TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Civil Engineering, Institute of Construction Materials

22. Kolloquium und Workshop, Rheologische Messungen an mineralischen Baustoffen, Regensburg, 11–12 März, 2015

Rheological characterization and prediction of pumpability of Strain-Hardening Cement-Based Composites (SHCC) at various temperatures

Egor Secrieru
Viktor Mechtcherine

DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

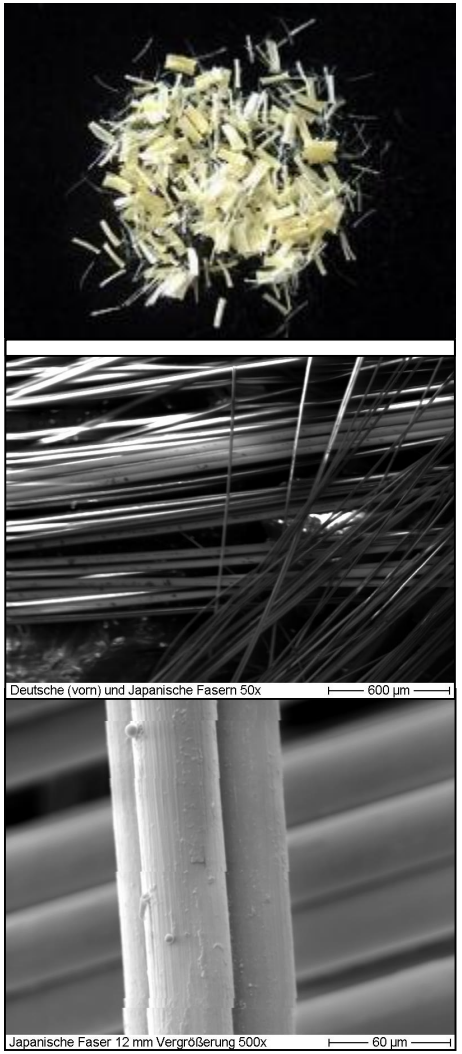
Highlights

- SHCC as innotative material
- Temperature effect on time depending fresh properties of SHCC
- Rheology, tribology and pumpability of fresh SHCC
- Plug flow and lubrication layer formation in the pipe
- Pumpability prediction by means of tribology

SHCC as innovative material

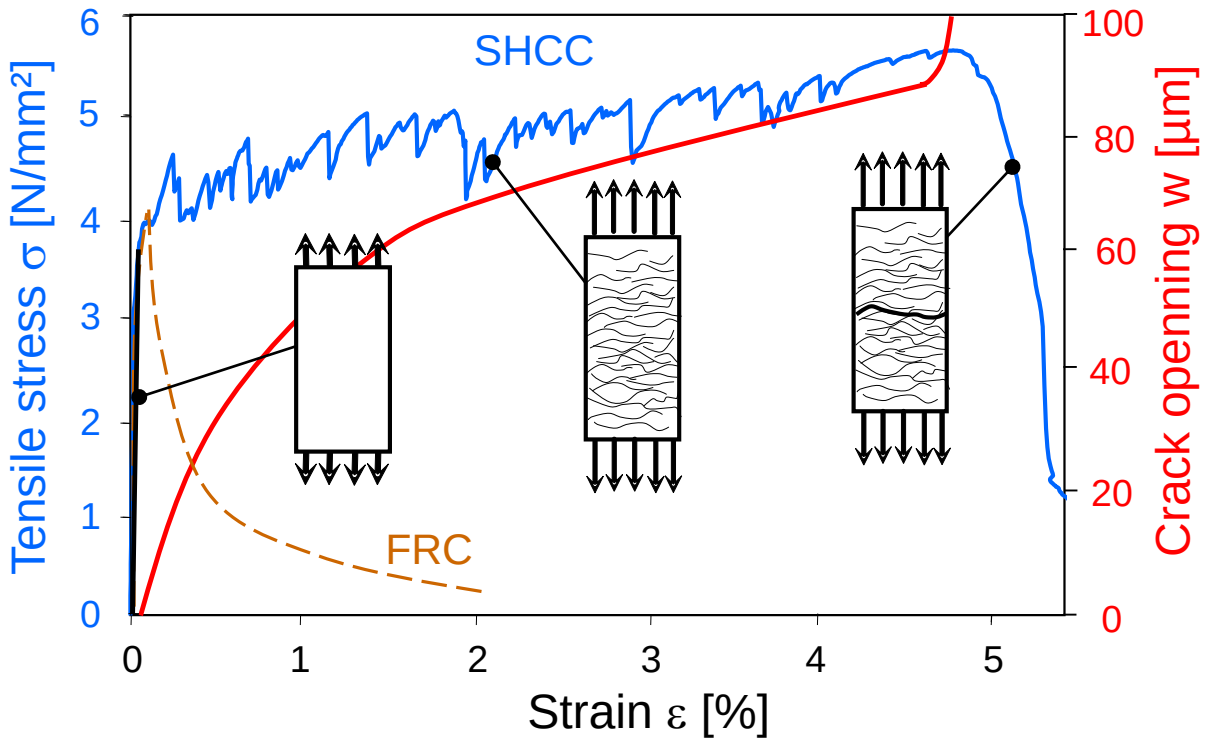
Concrete composition

Ingredients [kg/m³]	SHCC
CEM II	505
Fly ash	621
Coarse aggregates	–
Sand 0.06-0.2	536
Water	338
SP PCE	11
PVA-fibers 12/15	26
w/b	0.30



SHCC as innovative material

Typical stress-strain response for SHCC



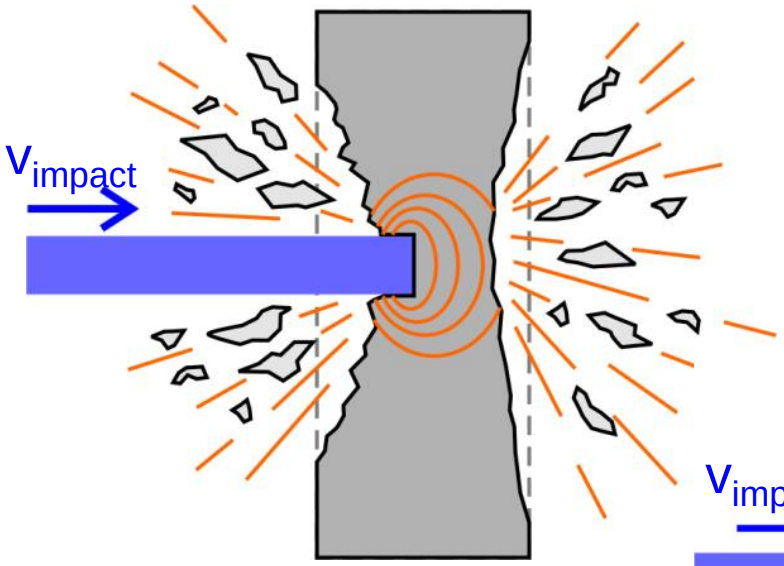
→ Ductile behaviour due to multiple crack formation

→ Very high strain capacity

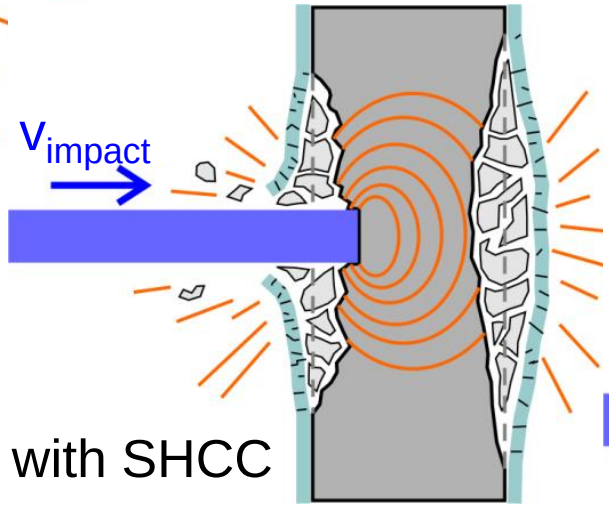
→ Crack widths below 0.1 mm up to ultimate strain

Jun, Mechtcherine, *Cement and Concrete Research* 32 (2010) 801-809.

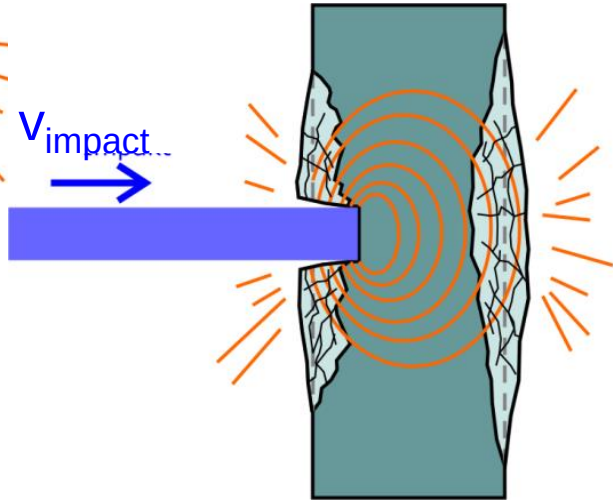
SHCC under dynamic impact



Ordinary concrete



Strengthening with SHCC



SHCC

Strengthening of masonry – Motivation

Achaia (Greece)

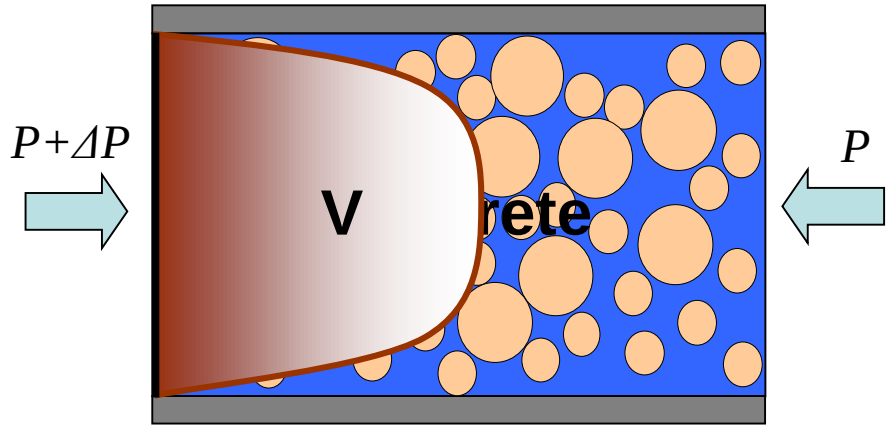
Izmit (Turkey)

China

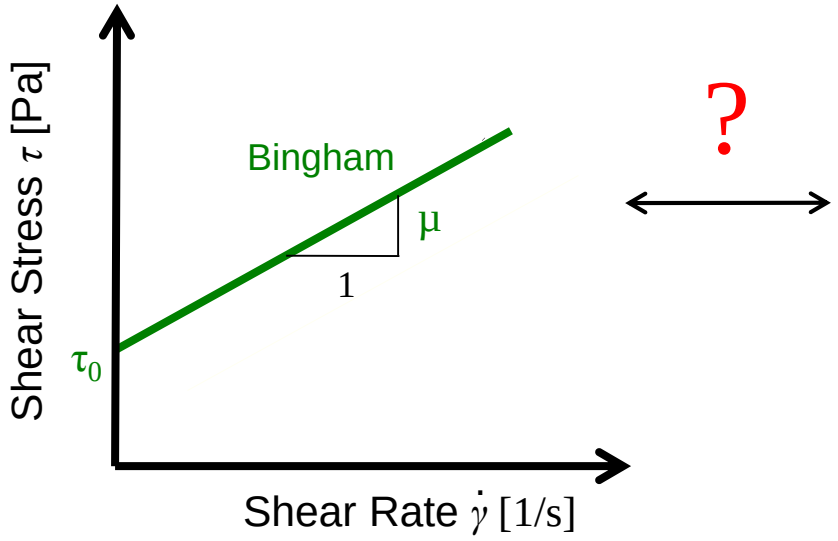
Strengthening of masonry – Wall tests

Producing slabs

Rheology vs. pipeflow and pumpability

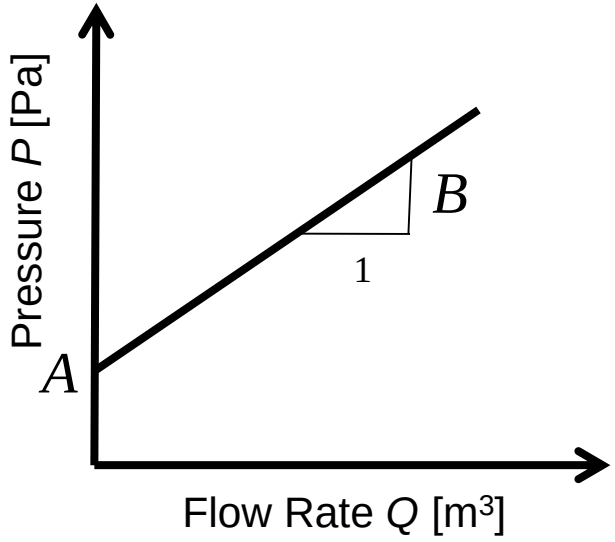


$\tau = \tau_0 + \mu \cdot \dot{\gamma}$



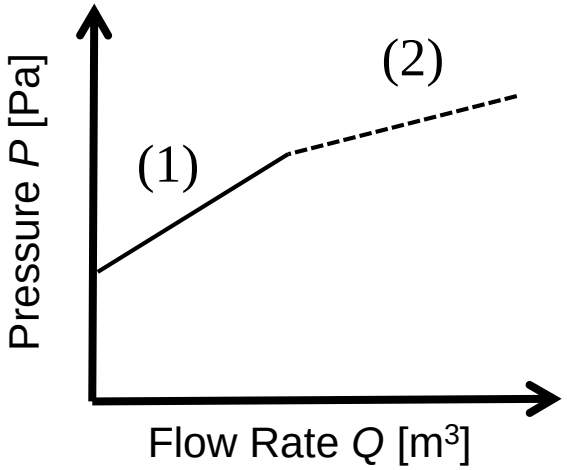
?

$P = A + B \cdot Q$



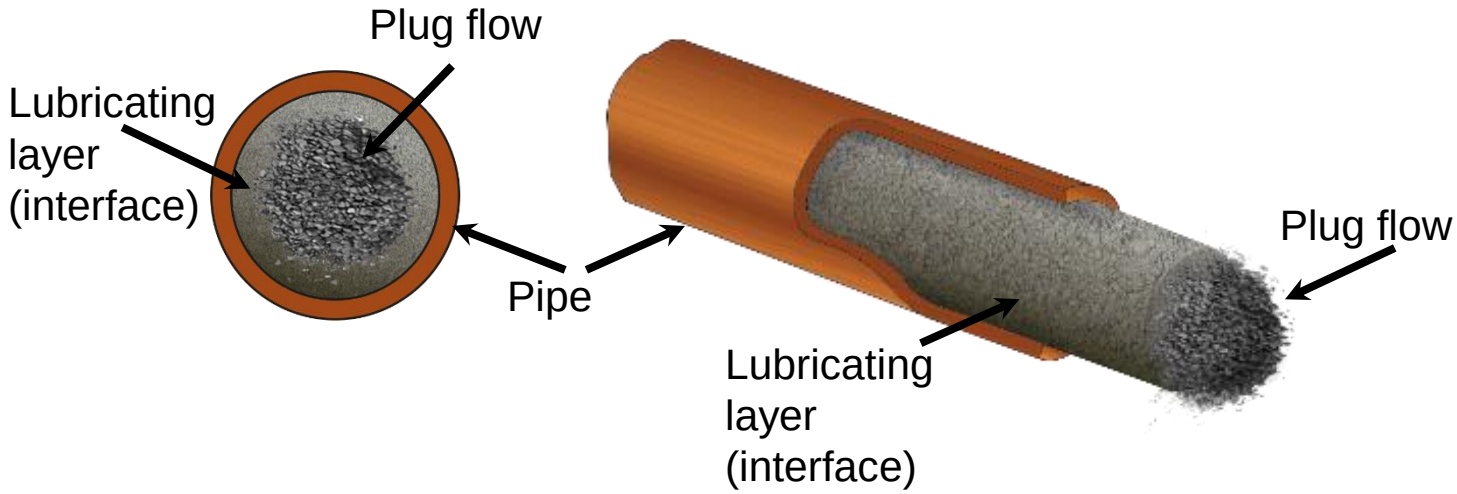
Parameters describing pumpability

Repair and protection of existing structures



(1) $P = P(\tau_{0i}, \mu_i, Q, L, R, k)$

(2) $P = P(\tau_{0i}, \mu_i, \tau_0, \mu, Q, L, R, k)$



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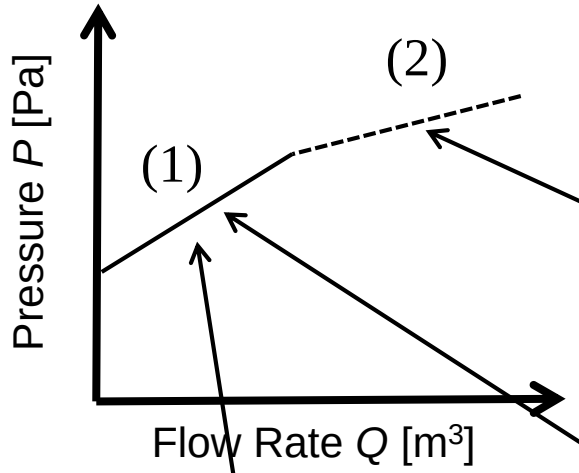

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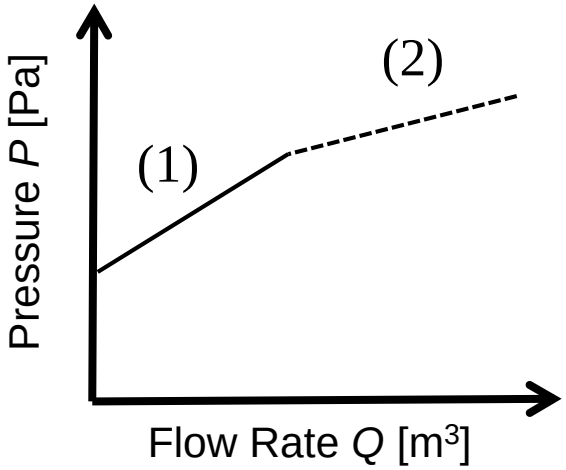
Secrieru, Butler, Mechtcherine, *Bautechnik, Heft* 11 (2014) 797-811.

Parameters describing pumpability

Repair and protection of existing structures



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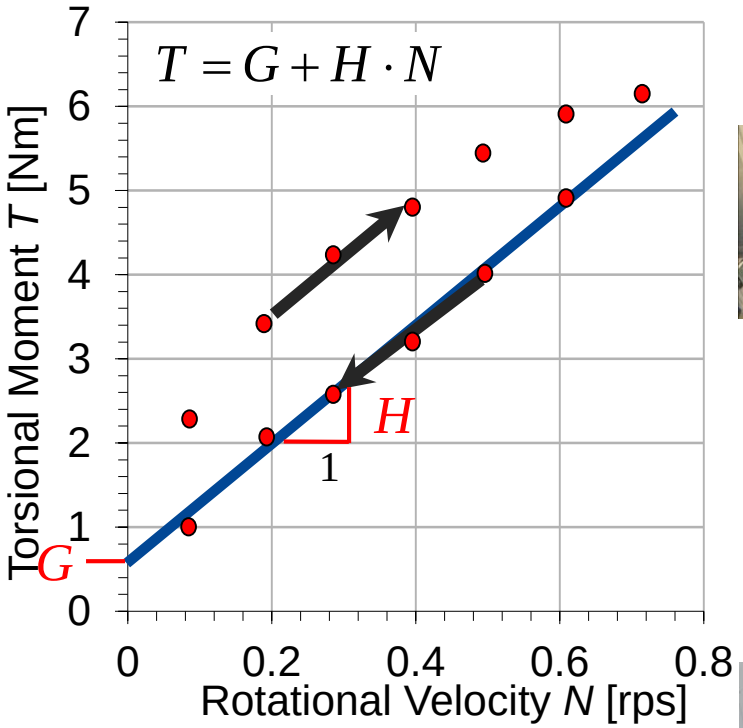
SLIPER

$$P = \frac{4L}{R} \cdot a + \frac{16 \cdot L}{\pi \cdot D^3} \cdot b \cdot Q = A + B \cdot Q$$

τ_{0i}, τ_0 $\quad$ μ_i, μ

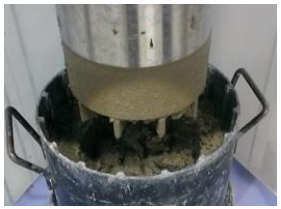
Rheometrical/tribological equipment

Continuous rotational test



Viscometer

Tribometer



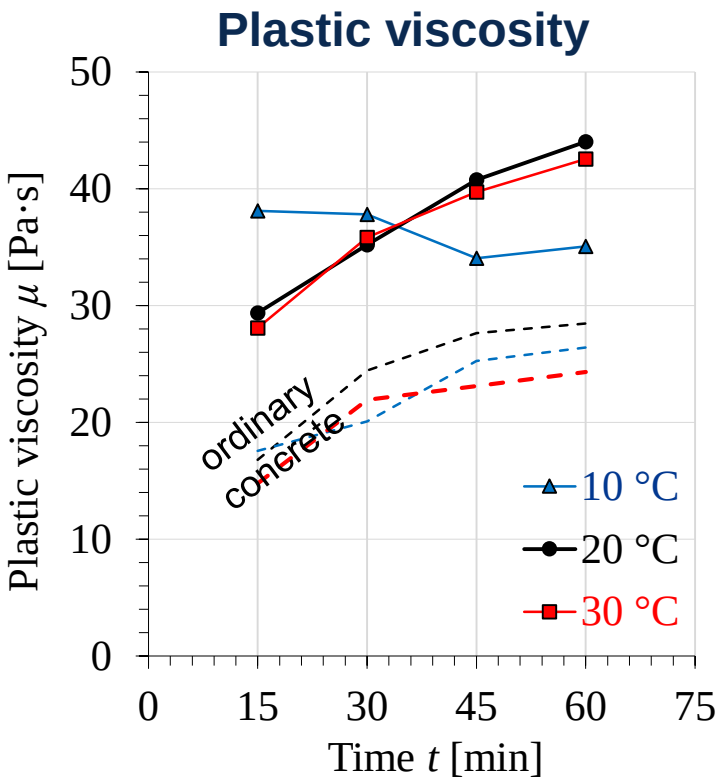
Concrete core

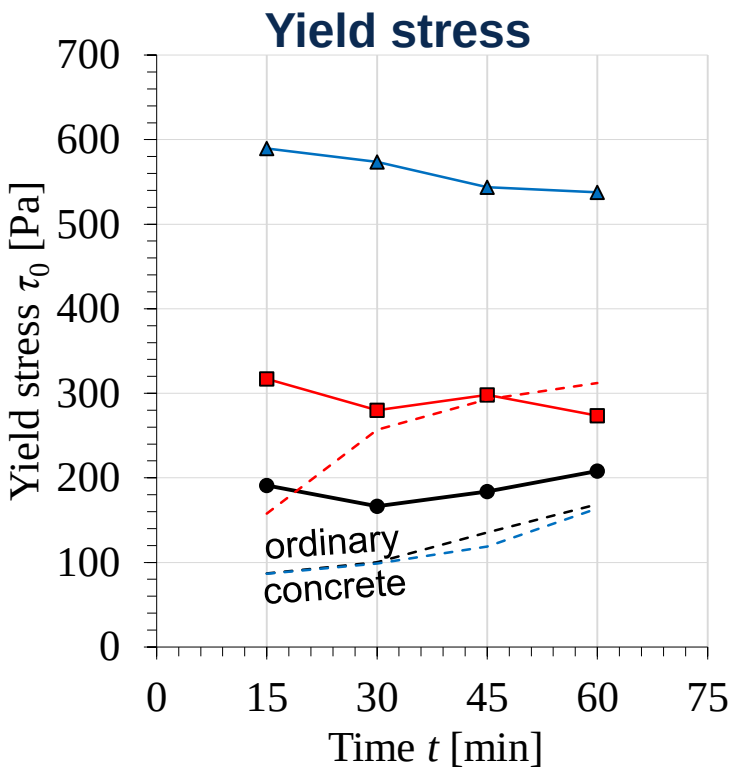
$$\begin{cases} \tau = \tau_0 + \mu \cdot \dot{\gamma} \rightarrow \left[\frac{1}{s}\right] \\ \tau_0 = \frac{G}{4\pi \cdot h}\left(\frac{1}{r_i^2} - \frac{1}{r_0^2}\right)\frac{1}{\ln(r_0 / r_i)} \\ \mu = \frac{H}{8\pi^2 \cdot h}\left(\frac{1}{r_i^2} - \frac{1}{r_0^2}\right) \end{cases}$$

Lubrication layer

$$\begin{cases} \tau = \tau_{0i} + \mu_i \cdot \nu \rightarrow \left[\frac{m}{s}\right] \\ \tau_{0i} = \frac{G}{2\pi \cdot r_i^2 \cdot h} \quad [Pa] \\ \mu_i = \frac{H}{(2\pi)^2 \cdot r_i^3 \cdot h} \quad \left[Pa \cdot \frac{s}{m}\right] \end{cases}$$

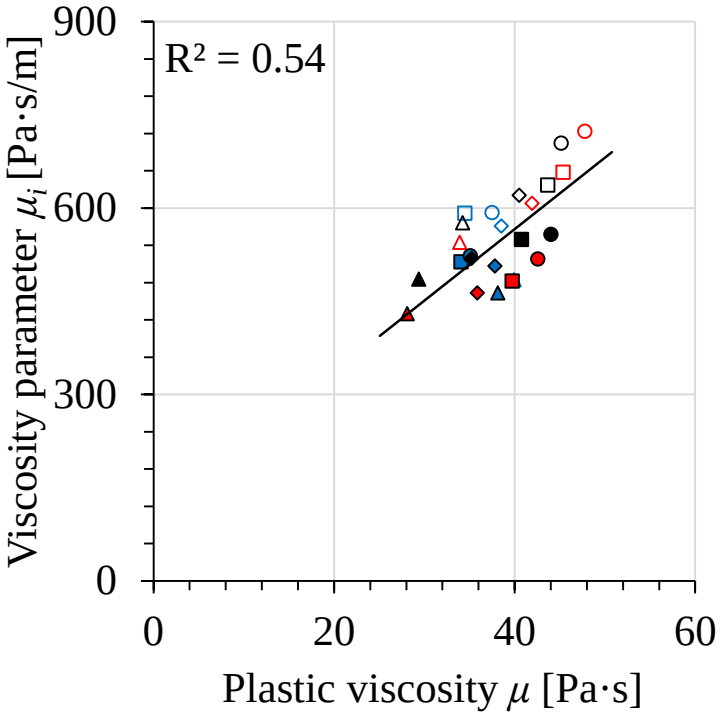
Evolution of plastic viscosity μ and yield stress τ_0



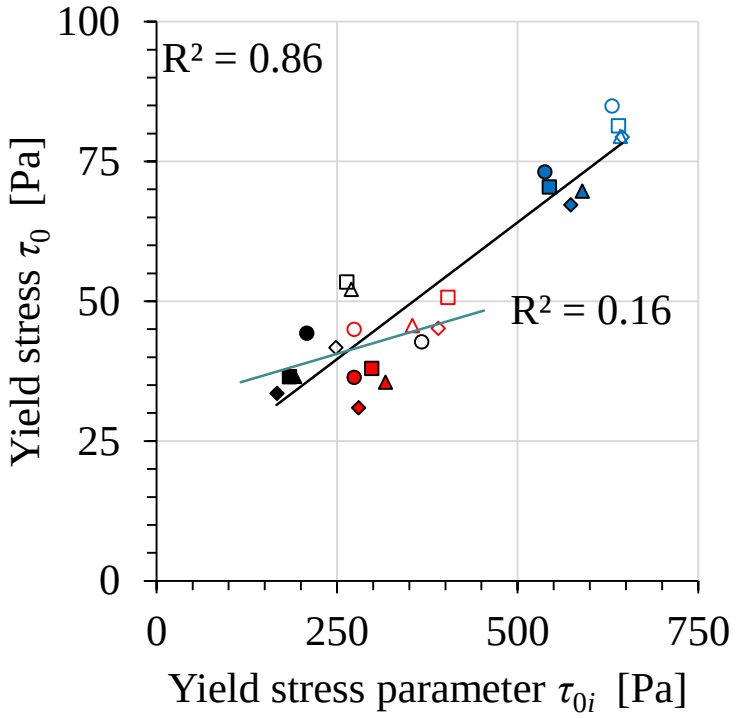


Correlation between viscometer and tribometer

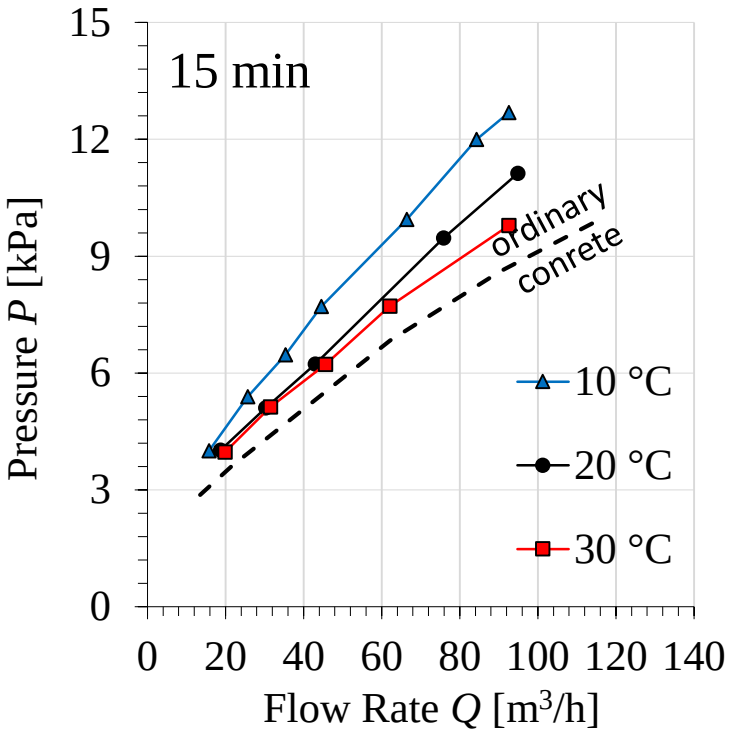
Viscosity

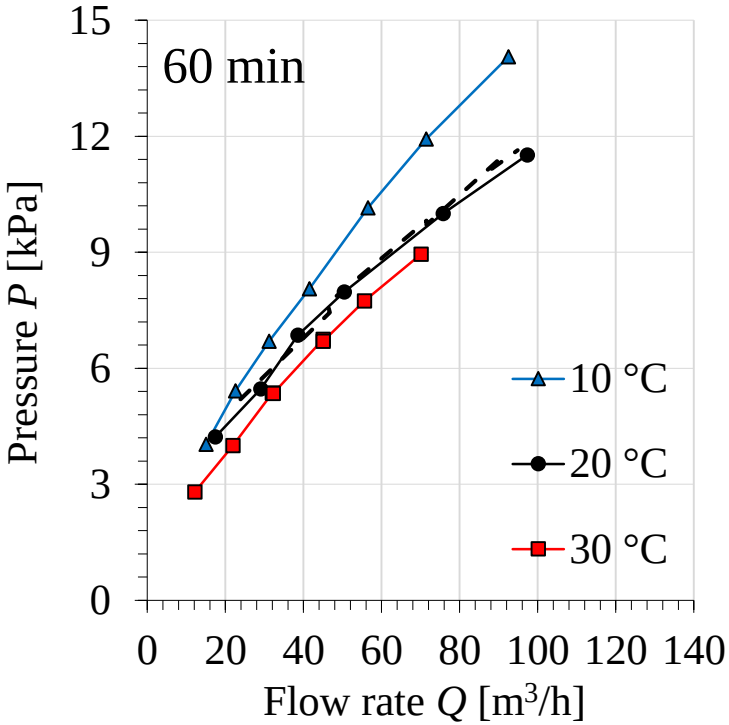


Yield stress



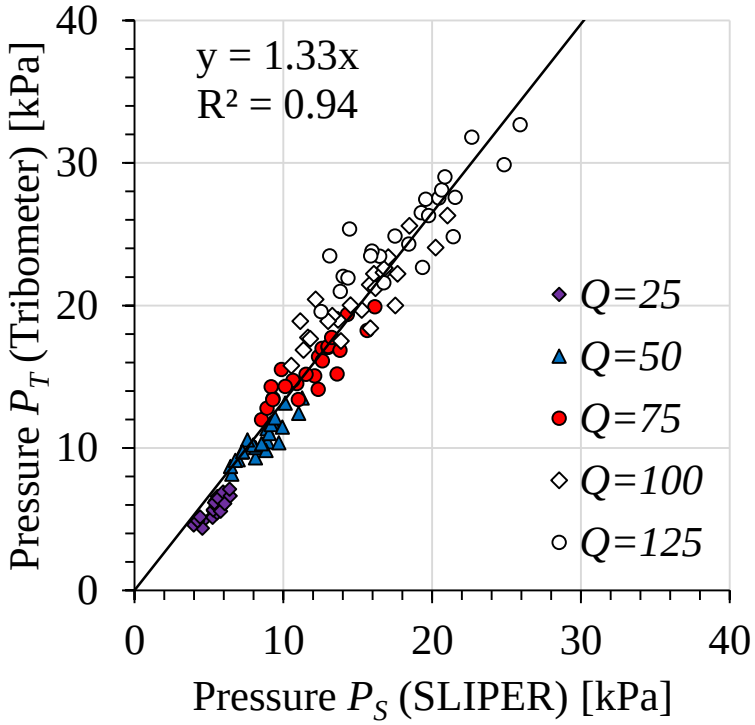
Evolution of pumpability



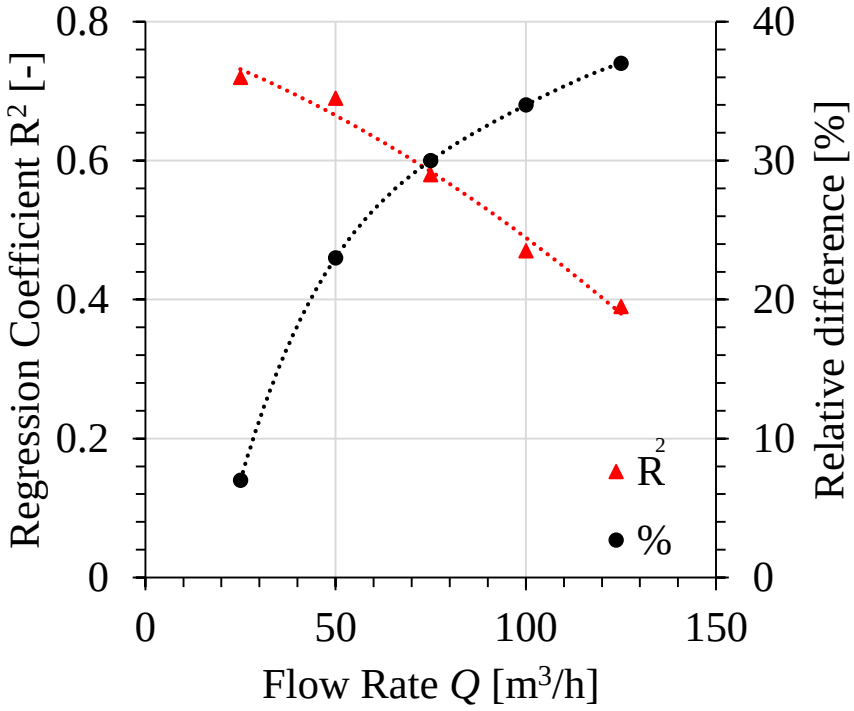


SLIPER vs. Tribometer

Pressure prediction



Variaton of R²



$$P = \frac{2L}{R}\left[\tau_{0i} + \frac{Q \cdot \mu_i}{\pi \cdot R^2 \cdot k}\right] \quad \longleftrightarrow \quad P = \frac{4L}{R}a + \frac{16 \cdot L}{\pi \cdot D^3}b \cdot Q$$

Tribometer SLIPER

Summary

- Key factors affecting the changes in rheology are PCE-binder interaction, time and temperature
- Changes in temperature – low impact on the plastic viscosity
- Changes in temperature – far more increased impact on yield stress
- Tribological tests and SLIPER revealed the special feature of SHCC – formation of very fine lubrication layer
- Movement of SHCC through the pipe – plug flow
- Pressure prediction with tribometer validated by SLIPER

Acknowledgements

Thank You!

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ESF
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Putzmeister