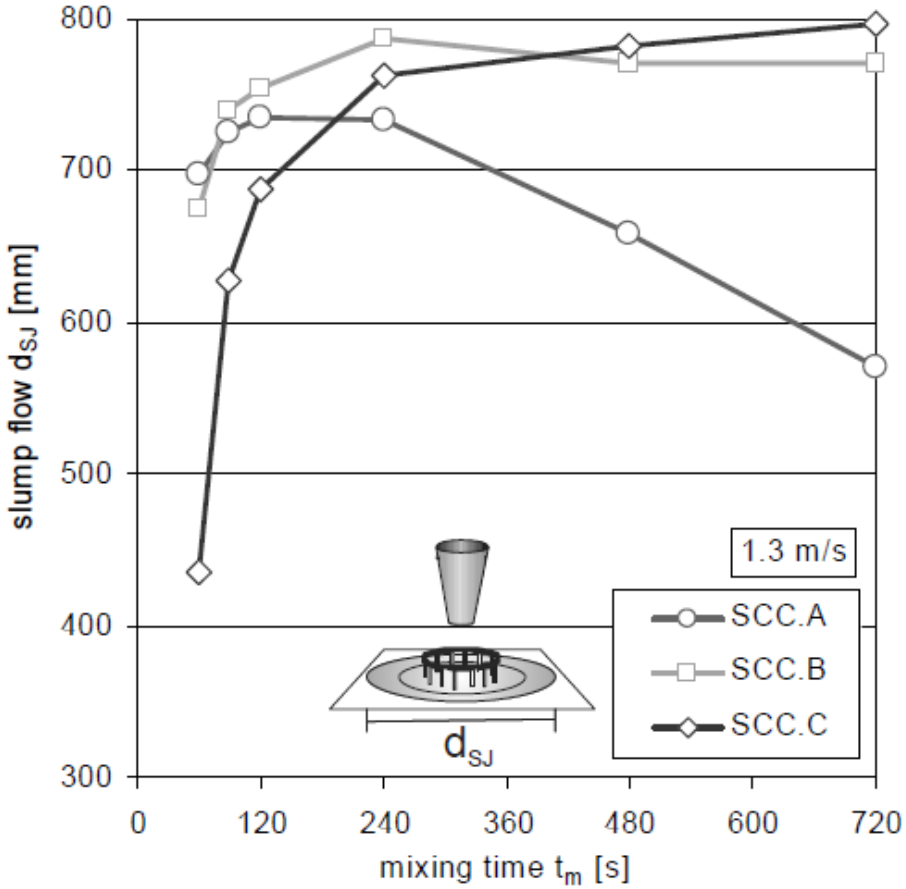
Self Compacting Concrete Underground ; Dahlhaus, Bier et. al, Ibausil, 2006

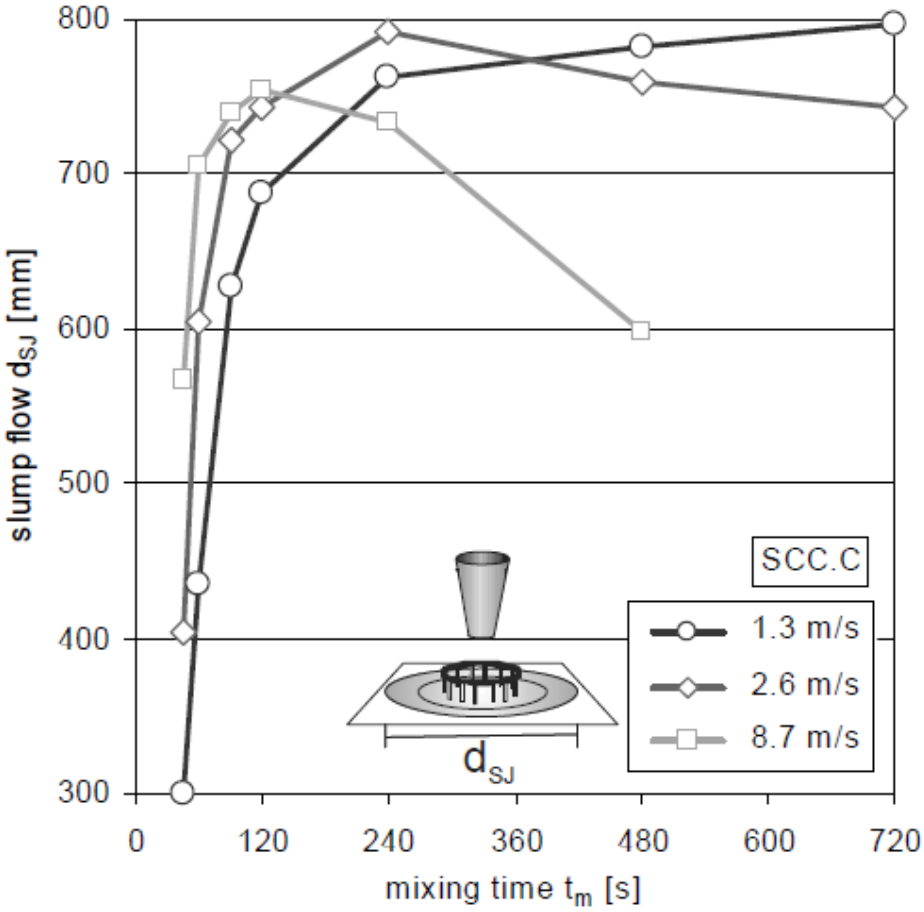
Slump Flow Time



Self Compacting Concrete Underground ; Dahlhaus, Bier et. al, Ibausil, 2006

Mixing time and mixing speed





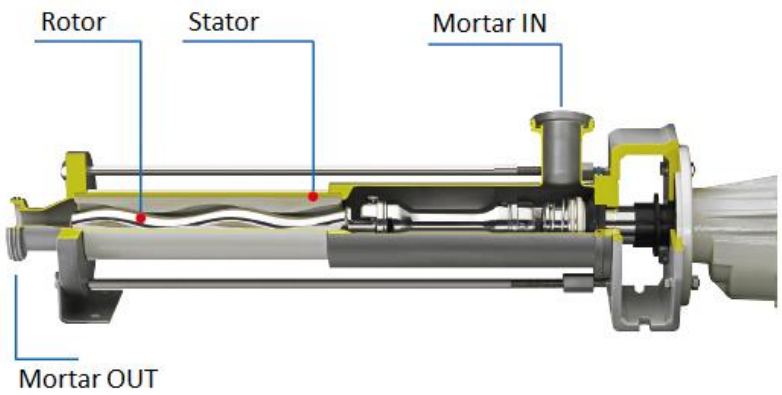
Optimum mixing time: SCC. B is longer than SCC. A
Chemical additive contents: SCC. C is higher than SCC. B

Lowke, D.; Schießl, P.: Effect of mixing energy on fresh proporties of SCC in: Proceedings of the 4th International RILEM Symposium on Self-Compacting Concrete, Chicago, USA, 2005

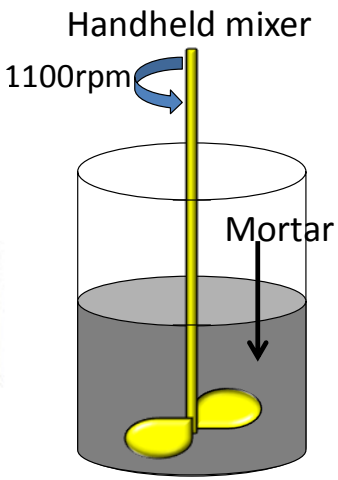
Composition of Materials

	Cement	Sand	PCE	HMC	Others*	Water
Grout	389	583	0.68	0.003	27.3	155
Cement paste	565	0	0.99	0	0	225

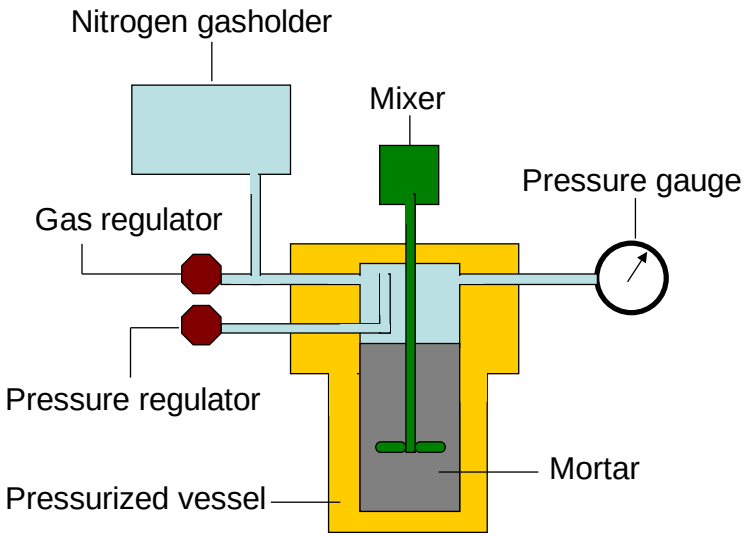
All tests were conducted at 20 ˚C using the same mortar mixed for 2 min.
Measured pumping pressure was 2 MPa @ 50 m and 3 MPa @ 100 m.



Snake pump



Handheld mixer

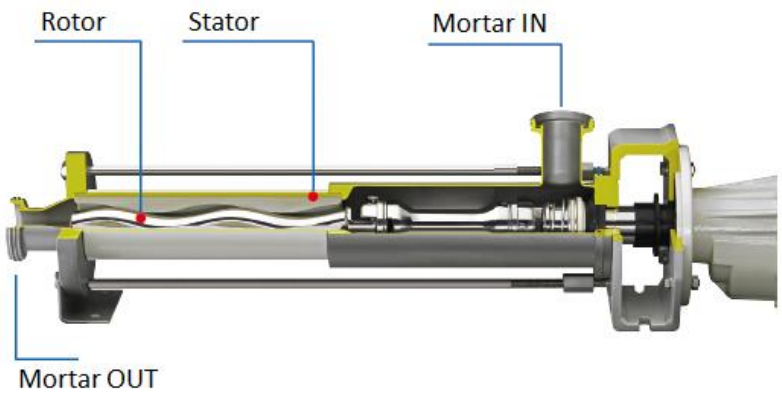


Pressurization apparatus

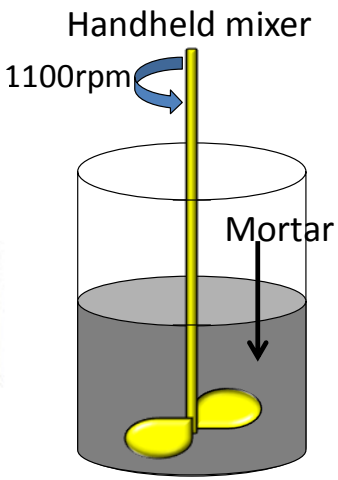
Testing methods

Factors	Pumping	Mixing	Pressurization	Sedimentation
Para-meters	Pumping distances	Additional mixing periods	Pressure values	Sedimentation periods
	0, 50 and 100 m	0, 3 and 5 min	0, 2 and 3 MPa	0, 3 and 5 min

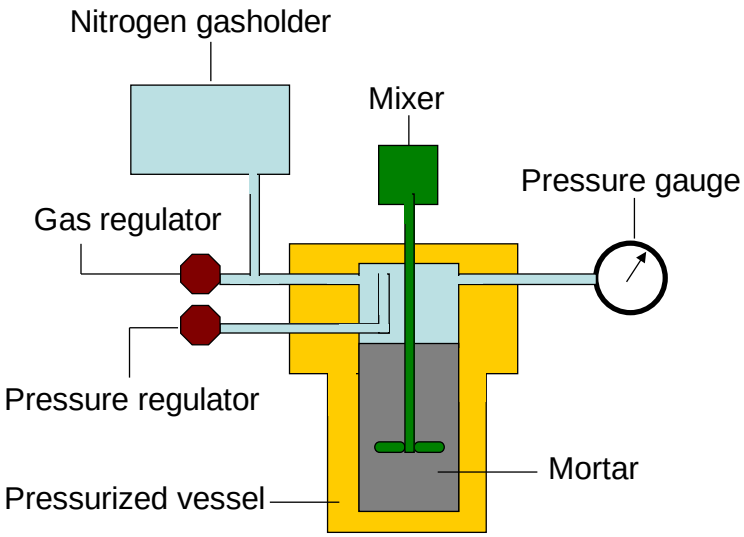
All tests were conducted at 20 ˚C using the same mortar mixed for 2 min.
Measured pumping pressure was 2 MPa @ 50 m and 3 MPa @ 100 m.



Snake pump

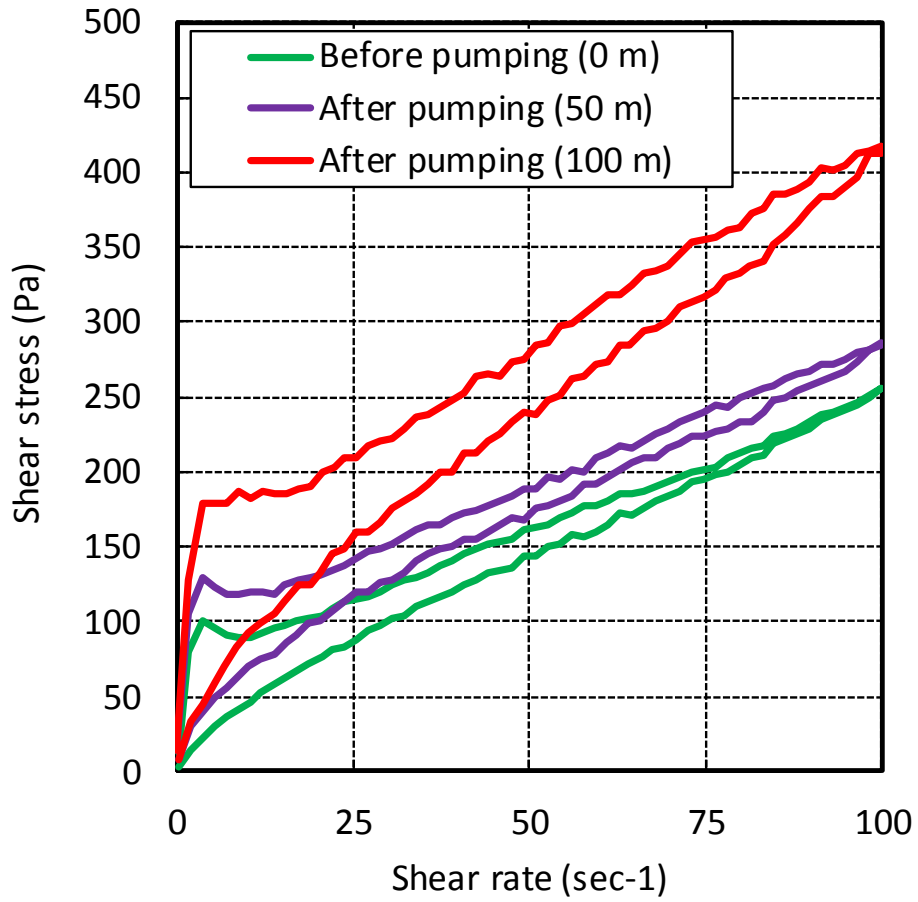


Handheld mixer

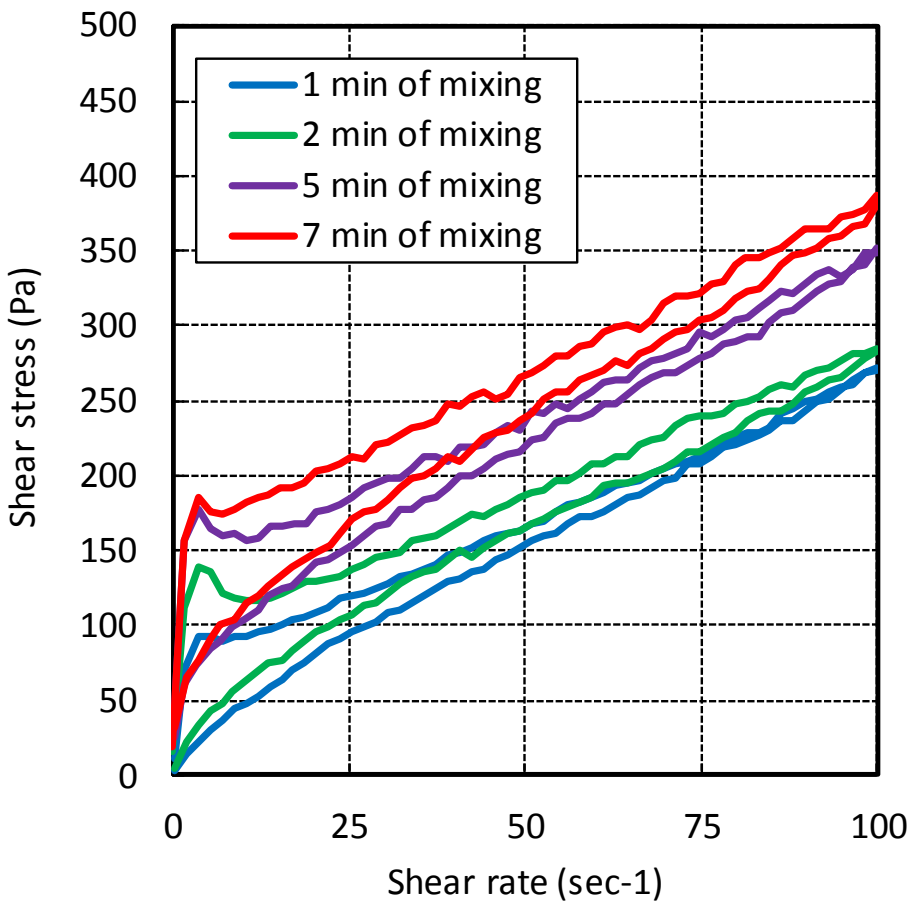


Pressurization apparatus

Flow Curves
Shear stress vs. shear rate

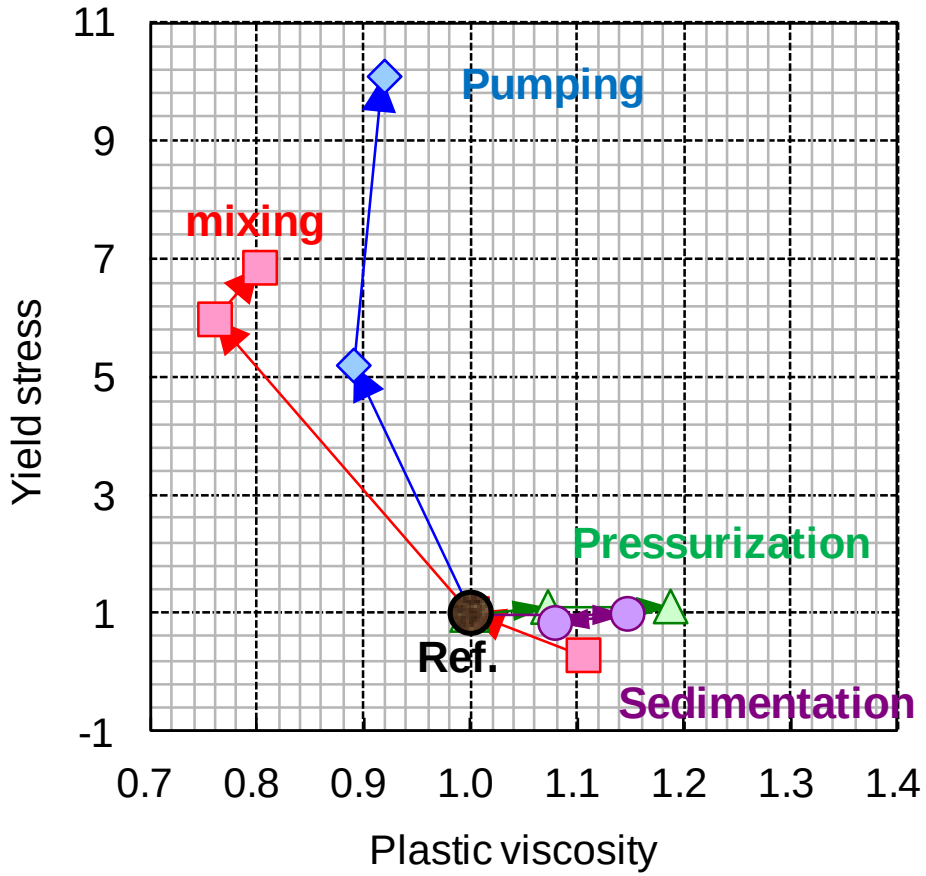


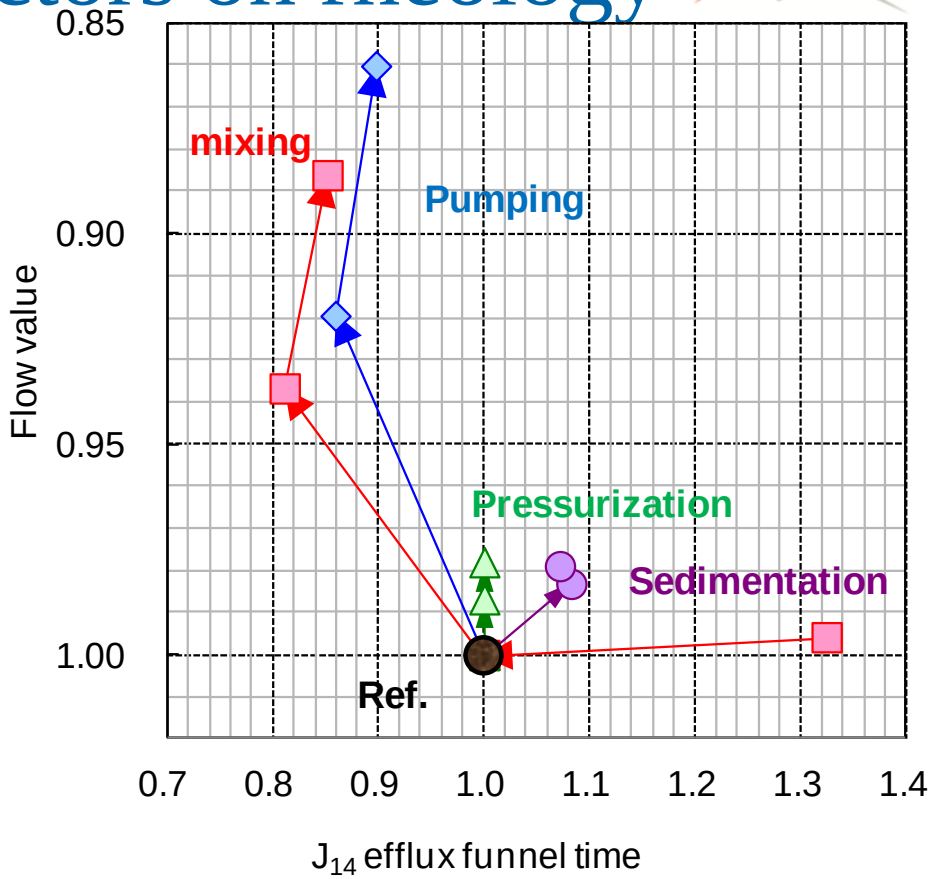
Pumping



Mixing

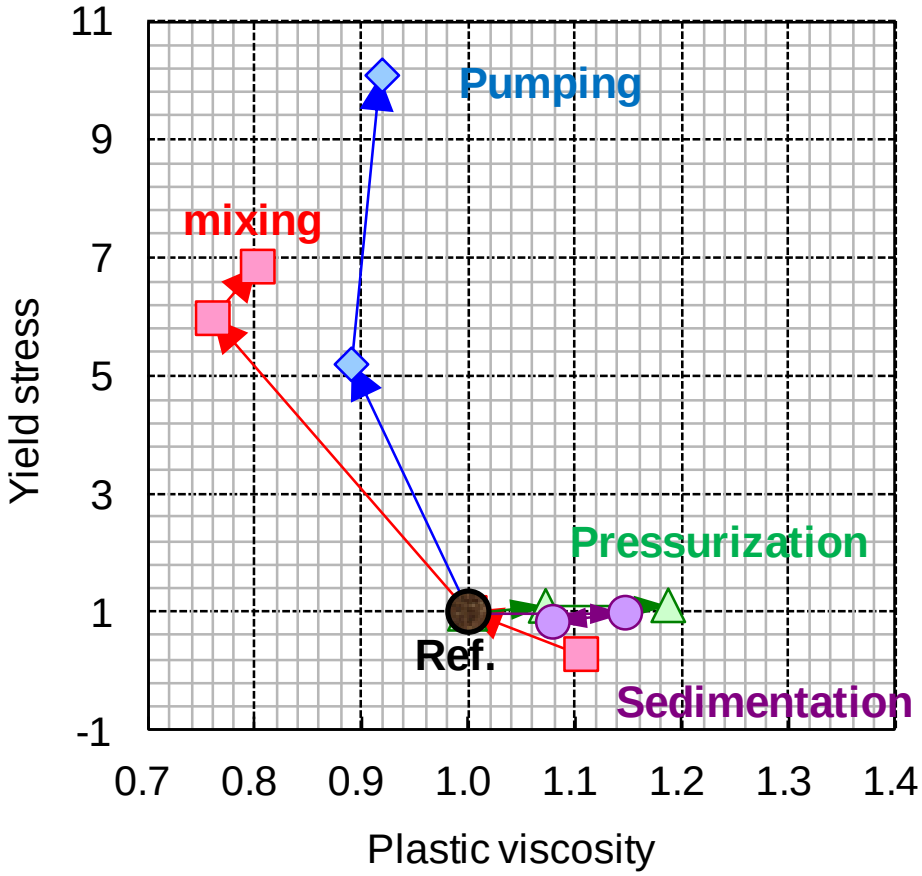
Rheographs:
Effects of several factors on rheology

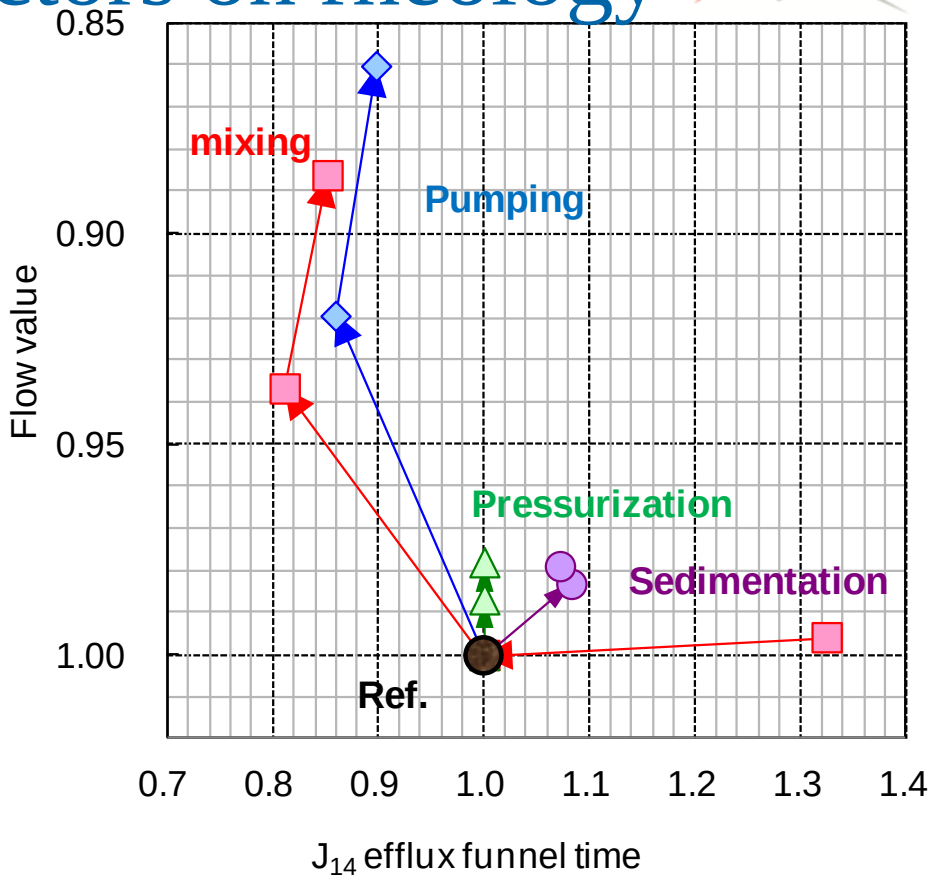




Reference point: after 2 min of mixing or before pumping
Mixing: 1→2→5→7 min, Pumping distances: before→after 50m→after 100m
Pressurization: 0→2→3MPa, Sedimentation: 0→3→5 min

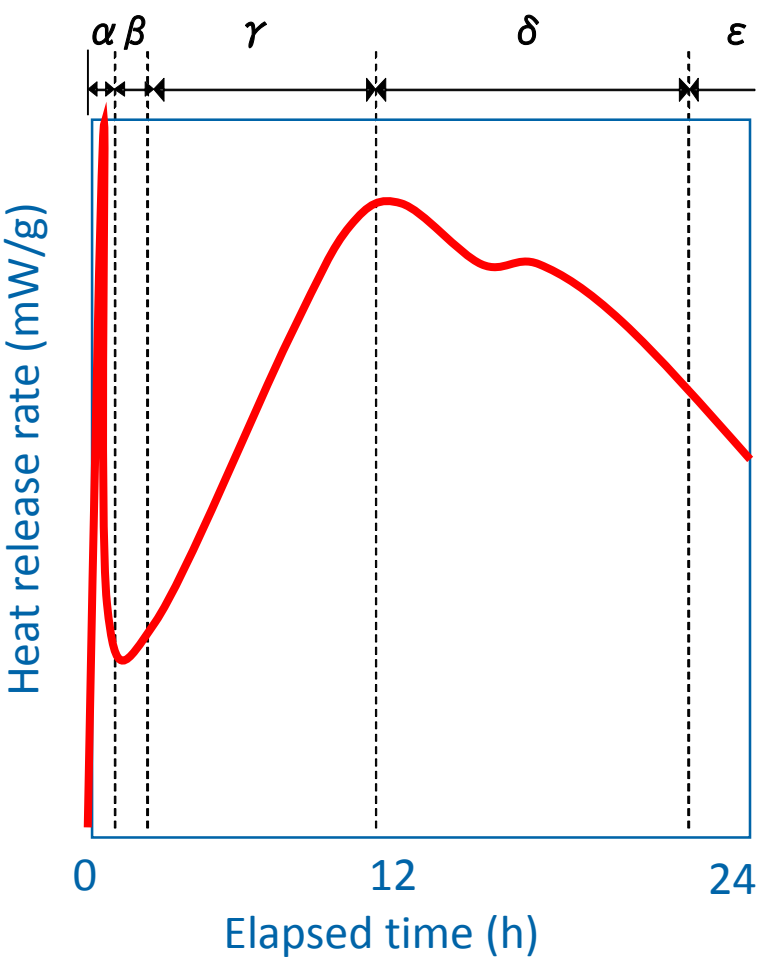
Rheographs:
Effects of several factors on rheology

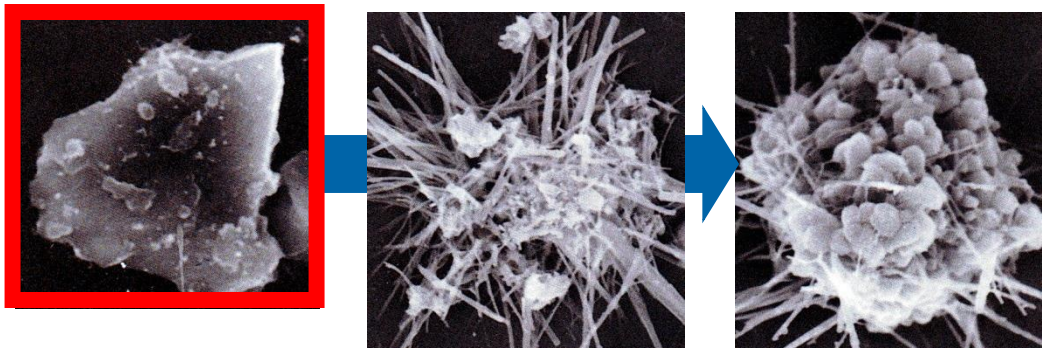




- Shearing action during mixing and pumping process as well does exhibit the most pronounced effect
- Pressurization and sedimentation induce only little changes
- Efflux time and flow value correspond to viscosity and yield stress, respectively

The early hydration process



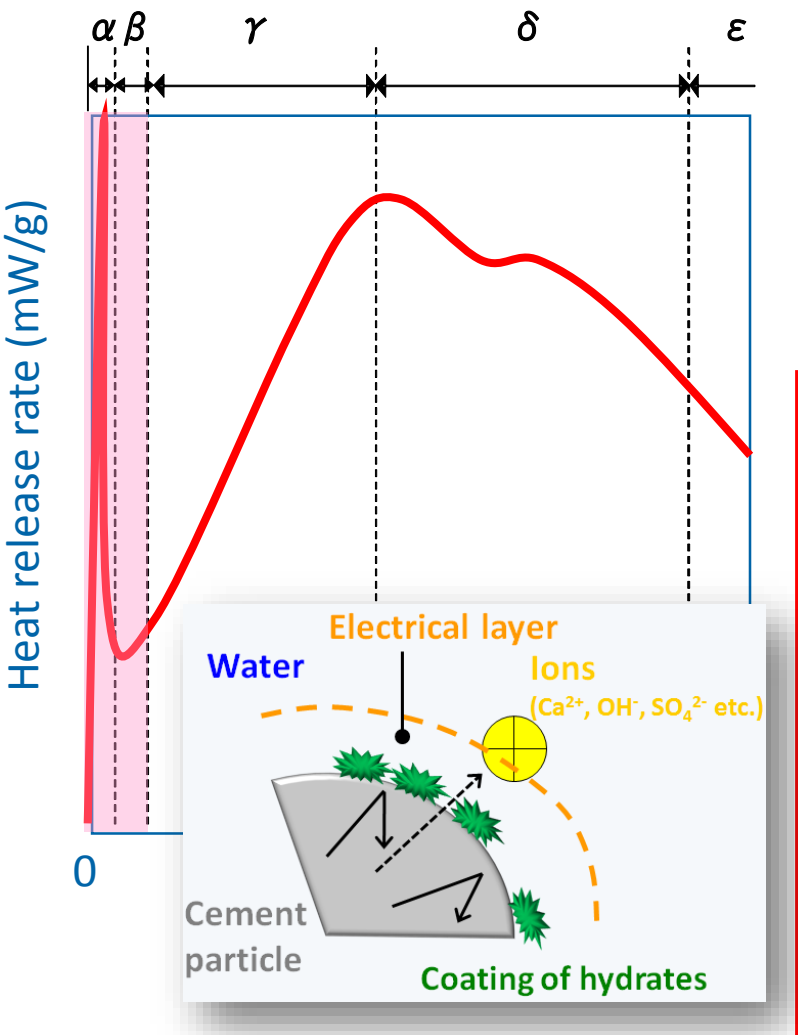


Hydration is

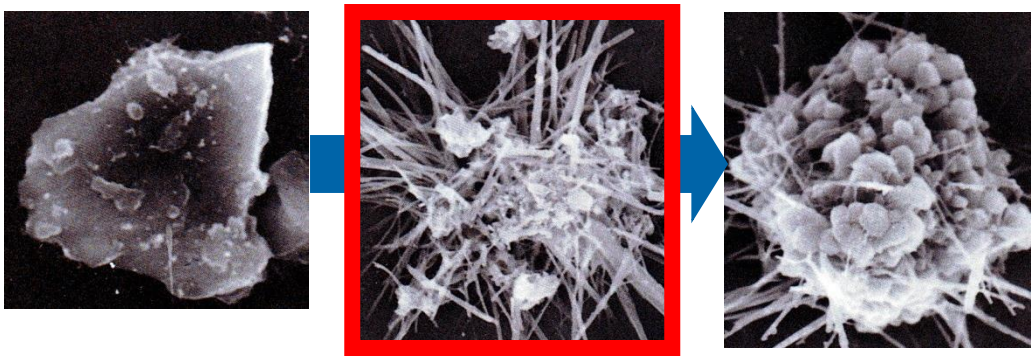
- exothermal reaction
- dissolution–precipitation process

Calorimetry curve for OPC paste

The early hydration process



Calorimetry curve for OPC paste

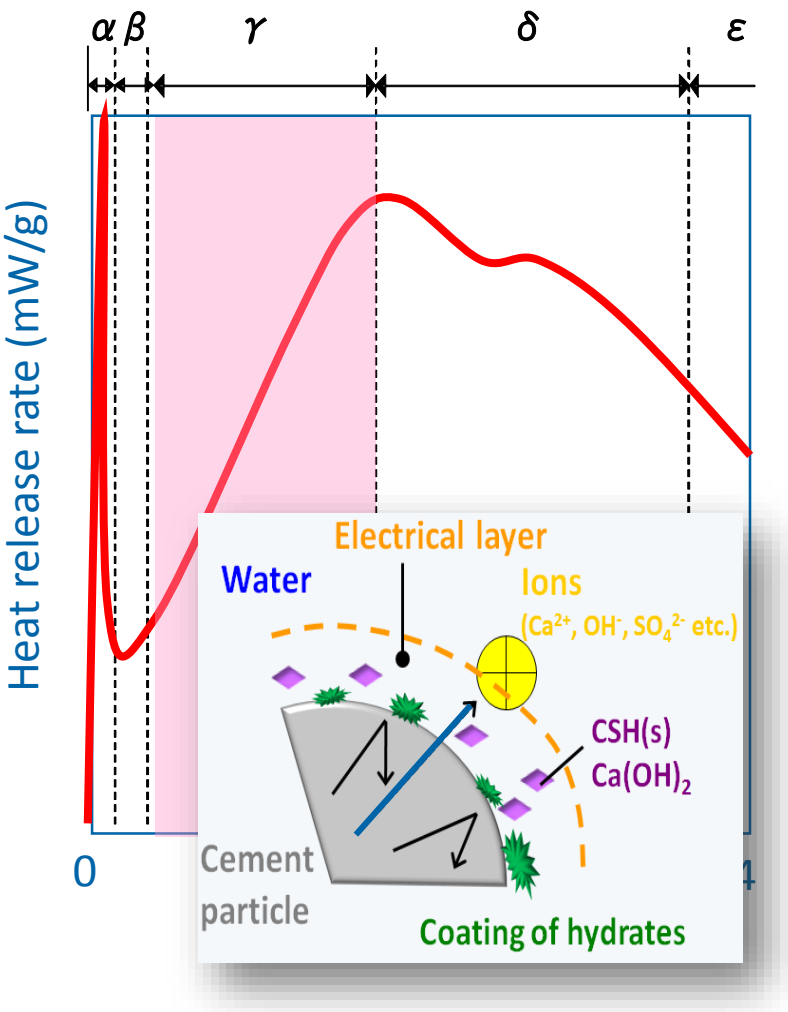


- Pre-induction (α) and induction (β) periods
- Initial dissolution and precipitation that provide a coating of hydrates (metastable layer, Stein, J. appl. Chem. 1964)

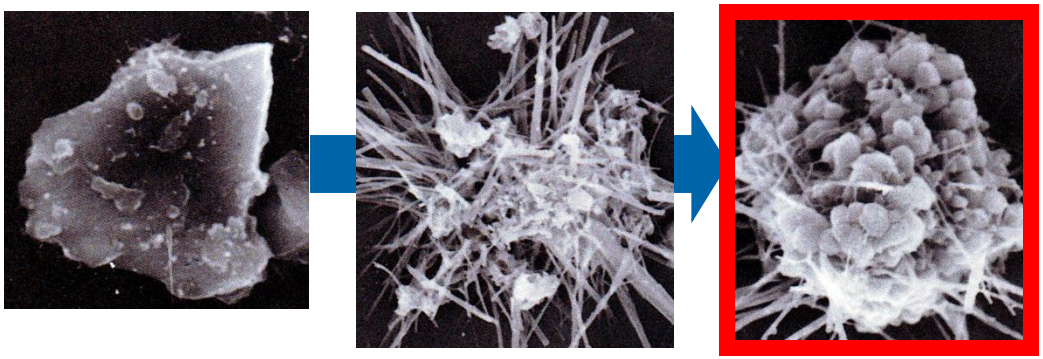
$$C_3S,\ C_3A \xrightarrow[+H_2O]{} CSH(m),\ \text{Ettringite}$$

- Set up of concentration gradient due to the increase of Ca^{2+} at the interface (electrical layer, Juilland, CCR, 2010)
- The layers slow down the reaction rate

The early hydration process



Calorimetry curve for OPC paste

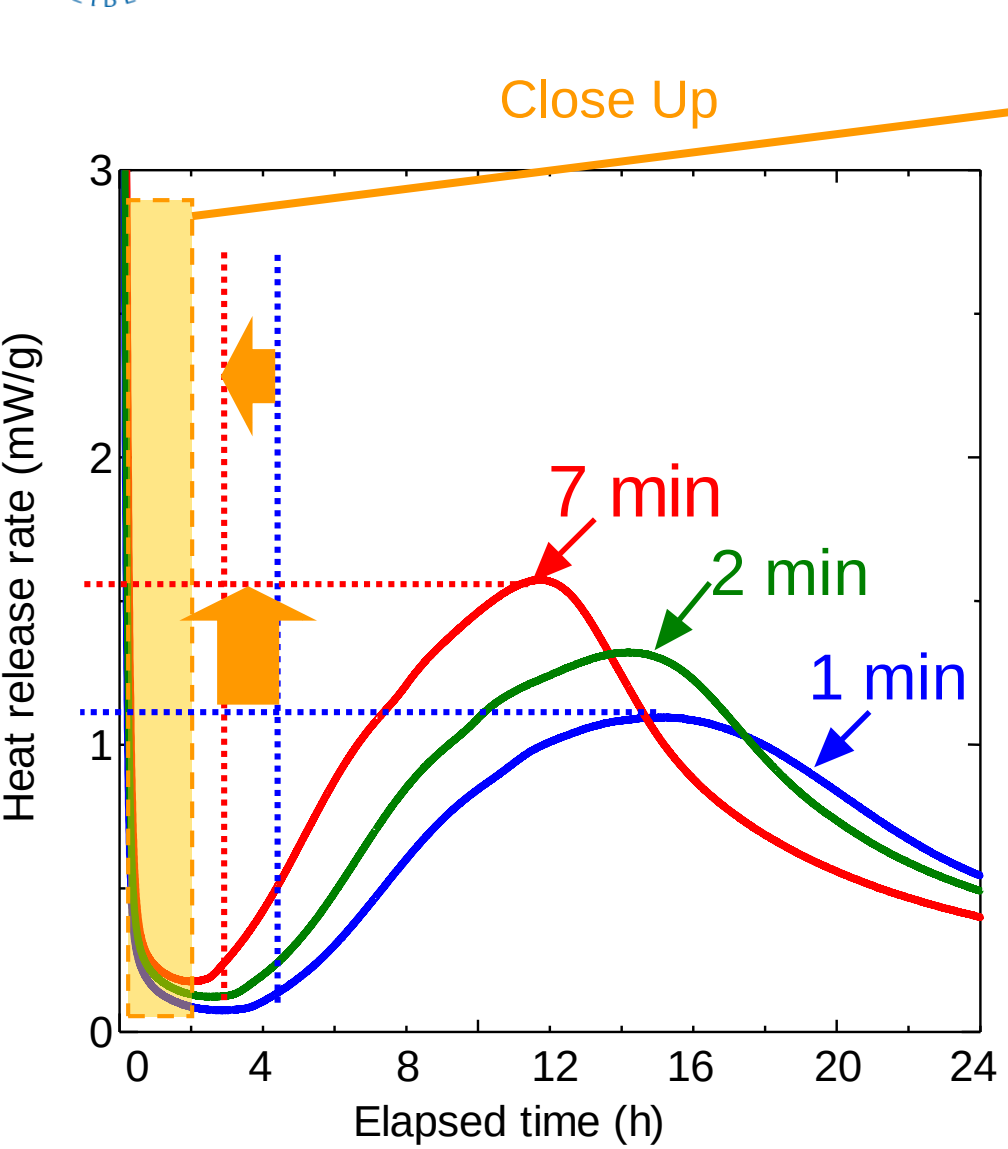


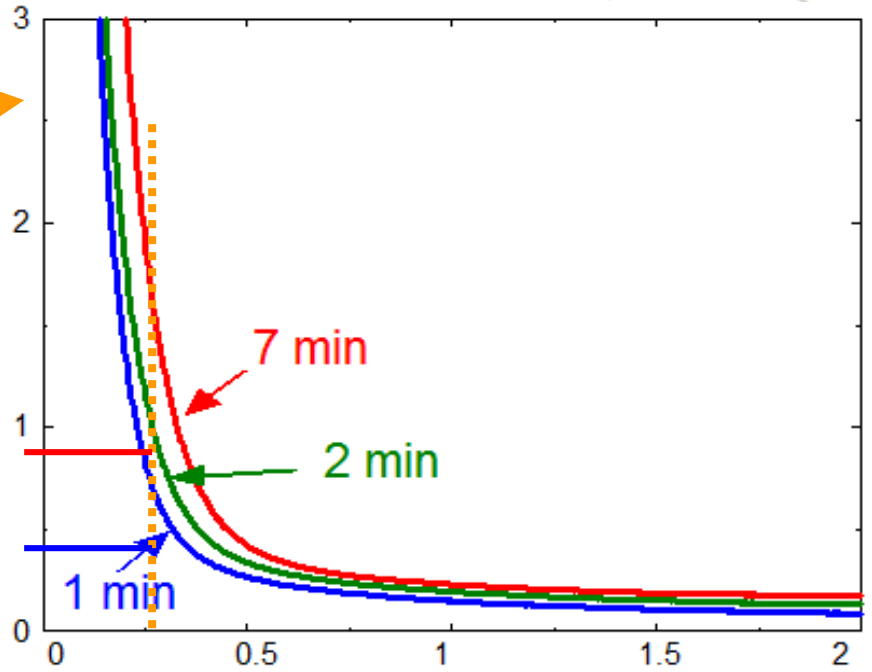
- Accelerated period (hardening process)
- Metastable layer continuously dissolves
- Ca^{2+} & OH^- increase slowly and approach the critical supersaturation of $Ca(OH)_2$
- $Ca(OH)_2$ and CSH grow at an exponential rate (massive hydration, 2nd peak)

$$C_3S,\ CSH(m) \xrightarrow{+H_2O} CSH(s) + Ca(OH)_2$$

- Set and increase in strength

Hydration and Calorimetry

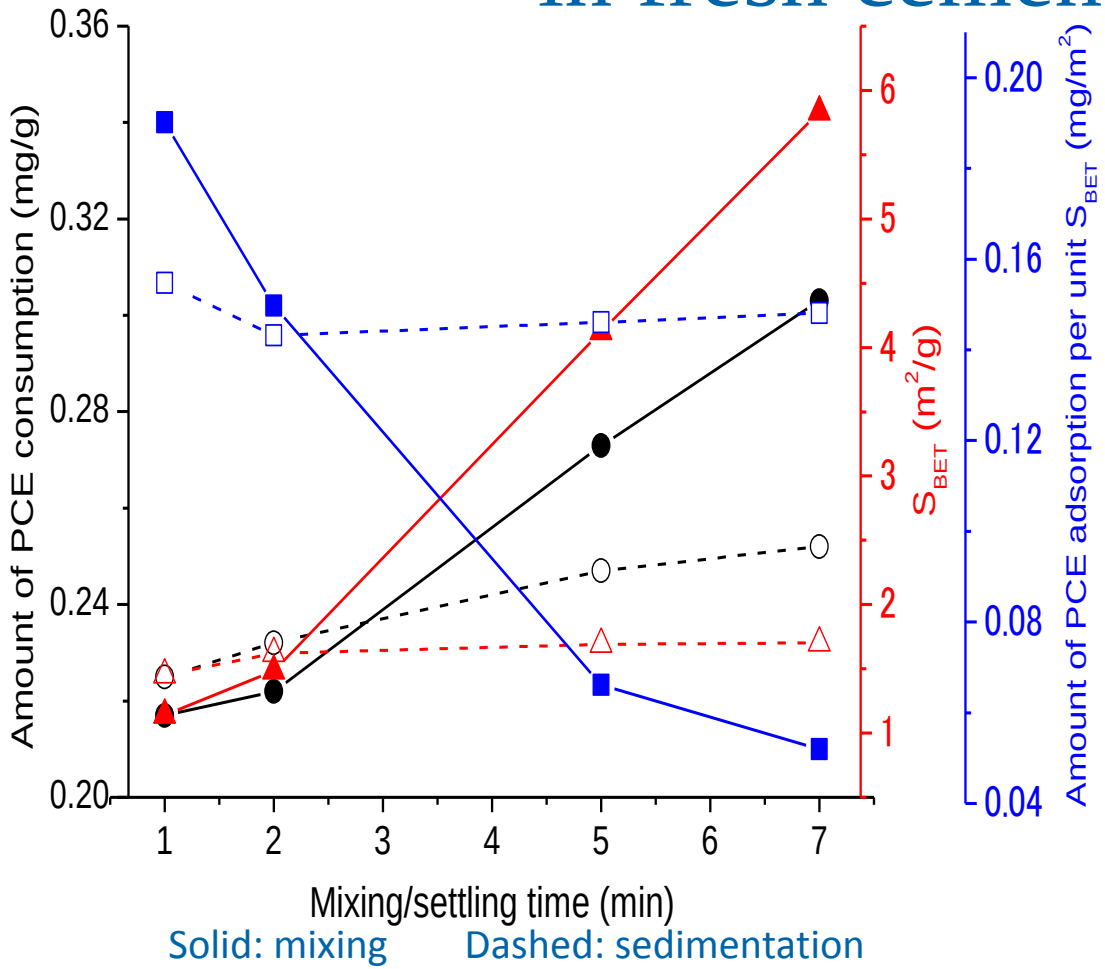




With increasing mixing time,

- Initial dissolution rate at a given time became more pronounced (accelerated)
- Start of massive hydration was advanced (accelerated)
- Second peak of the calorimetric curves increased

Adsorption behavior of PCE in fresh cement paste



Solid: mixing Dashed: sedimentation

As mixing time became longer,

- ● Amount of PCE consumption in the solution phase increased
- ▲ S_{BET} increased significantly
- ■ PCE adsorption per unit S_{BET} decreased

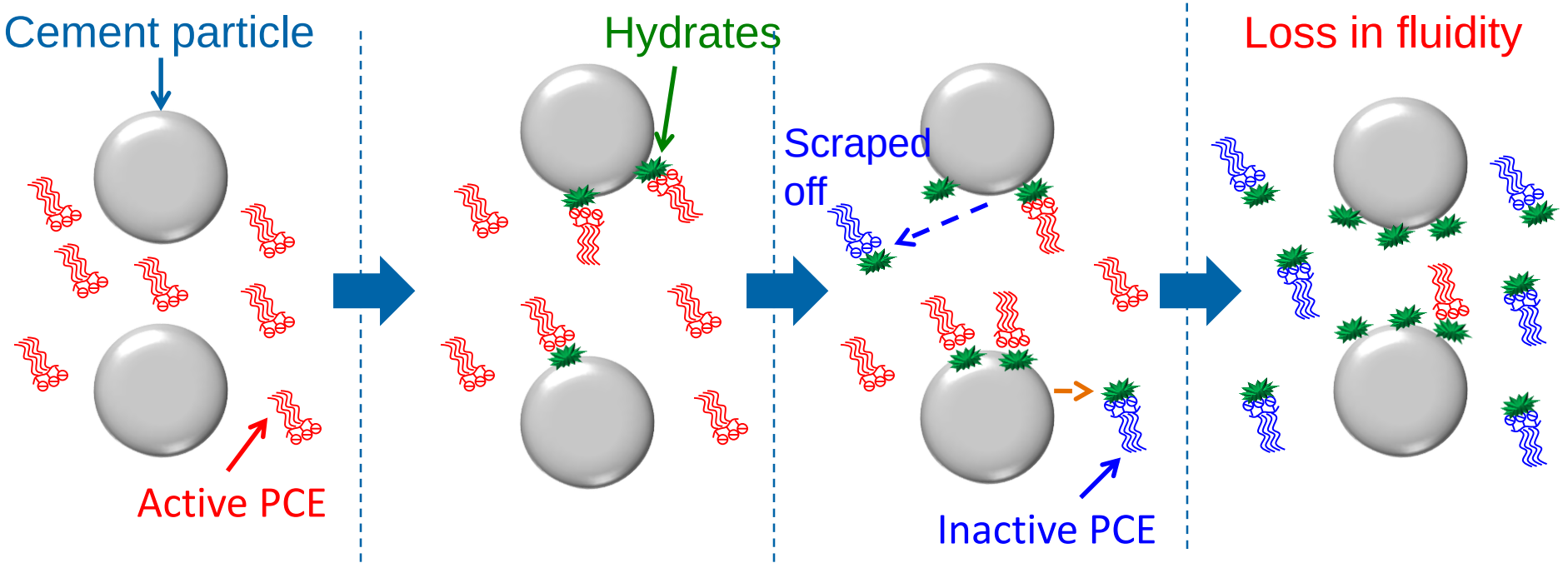
Sedimentation has little change

Extended surface area by mixing increases PCE consumption and subsequently causes degrading changes in fluidity

Mechanism for changes in fluidity

Active PCE adsorb onto hydrates and disperse cement particles

Shearing action (dominanting factor) = Further hydrates formation



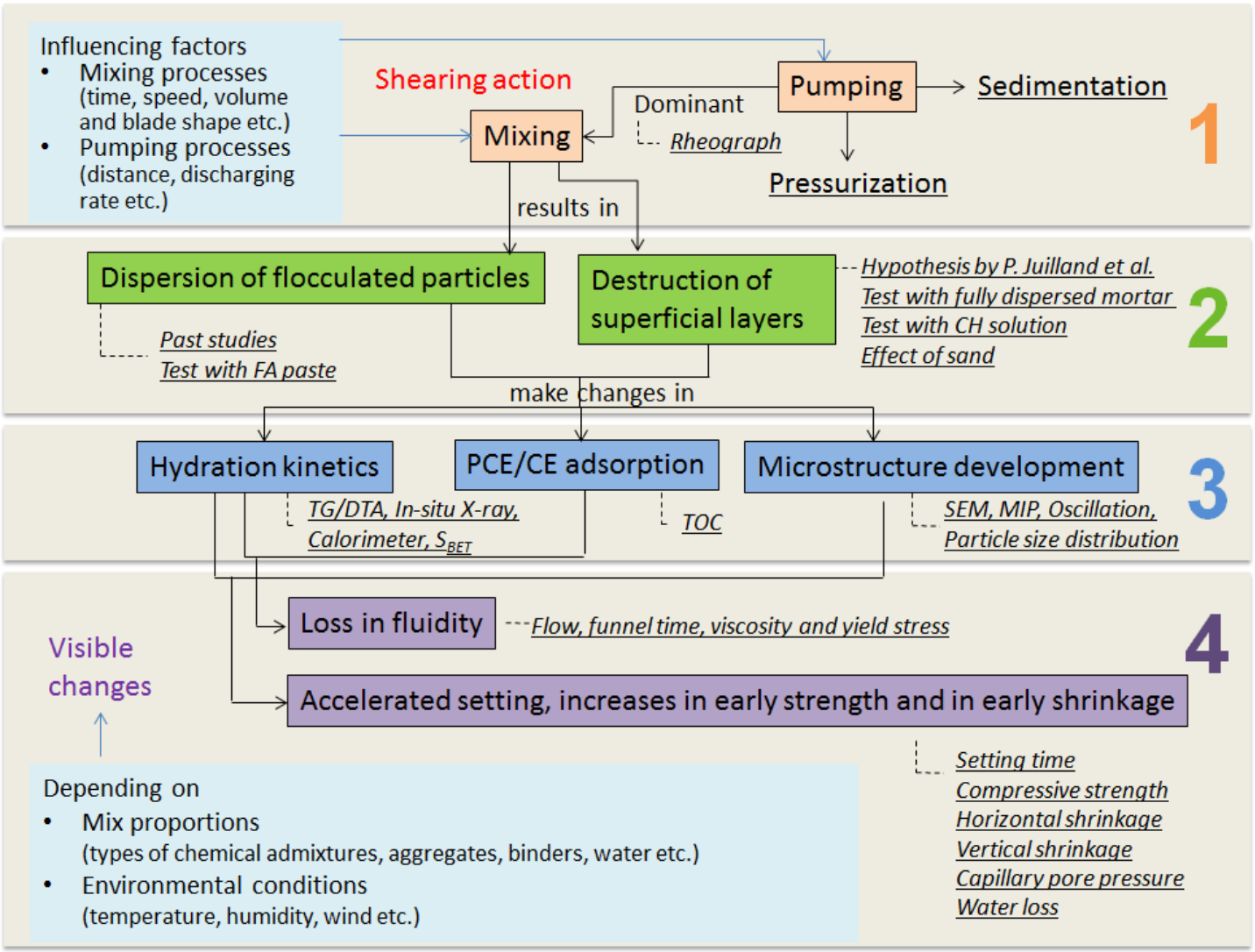
Immediately after adding water

Adsorption of PCE

Abrasion by shearing action

After repetition, active PCE decreases

Graphical Summary and Concept



Conclusions

- ✓ With extended mixing or pumping distance
  - Yield stress and flow value decrease
  - Viscosity and efflux time increase
- ✓ Analysis results using rheographs indicate
  - Shear stress during mixing and/or pumping is a major factor influencing mortar rheology
- ✓ On a microstructural level
  - the consumption of active PCE in solution,
  - the increase in specific surface area of the cement
  - and a subsequent decrease for PCE per unit S_{BET}

can explain a change in state of dispersion and the observed changes in rheological properties

Thank you for your attention!