Relevanz von Thixotropie und Strukturaufbau für die Verarbeitungseigenschaften von Beton

Relevance of thixotropy and structural build-up for workability of concrete

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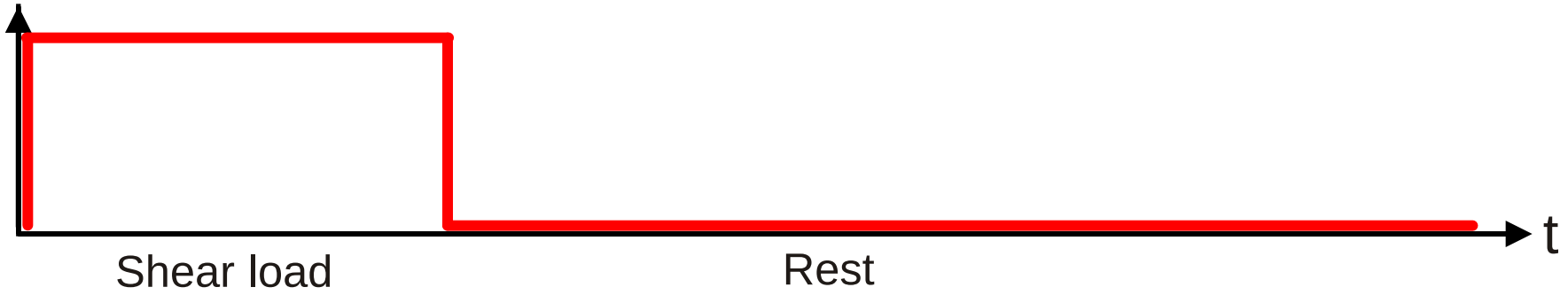
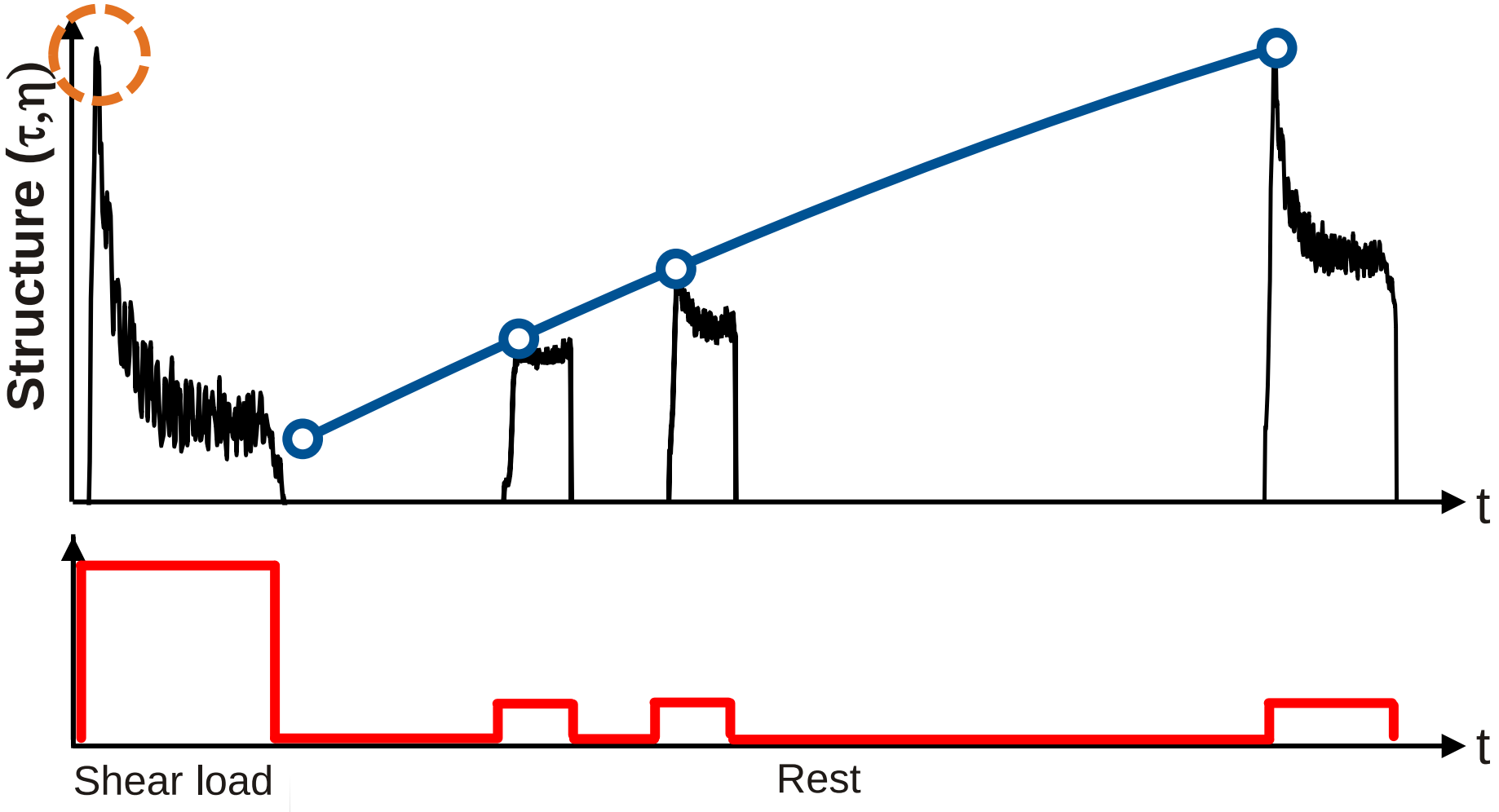
Thixotropy

Thixotropy [greek] property of certain two-component-systems, to fluidify under mechanical load (stir, shake, ultra sonic) at constant water content. At rest, the substance hardens again. - **Herbert Freundlich** (1880-1940)

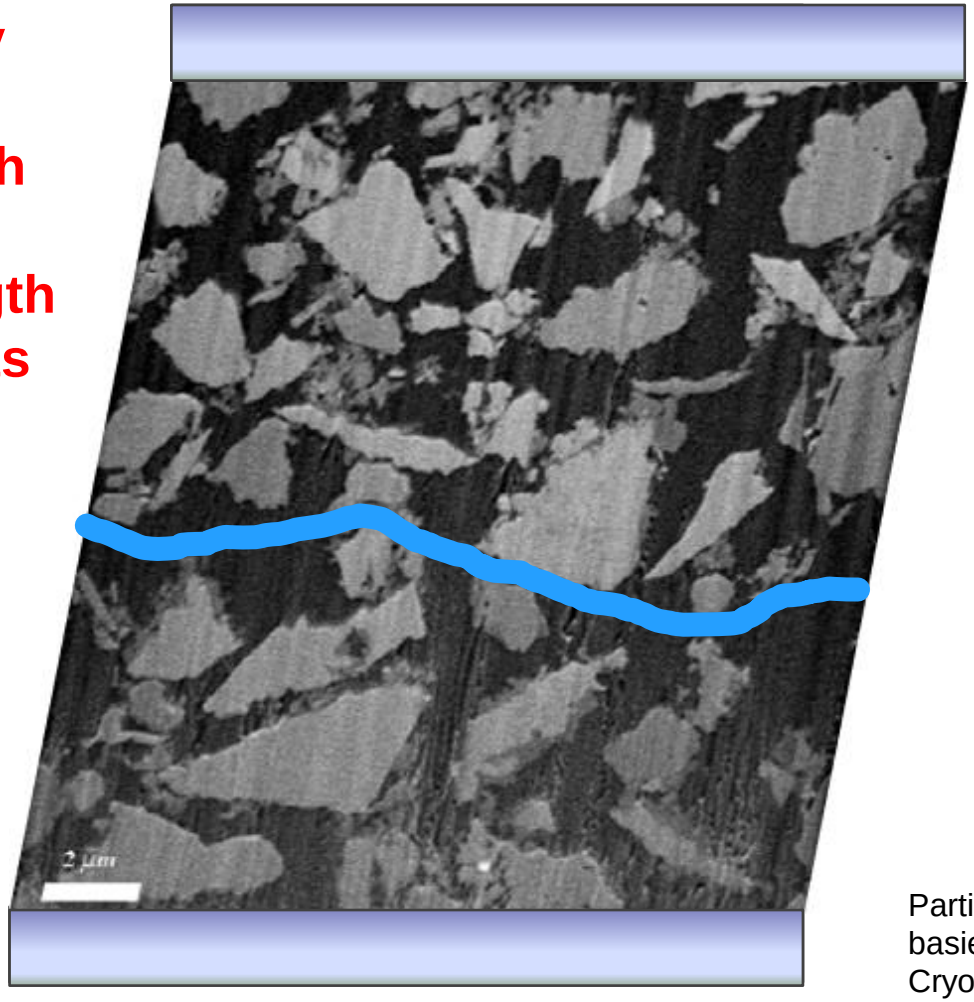


Thixotropy of cement-based suspensions



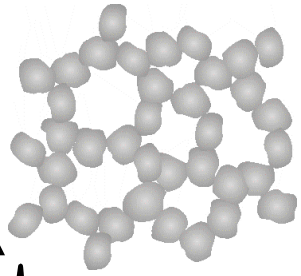
Microstructure in cement-based suspensions

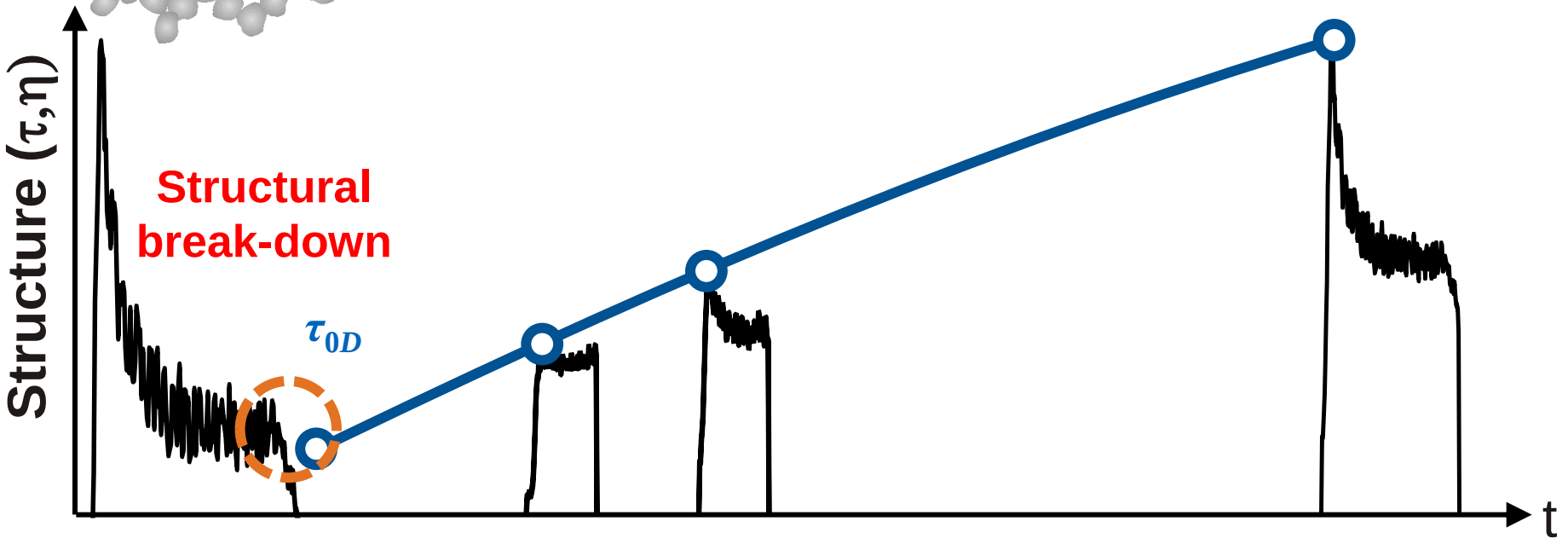
“Static” rheology
=
Structural strength
=
Number and strength of particle contacts

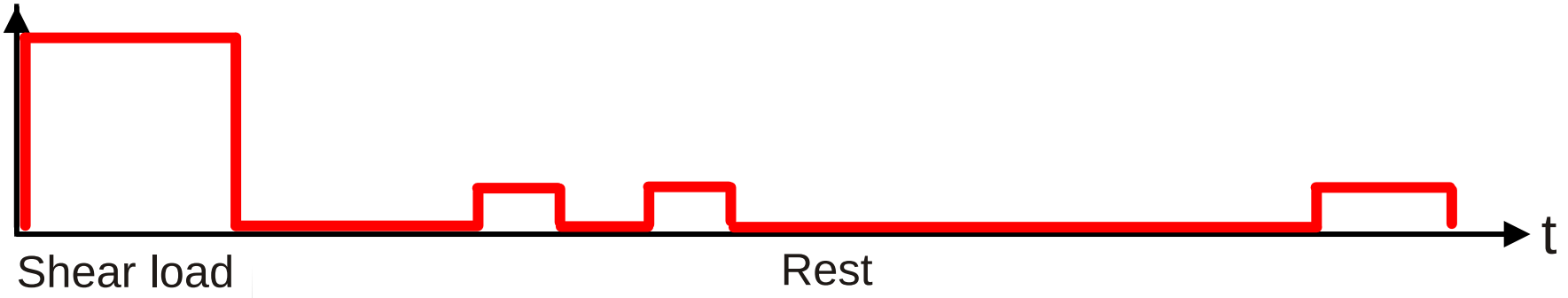


Particle structure in a cement-basied suspension.
Cryo-FIB-record
duration of hydratation: 24 min
Zingg [2008]

Microstructure in cement-based suspensions

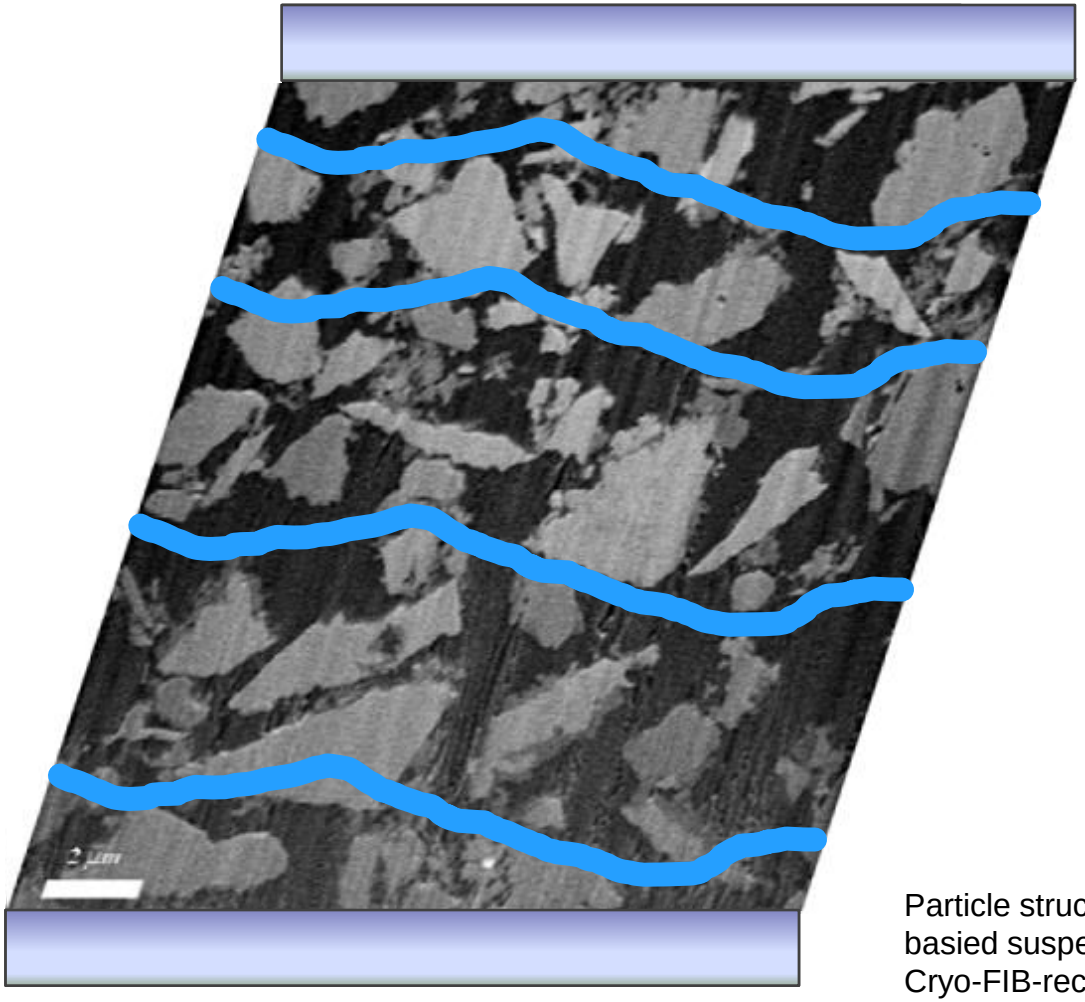






Microstructure in cement-based suspensions

Dynamic Rheology = Structural break-down



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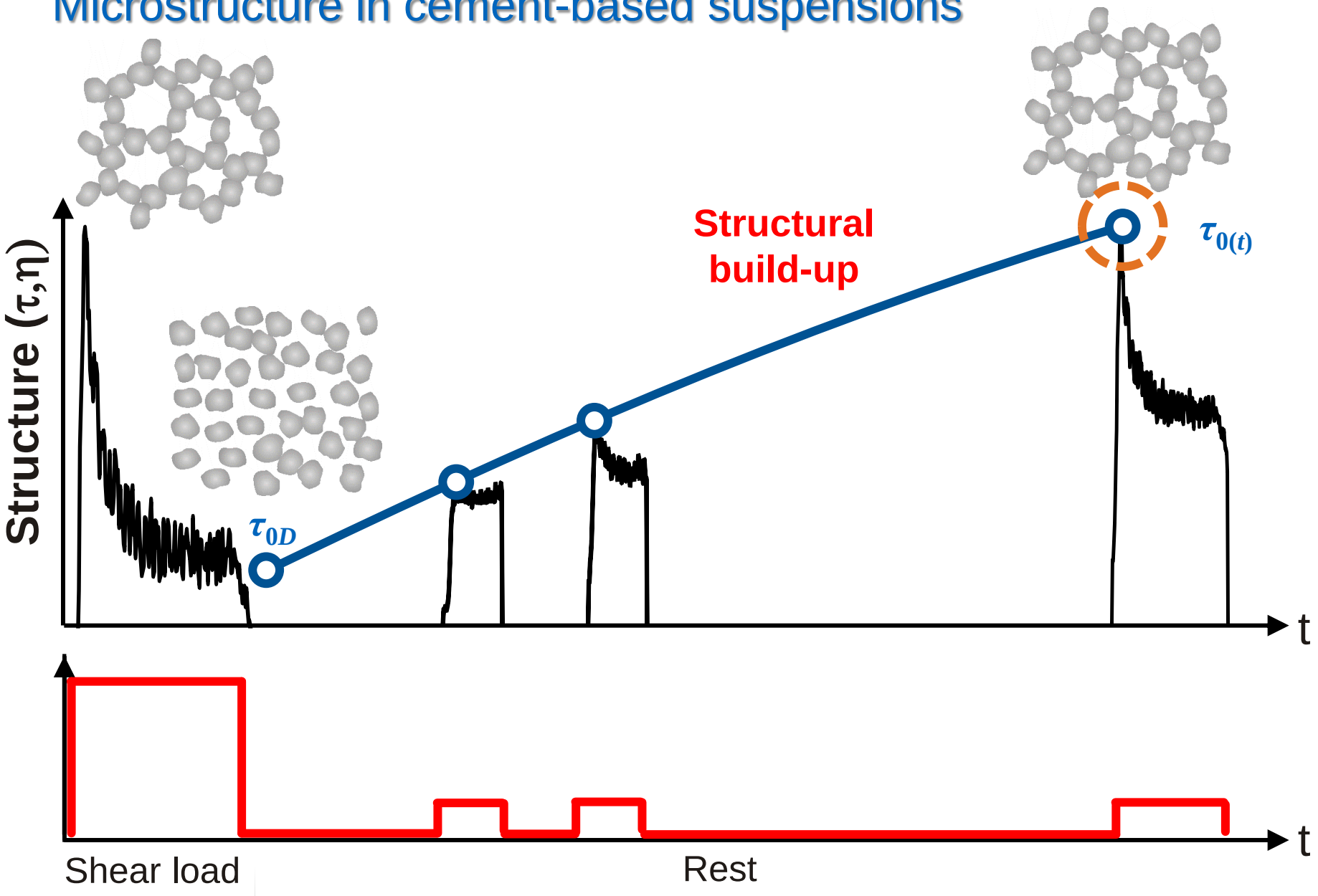


Structural build-up – Mechanisms and temporal progression

COLLOIDAL SURFACE INTERACTIONS

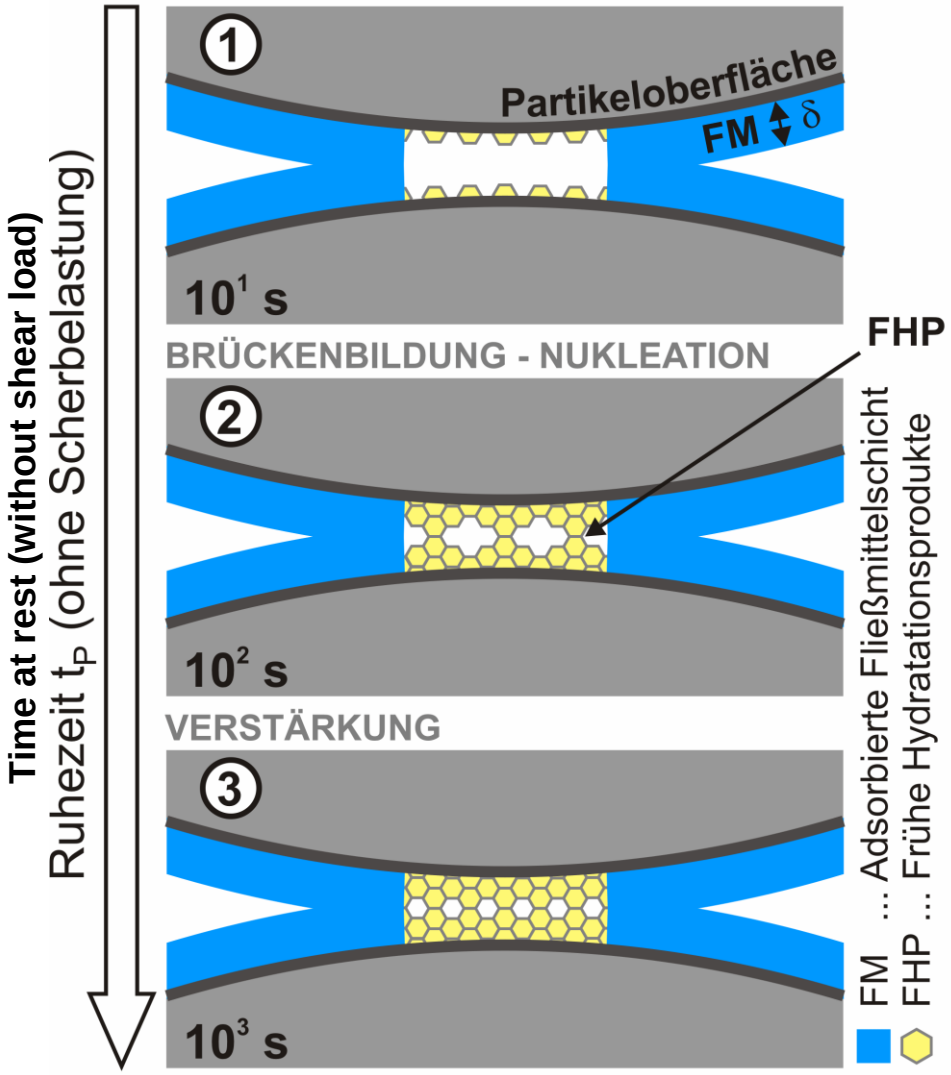
KOLLOIDALE OBERFLÄCHEN-WECHSELWIRKUNGEN

BRIGDING - NUCLEATION

BRÜCKENBILDUNG - NUKLEATION

STRENGTHENING

VERSTÄRKUNG



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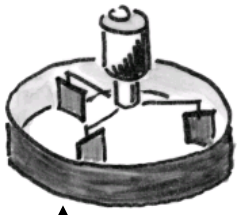
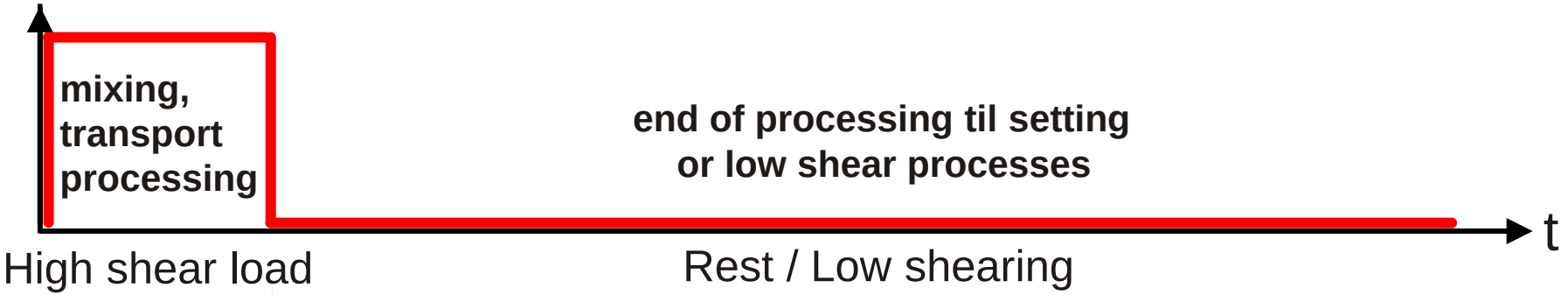
Microstructure during construction process



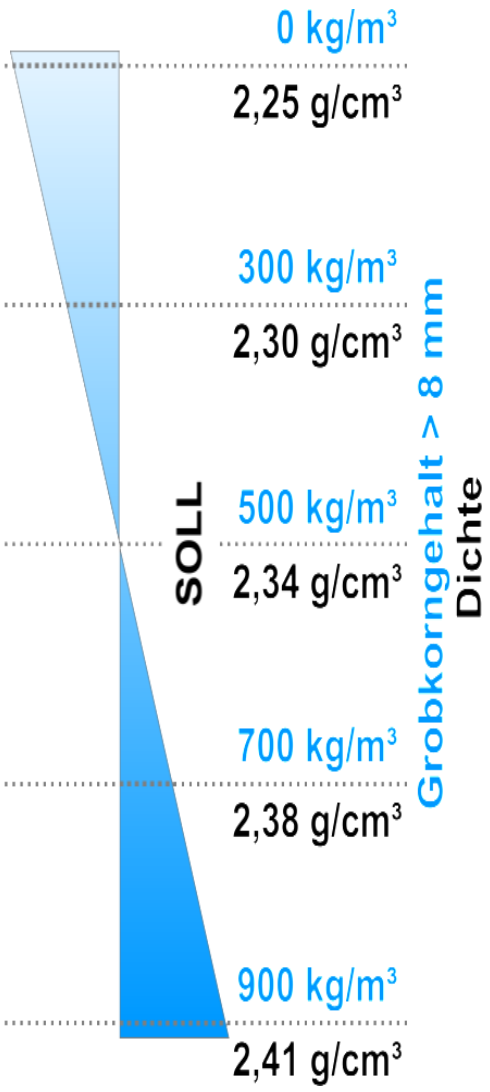
Structural break-down: Flow-ability

Structural build-up: **Segregation resistance**
Formwork pressure
Form-filling



Segregation resistance

Overdosage of water



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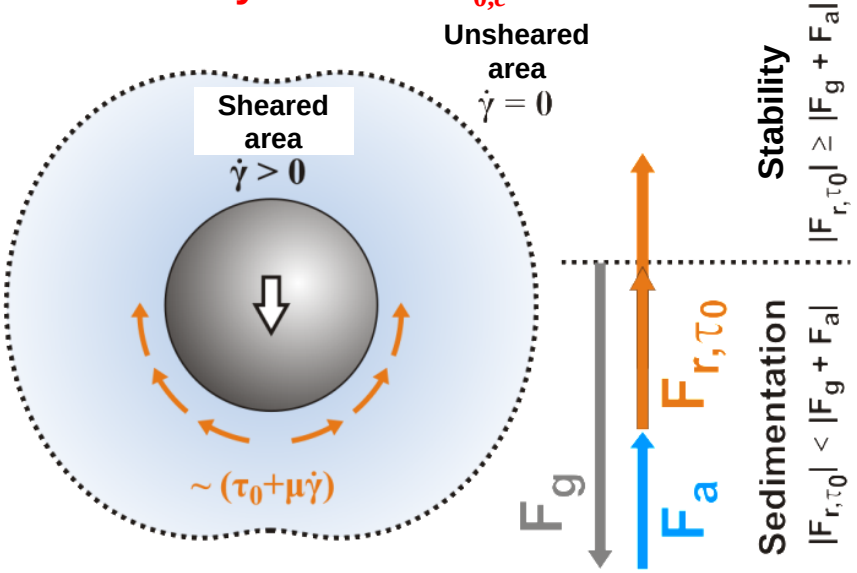
Theoretical Background

1. Stability criterion $\tau_{0,c}$:



$$F_m = F_g + F_a = V\,\Delta\rho\,g = \frac{\pi d^3}{6}\left(\rho_s - \rho_f\right)g$$

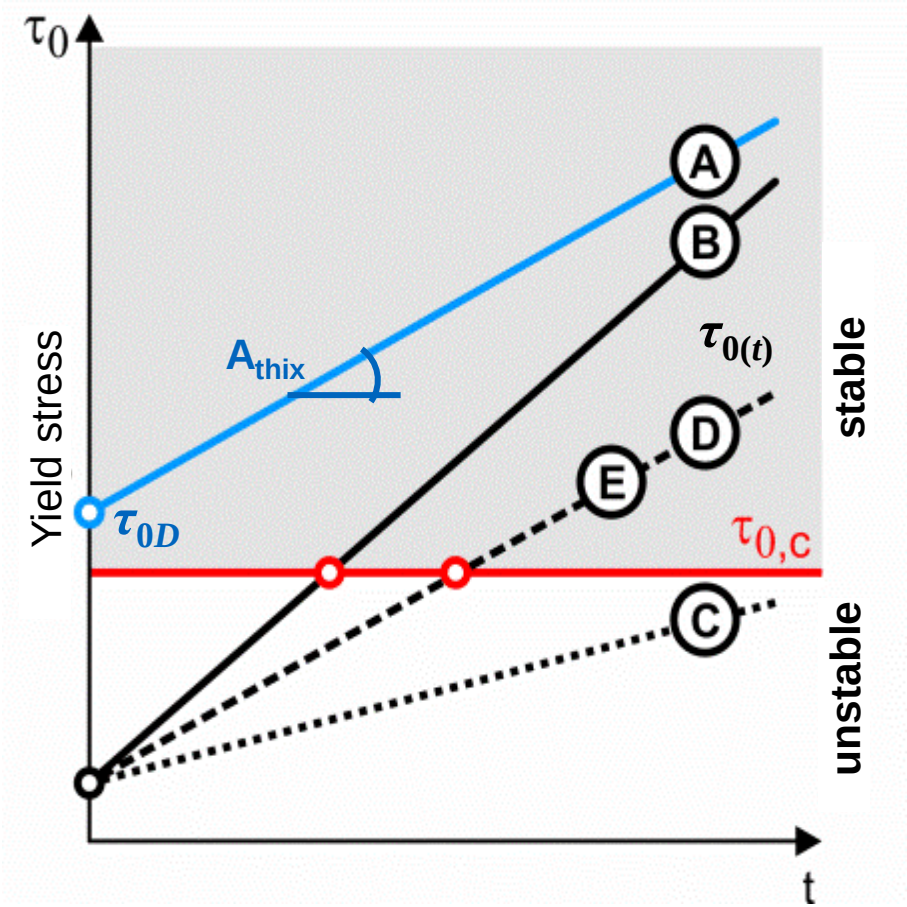
$$F_r = 3\pi\, d\, \mu\, v_s + 3\pi\, d^2\, \tau_0$$

$$\tau_{0,c} \geq \frac{d}{18}\left(\rho_s - \rho_f\right)g$$

2. Structural build-up $\tau_{0(t)}$

$$\tau_{0(t)} = \tau_{0D} + t \cdot A_{thix}$$

3. Strategies to ensure segregation resistance



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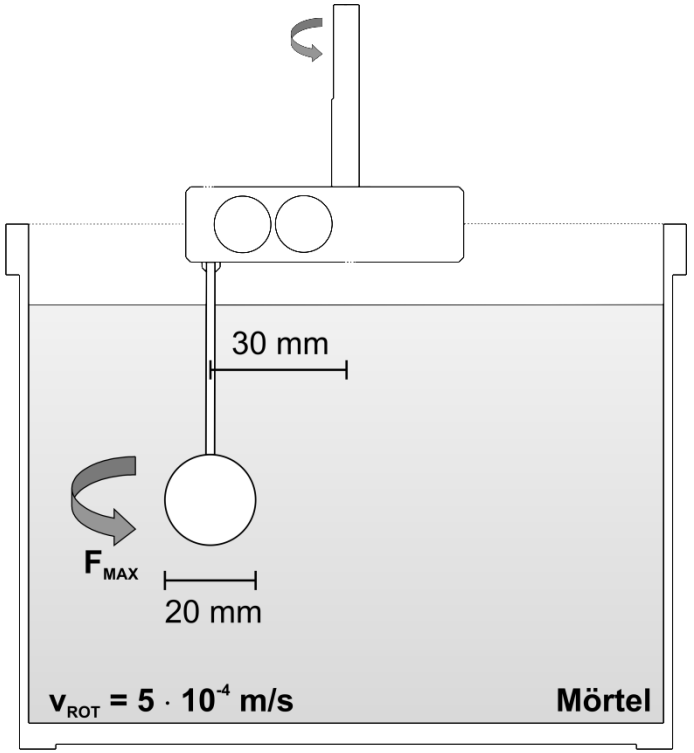
Rheology - Characterisation of Thixotropy



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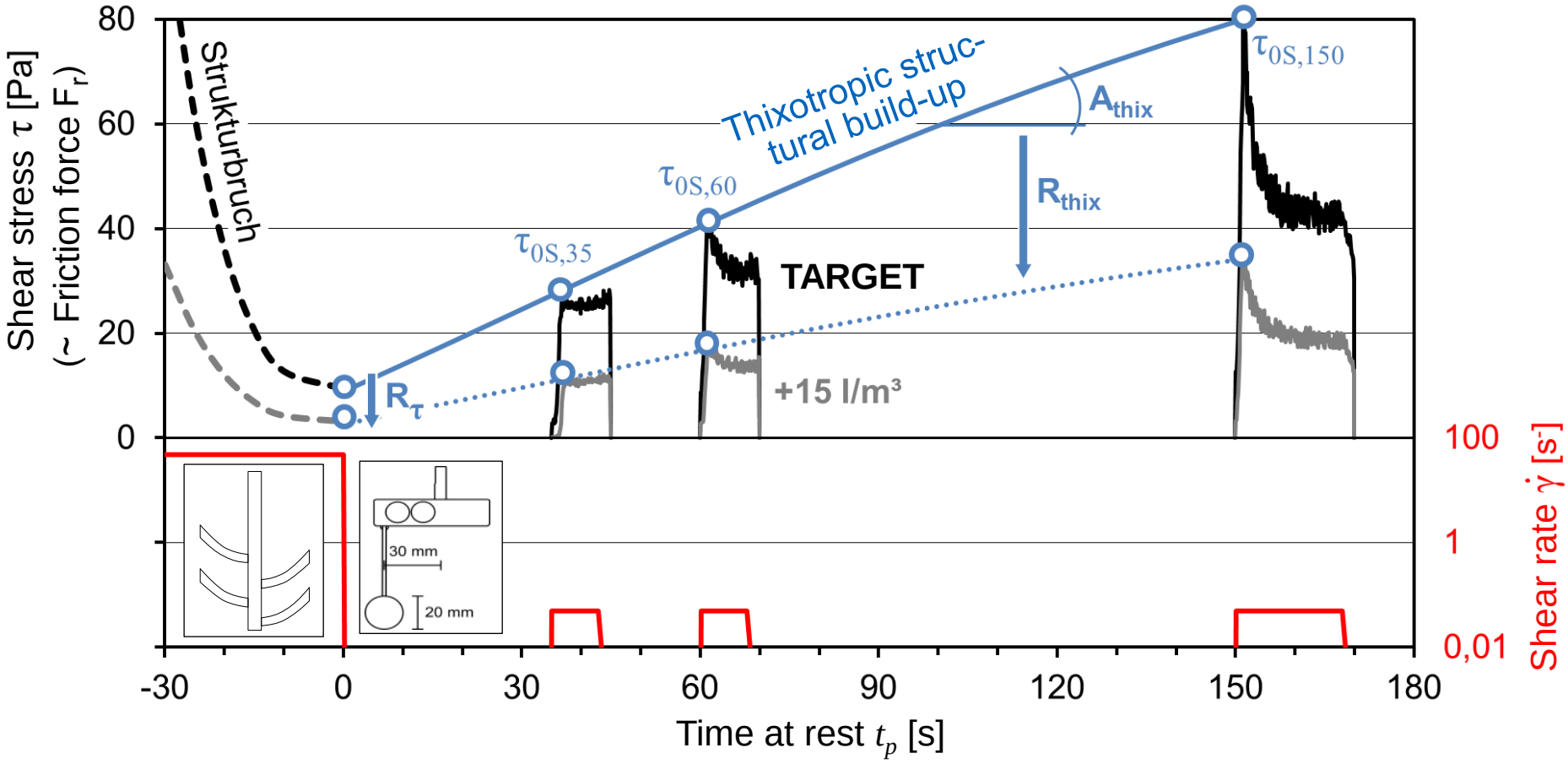

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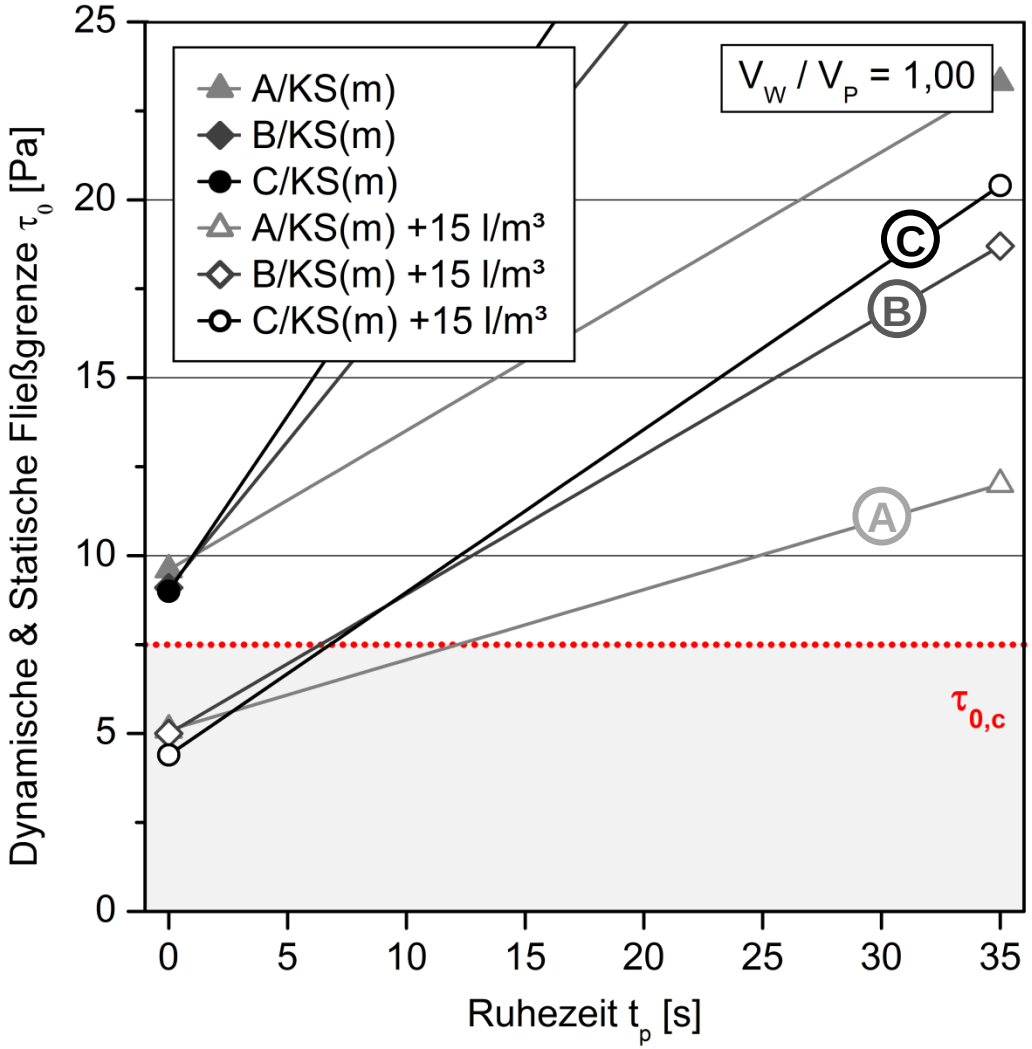
Variation Zusammensetzung Zement (Fließmittelbedarf)



FM(θ): A > B > C ► Thixotropie $A_{thix,C} > A_{thix,B} > A_{thix,A}$

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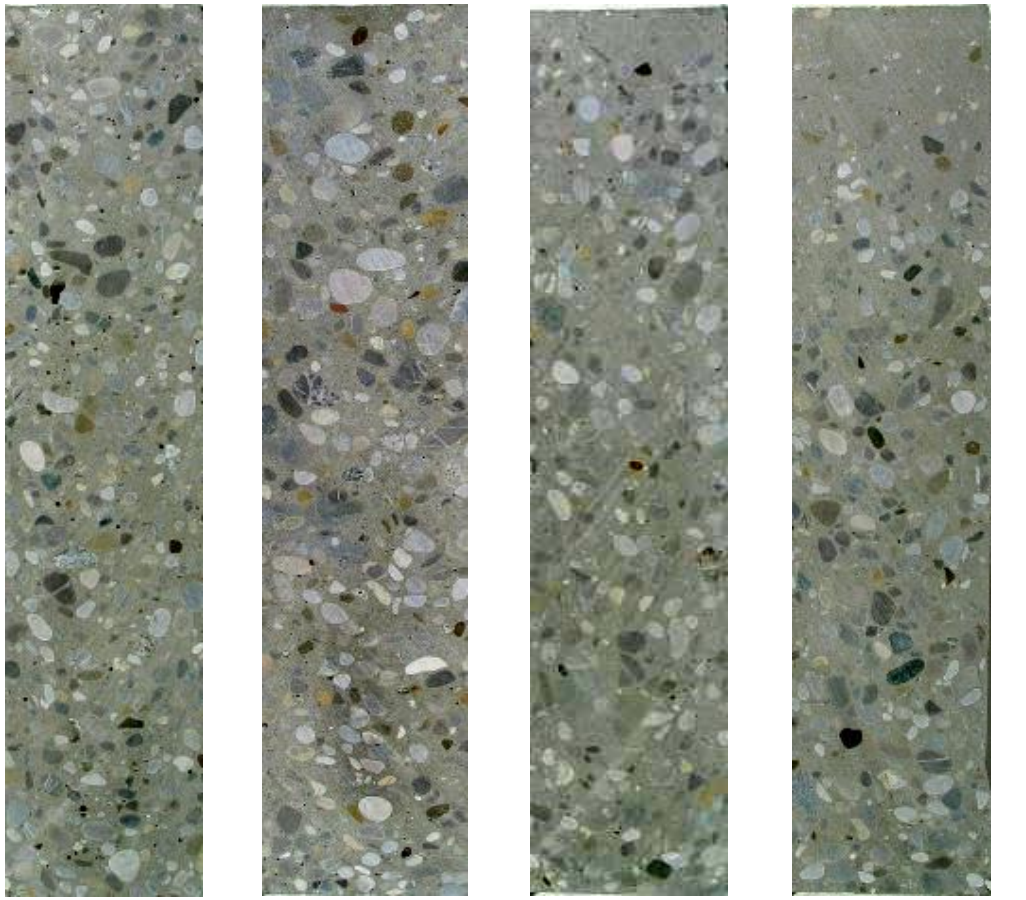
Cylinder-Sedimentation-Test

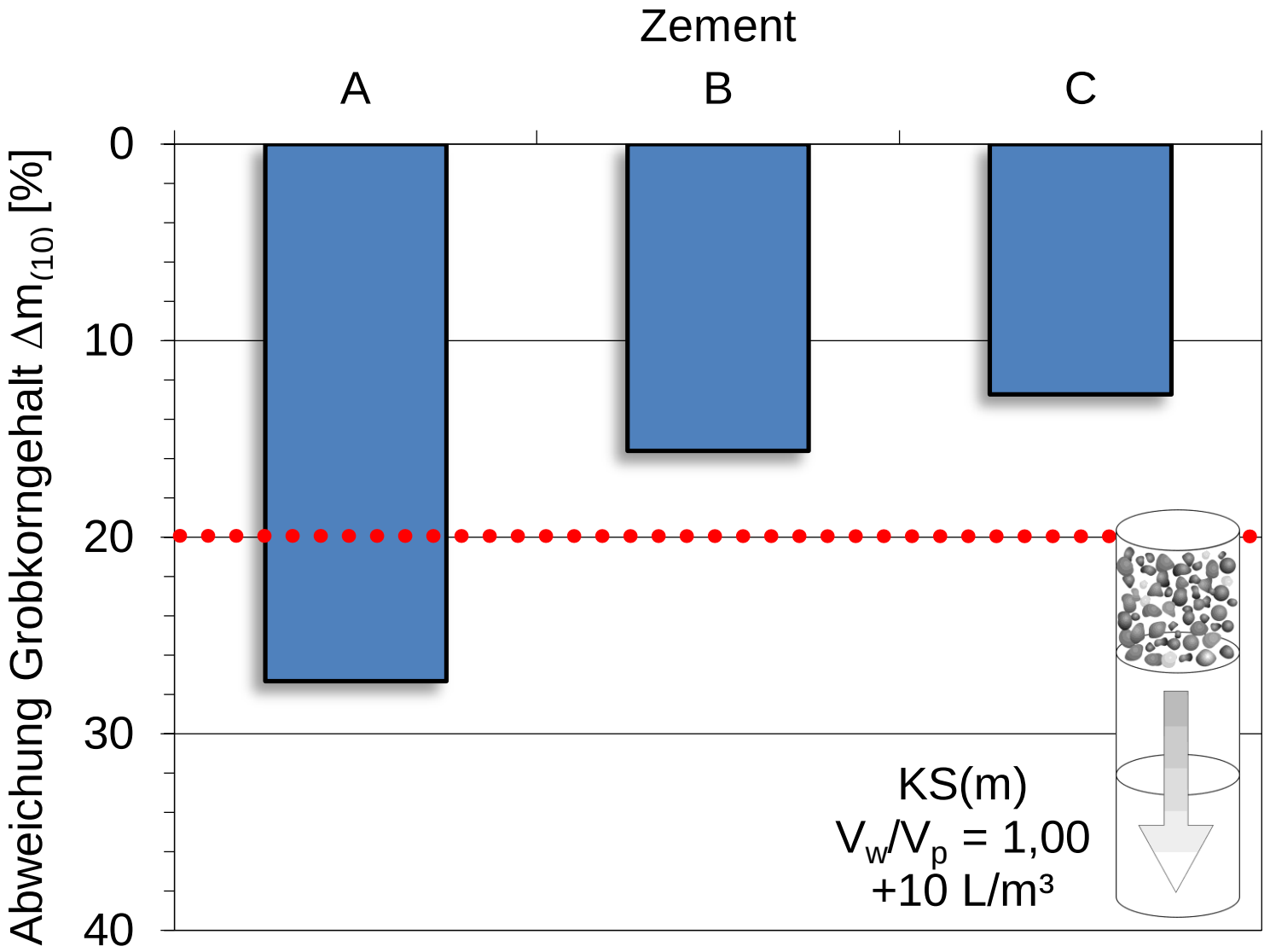
$$\Delta m = \max \left| 3 \cdot \frac{m_i}{\sum_{i=1}^{3} m_i} - 1 \right|_{i=1}^{3} \cdot 100 \quad [\%]$$



-5,0	-12,5	-22,0	-29,3

Δm [%]

Segregation of coarse aggregate in concrete



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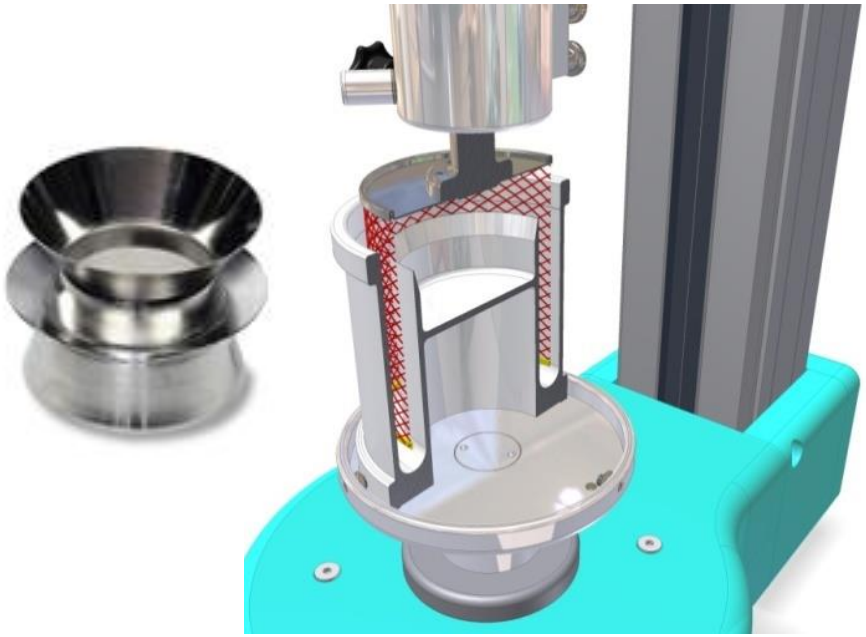
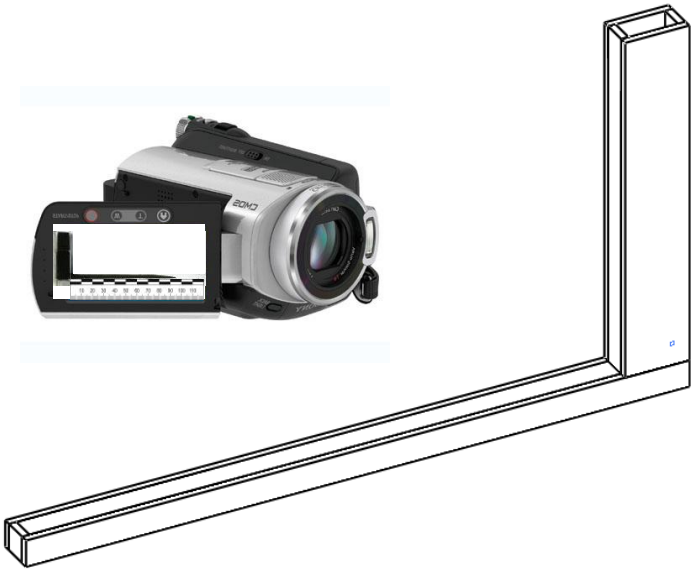
Form-filling properties

Experimental setup

Rheology



Form-filling



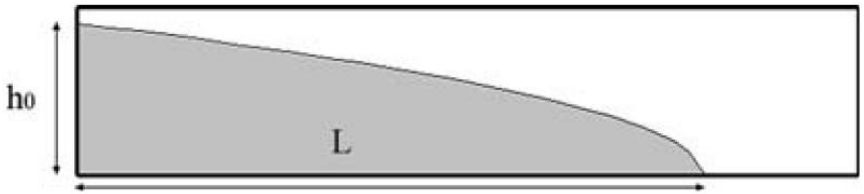
Concrete composition and yield stress

V_w / V_p	0,60*	0,65	0,60	0,55	0,47
V_{cement}	55 Vol.%	---------- 65 Vol.% ----------			
V_{quartz}	30 Vol.%	---------- 20 Vol.% ----------			
V_{paste}	---------- Constant ----------				
Slump flow	Constant at 70 ± 2 cm				
Yield stress $\tau_{0,4c}$	Constant at 13 - 18 Pa				

Flow distance in LCPC-Box for SCC [Roussel 2007]

$$V = l_0 \int_0^{h_0} x \, dh = \frac{l_0^4 \rho g}{2\tau_0} \left(\ln\left(1 + \frac{2h_0}{l_0}\right) + 0{,}5\left(\frac{2h_0}{l_0}\left(\frac{2h_0}{l_0} - 2\right)\right)\right)$$

$$L = \frac{h_0 \rho g l_0}{2\tau_0} + \frac{l_0^2 \rho g}{4\tau_0} \ln\left(\frac{l_0}{l_0 + 2h_0}\right)$$



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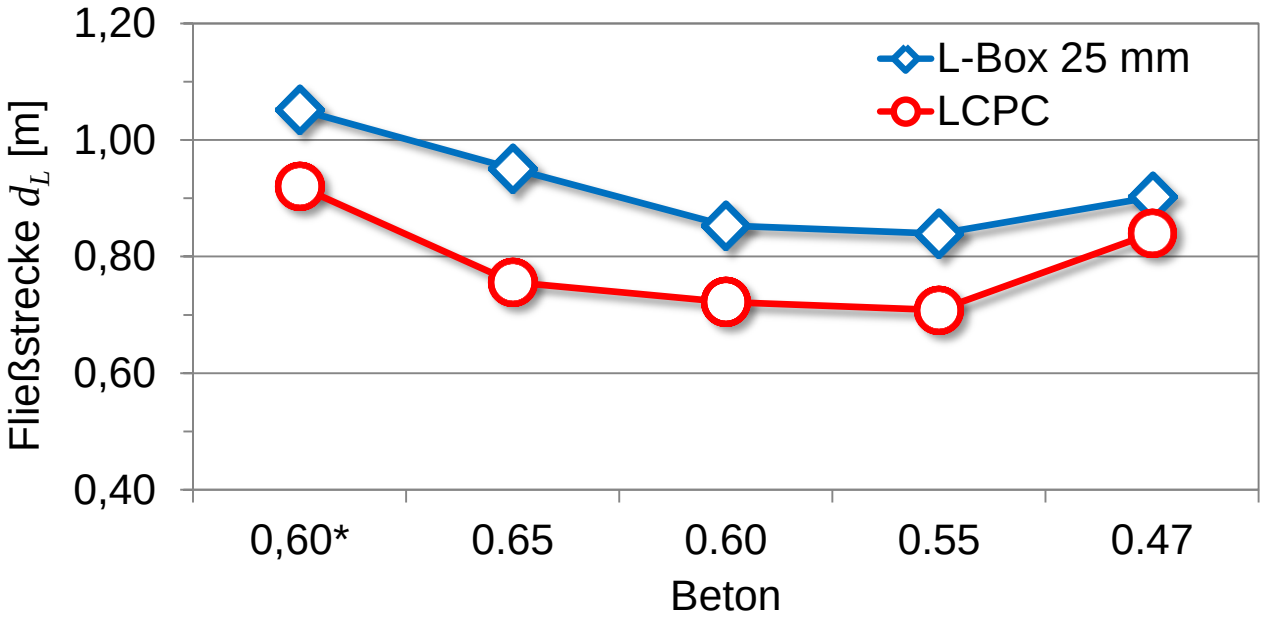

Effect of viscosity and thixotropy on form-filling - Theory

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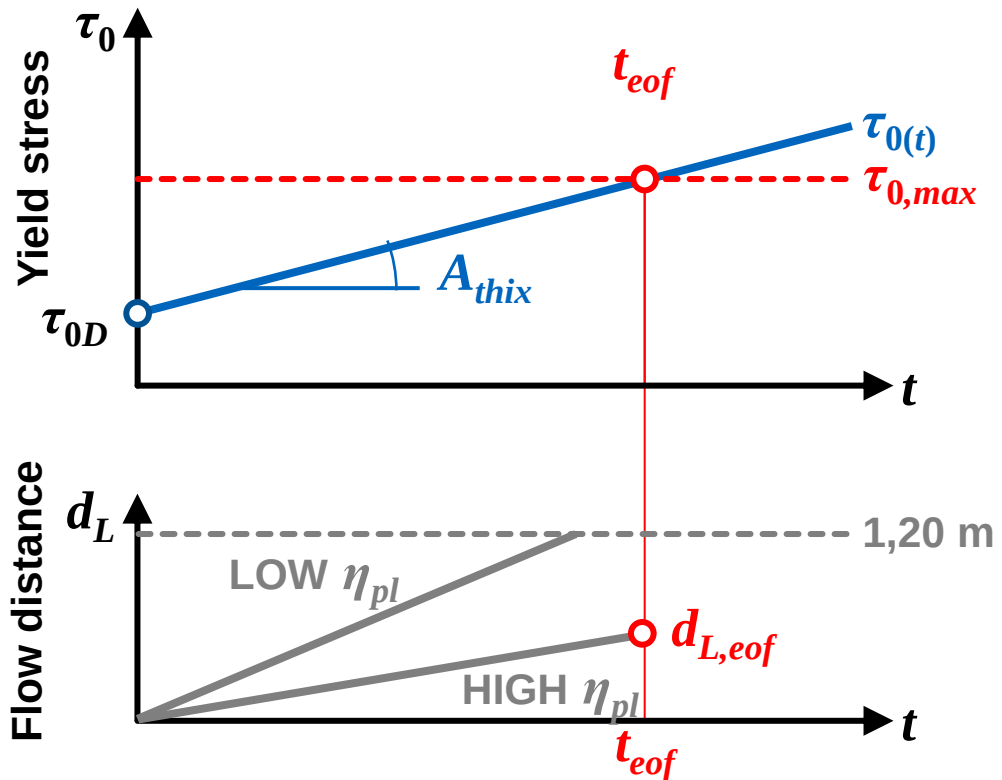
Yield stress $\tau_{0D,4c}$	Constant at 13 - 18 Pa				



1. Yield Stress - Flow condition :

$$\tau_0 = f(t) \overset{!}{<} \tau_{0,max}$$

2. Thixotropy - End-of-flow-time t_{eof} :

$$\tau_{0(t)} = \tau_{0D} + t \cdot A_{thix}$$

$$t_{eof} = (\tau_{0,max} - \tau_{0D}) / A_{thix}$$

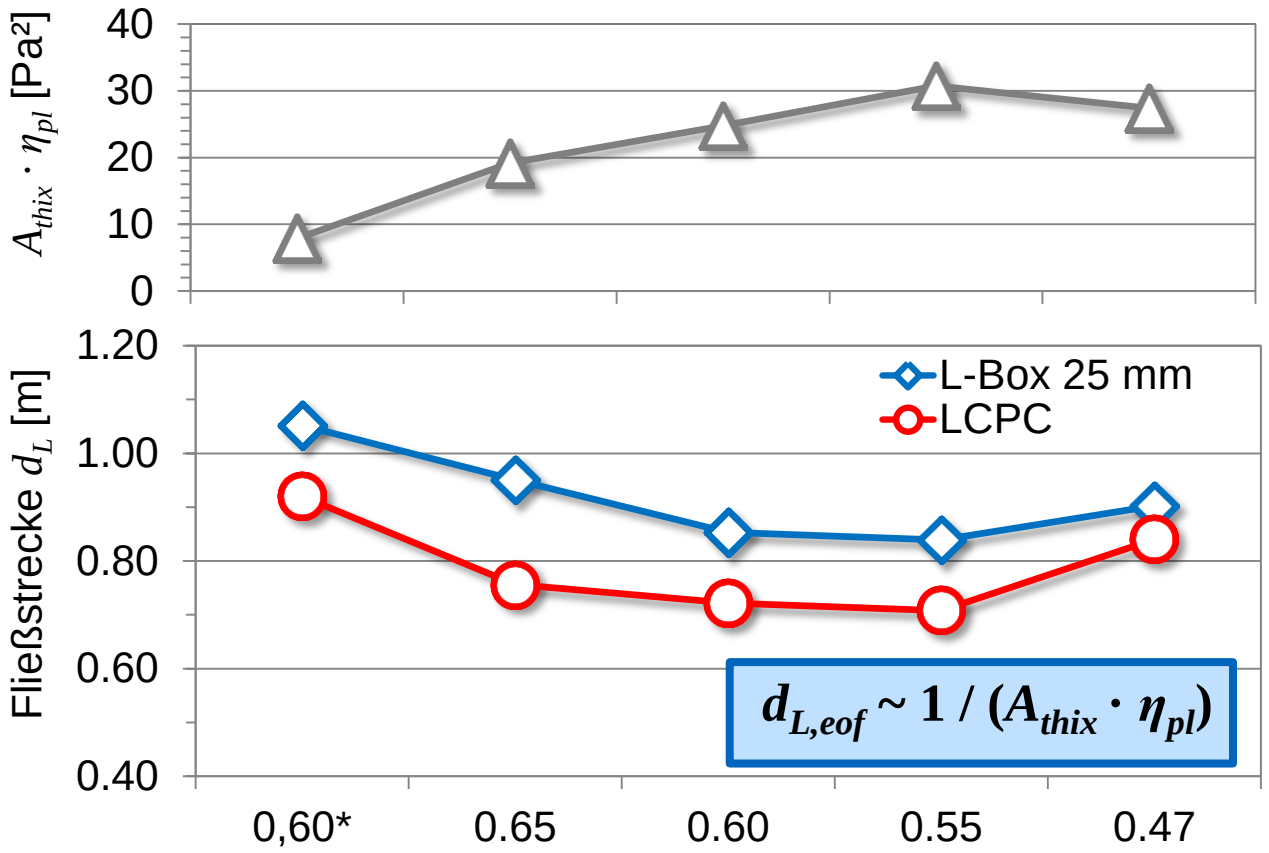
3. Viscosity - End-of-flow-distance $d_{L,eof}$:

$$d_{L(t)} \sim t / \eta_{pl}$$

$$d_{L,eof} \sim 1 / (A_{thix} \cdot \eta_{pl})$$

Effect of viscosity and thixotropy on form-filling - Results

V_w / V_p	0,60*	0,65	0,60	0,55	0,47
Yield stress $\tau_{0D,4c}$	Constant at 13 - 18 Pa				



Thixotropy is decisive for…

- **Form-filling of filigree structures**
- **Workability over long processing time**
  (e.g. deep foundation concrete)
- **Segregation resistance**
- **Formwork pressure**

As well as

- **Rheological measurements**
  (constant time span between structural breakdown and start of measurement)

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