25th Conference on Rheology of Building Materials
Regensburg, March 2016

Application of Rheology to Characterize the Stability of Mortar Compositions under Vibration

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Outline

- Background Information
- Objective of Research
- Research Methodology
- Investigation Results
- Discussions
- Conclusions

Modern Engineering Structures

- **Complex geometries, slender structural elements and dense reinforcements**

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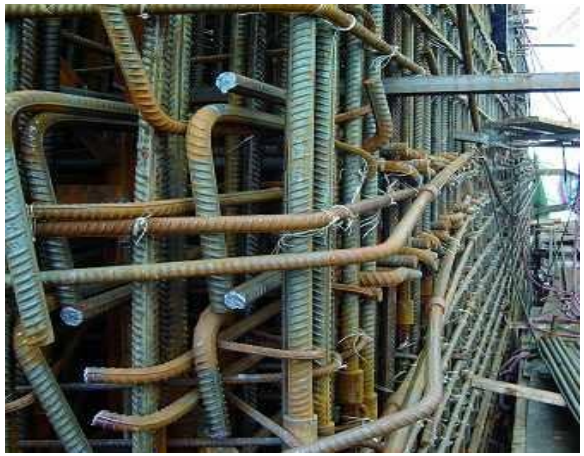
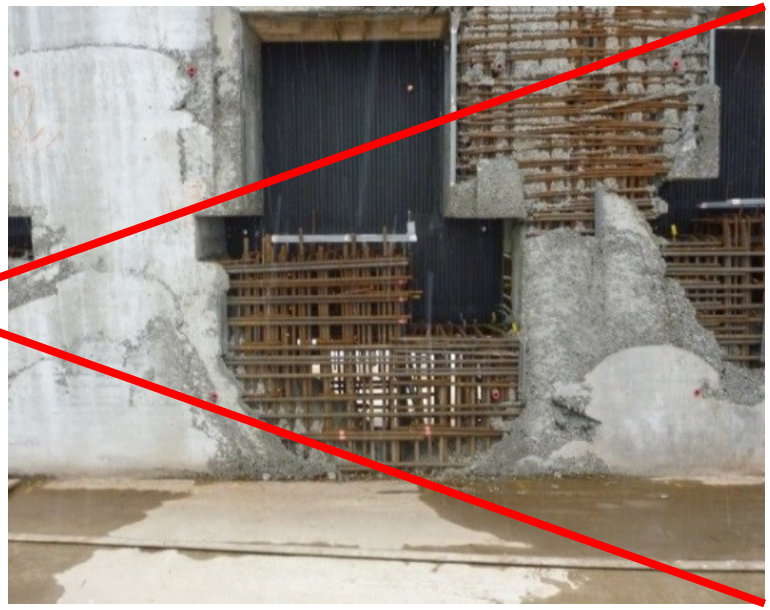


Normal Concrete?

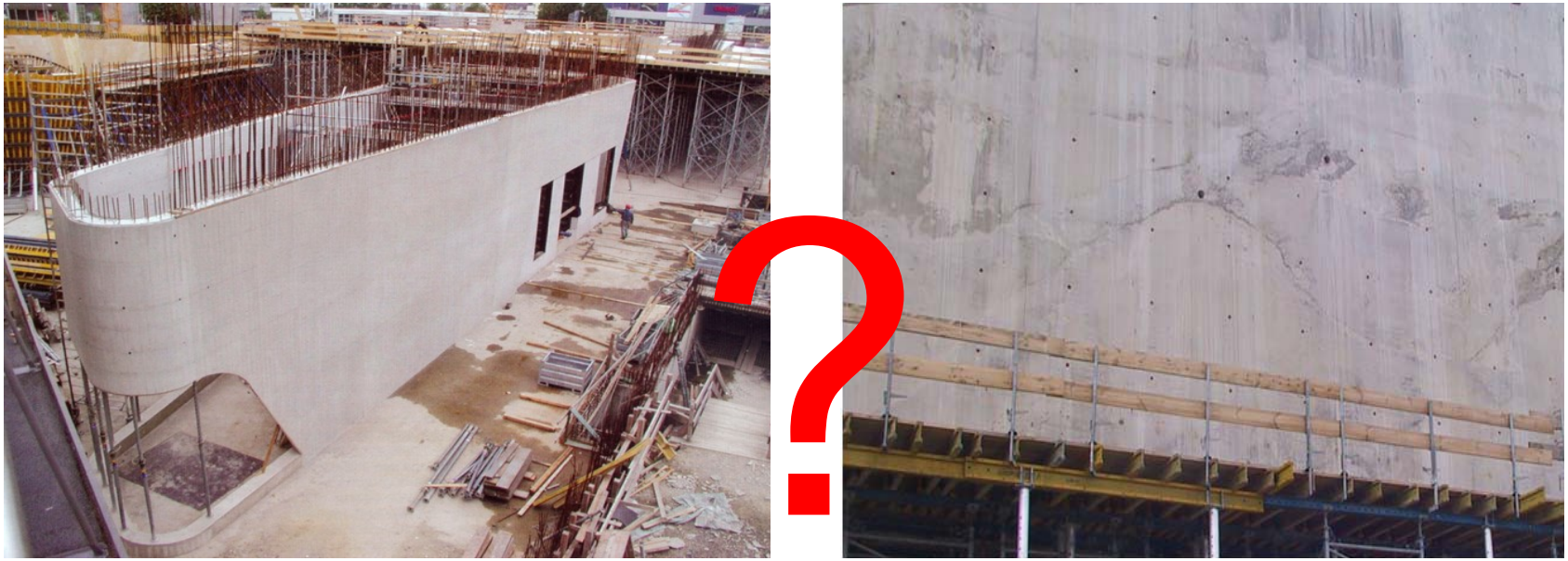


© Antrag AiF: Fließfähige Betone mit erhöhter Pump- und Rüttelstabilität

- Poor workability ⇒ Problems with formwork-filling
- Poor durability due to inadequate concrete cover
- Poor bondage between reinforcements and the concrete itself

Solutions: SVB?

- **In principle YES, but…**



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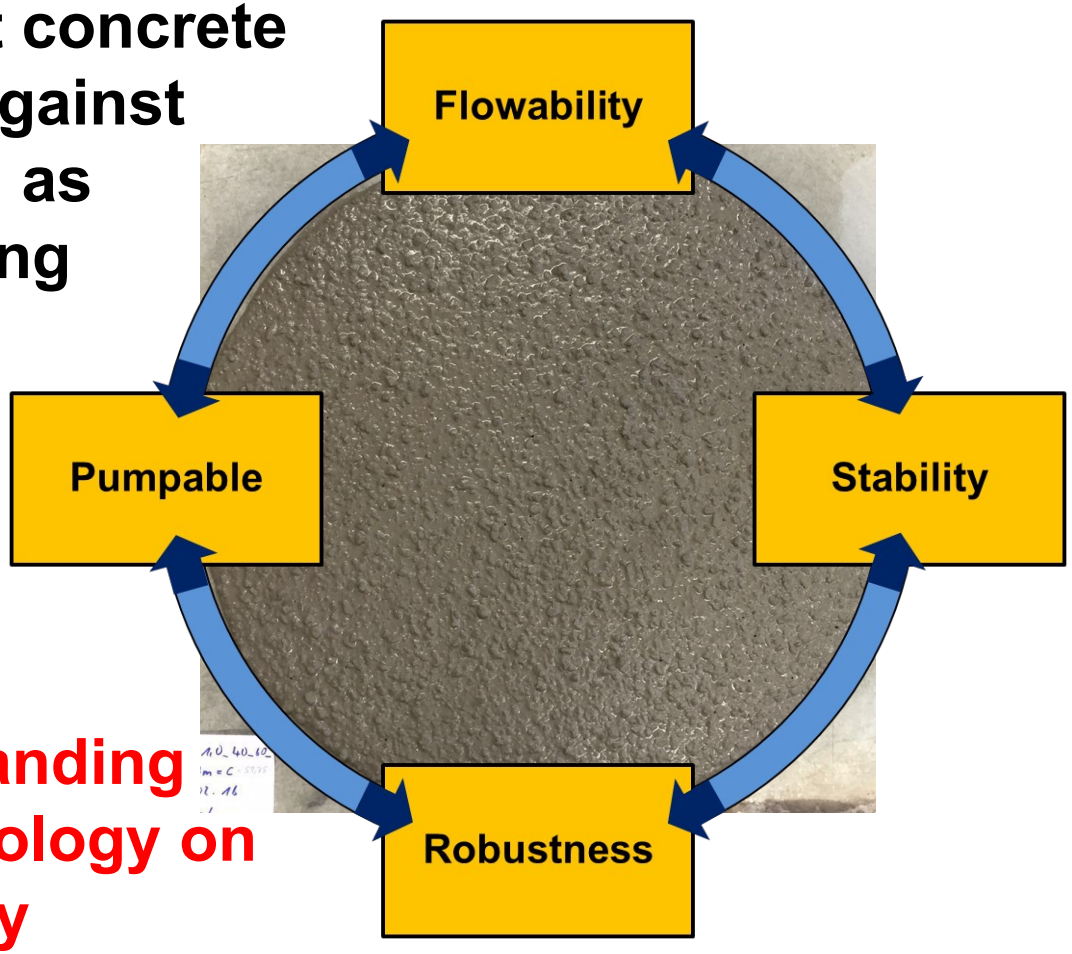
- Meticulous mix-design ⇒ poor robustness
- Current market share < 2,0 %
- Expensive

The Perfect Solution

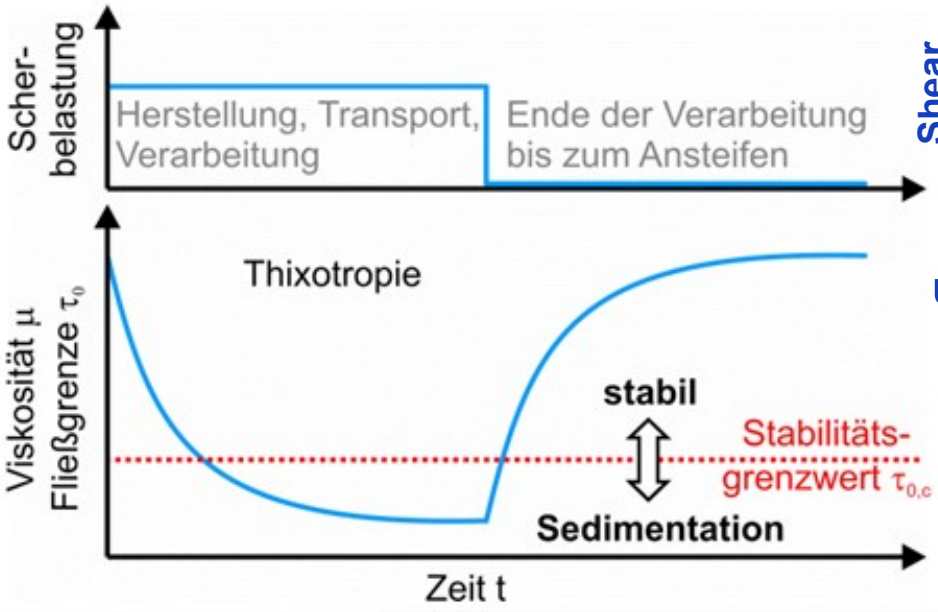
- **Flowable and robust concrete with good stability against external forces such as vibration and pumping**



- **No holistic understanding of the effects of rheology on the dynamic stability**

Rheology in SCC and FVC

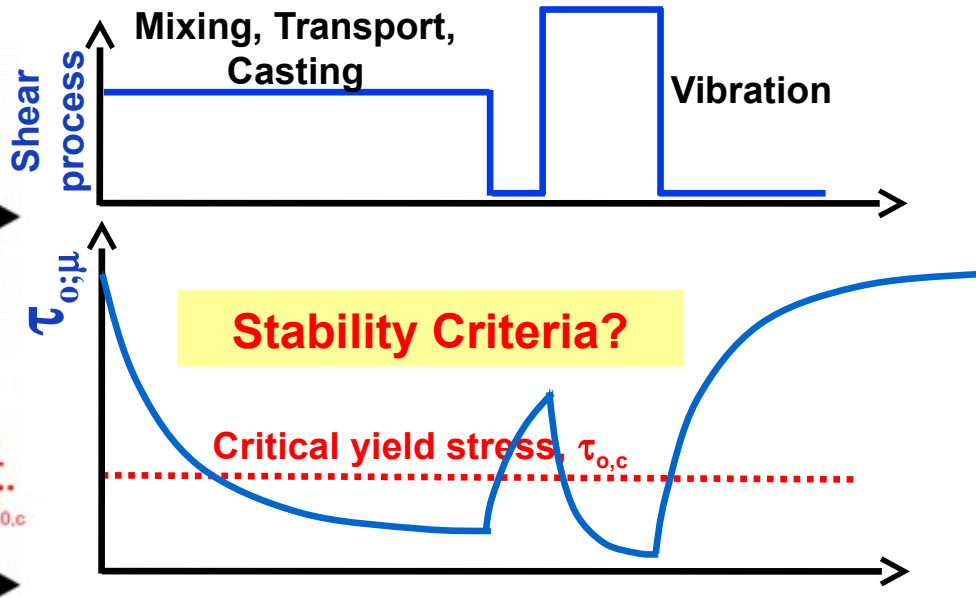
Self Compacting Concrete **SCC**



Source: Dissertation (Löwke, 2013)

- $\tau_o \geq \tau_{o,c} \Rightarrow$ No sedimentation
- $\tau_o < \tau_{o,c} \Rightarrow$ rapid structure build-up to limit sedimentation

Flowable Vibrated Concrete **FVC**



Source: Dissertation in progress (Yared Abebe 2016)

- $\tau_{o,\,vib} \approx 0 \Rightarrow \tau_{o,c}$ is inadequate
- Structural breakdown and the corresponding rheological phenomena is relevant

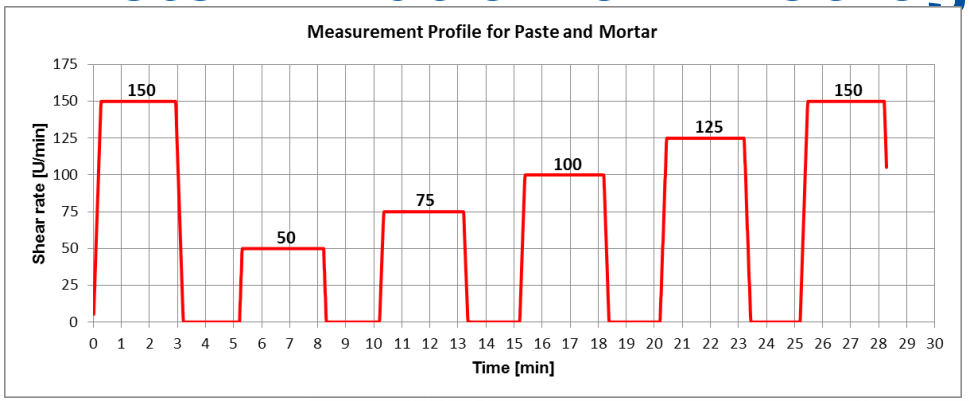
Objective

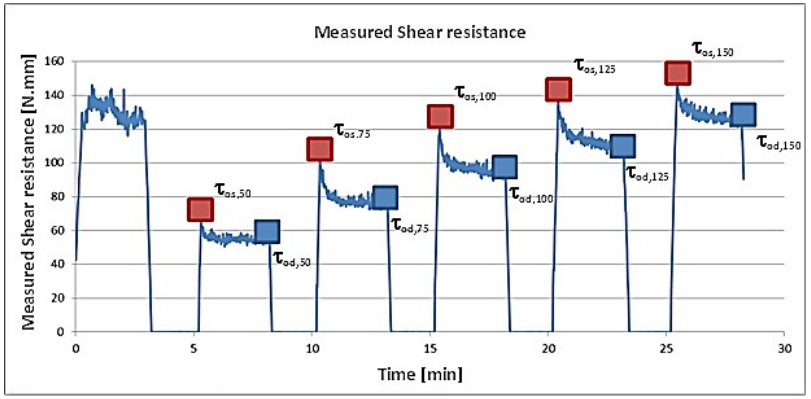
- **Introduction of a new method for the determination of the rheological parameters (yield stress, viscosity and thixotropy) during structural breakdown.**
- **Investigation of the effects of paste compositions on the stability of mortar under vibration**
- **Explaining the stability properties of mortar compositions based on the rheological characteristics of paste**
- **Defining stability criteria by making use of rheological parameters**

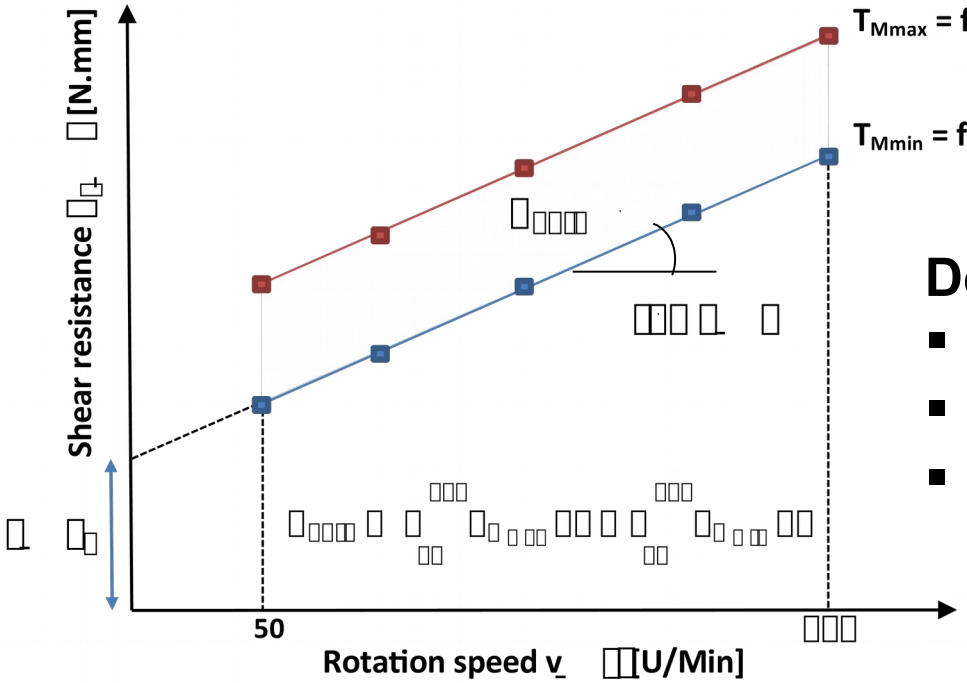
Determination of Rheological Parameters

Viskomat NT

Determination of Rheological Parameters



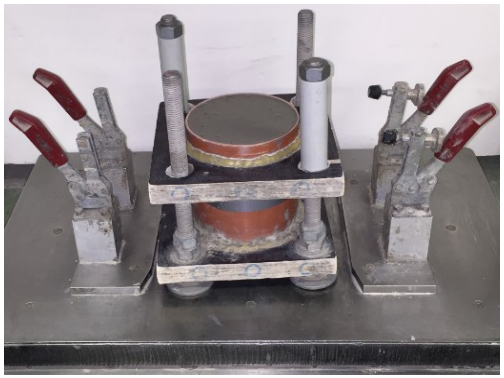




Determination of

- **Yield stress (τ_0)**
- **Viscosity (μ)**
- **Thixotropy (A_{thix})**

Investigation of Stability under Vibration



Vibrated mortar
30 sec.

Sieve test

Wash-out test

Penetration test

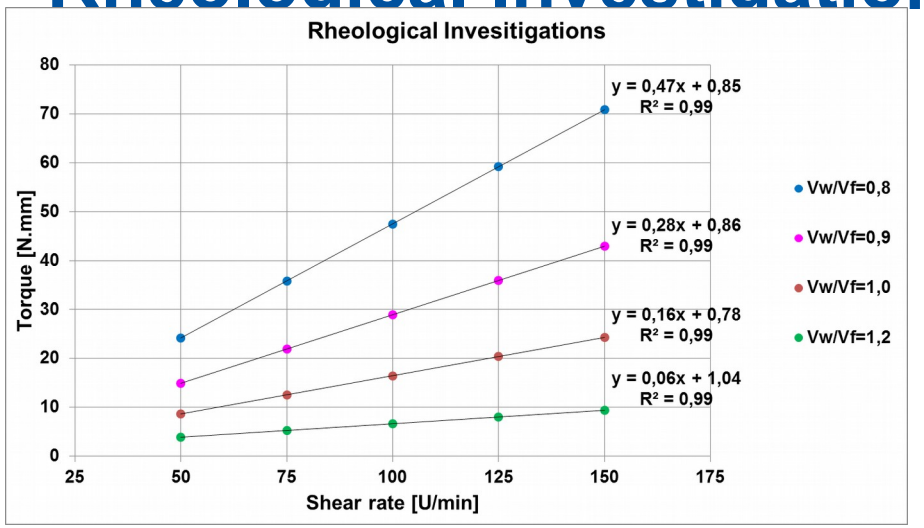
Materials and Mixtures

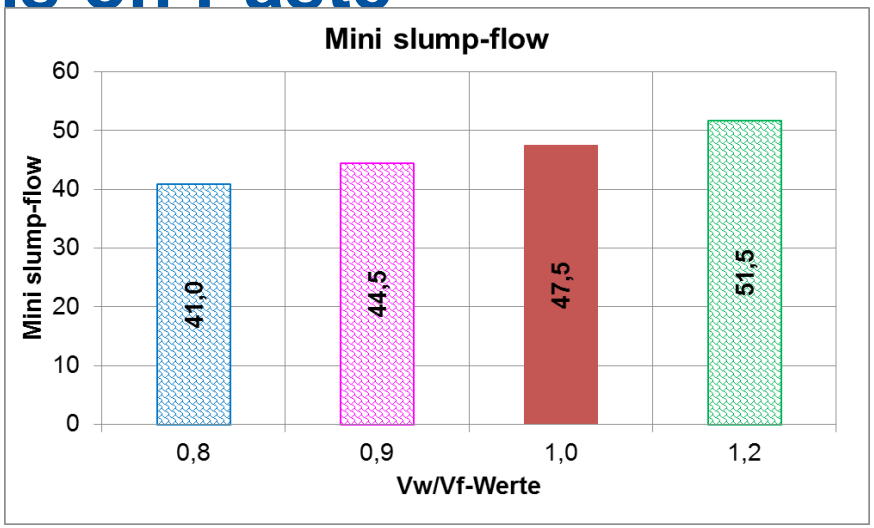
- **Paste Compositions (see Table)**

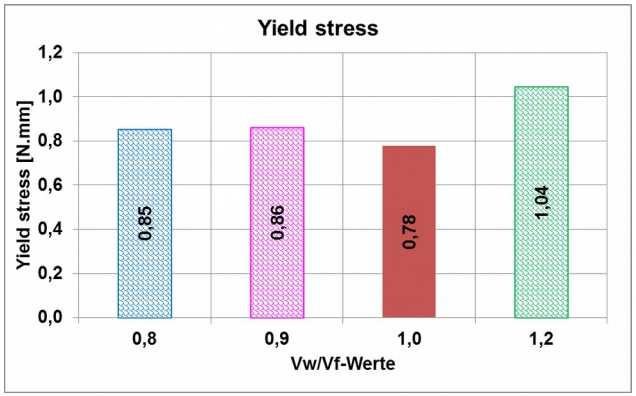
Material type	Sp. gr. (kg/dm³)	w/c = 0.6			
		$V_W/V_F = 0.8$	$V_W/V_F = 0.9$	$V_W/V_F = 1.0$	$V_W/V_F = 1.2$
CEM I 42.5 N [ml]	3.13	232.2	247.5	261.2	285
Fly ash [ml]	2.31	315	270.9	231.3	162.7
Water [ml]	1.0	437.8	466.6	492.5	537.3
Air voids [ml]	-	15	15	15	15
SP [% of water]	1.05	5.41	5.41	5.41	5.41

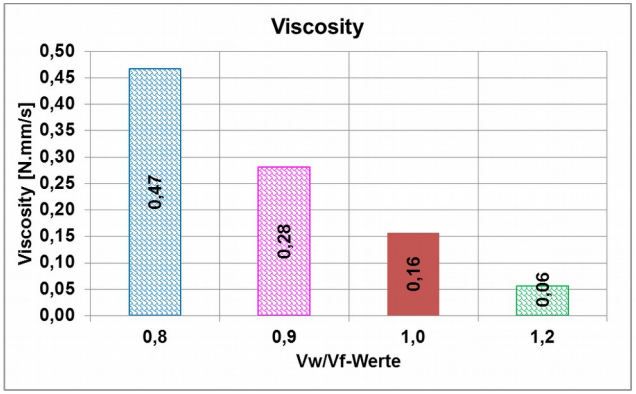
- **Mortar compositions: with constant sand volume of 45.6%.**

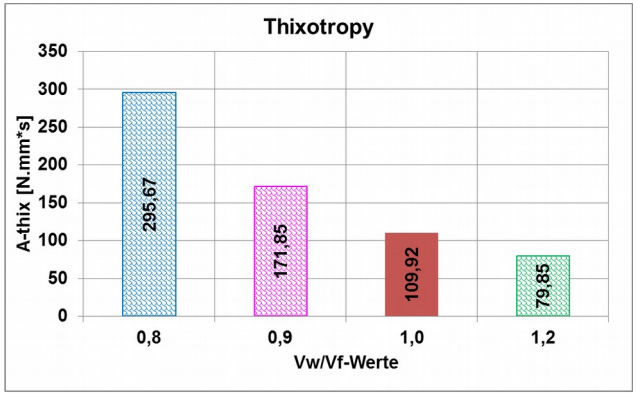
Rheological Investigations on Paste





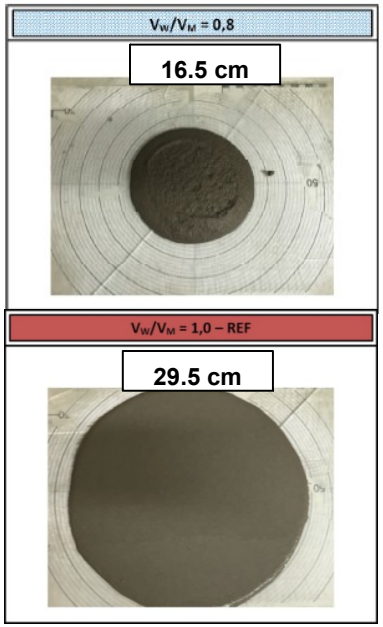


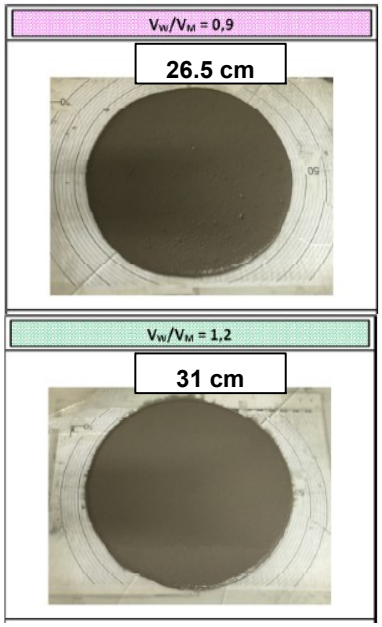


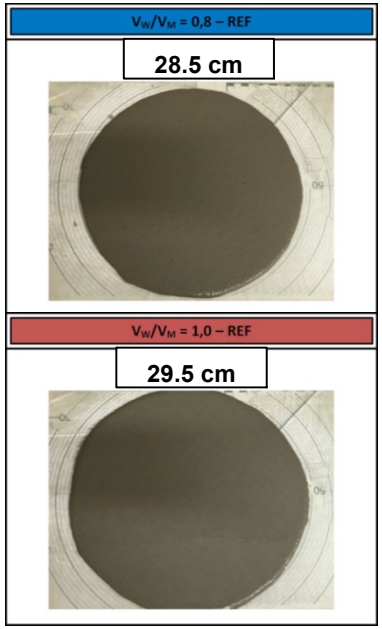


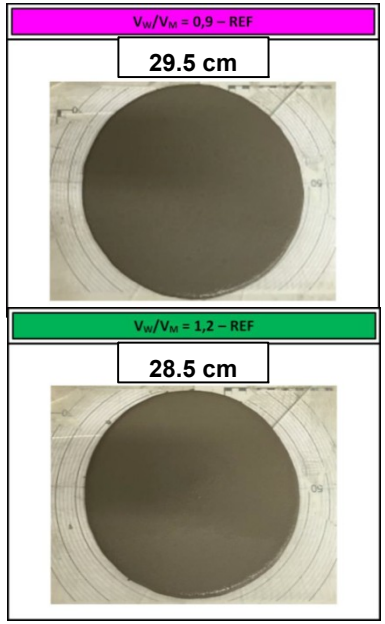
- **The viscosity and the residual interparticle structure are the relevant rheological properties during a structural breakdown process.**
- **The yield stress has no significant role.**

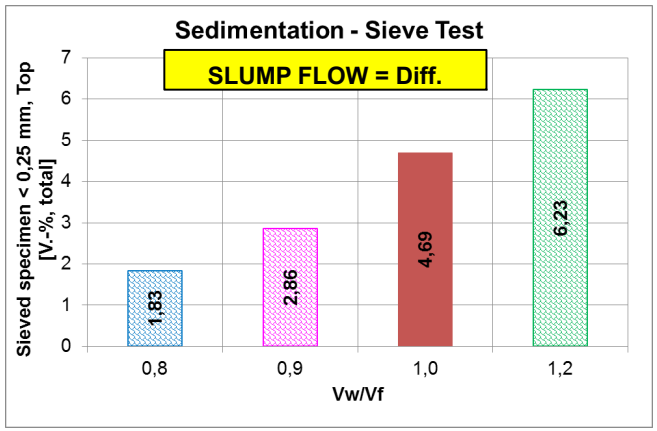
Sieve Stability Investigations on Mortar (vibrated)



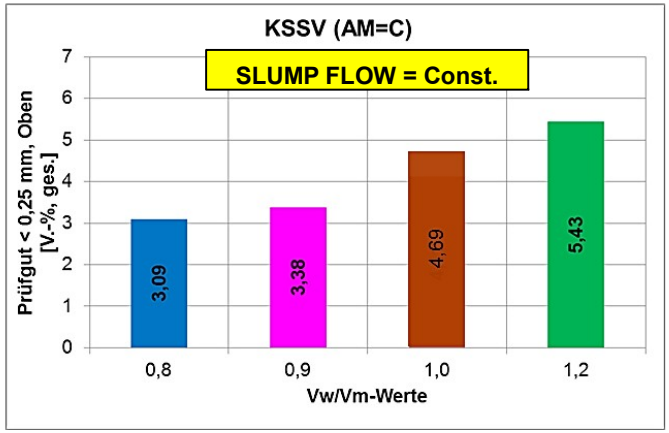




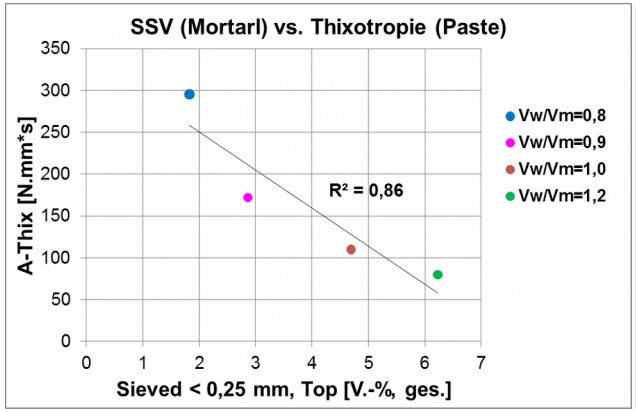


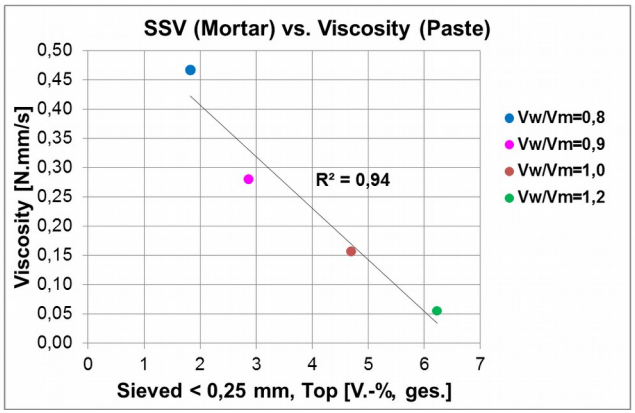


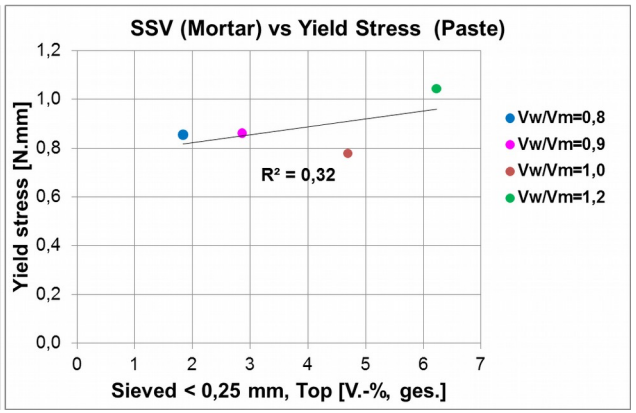
Similar Trend



Relationship between Stability and Rheology

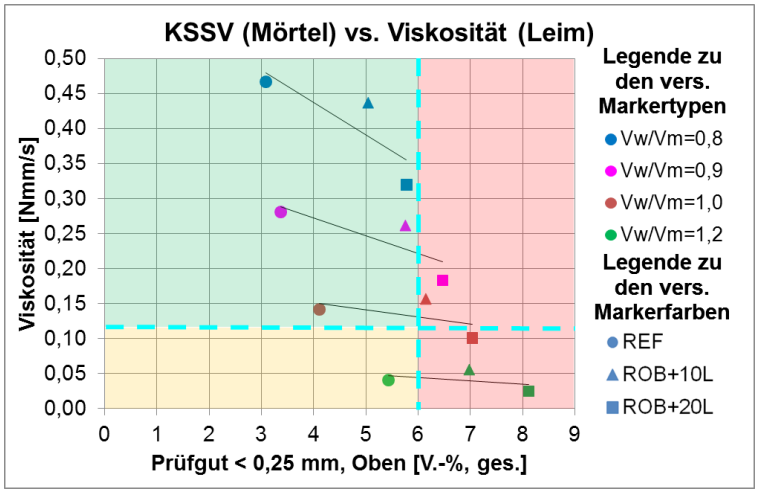


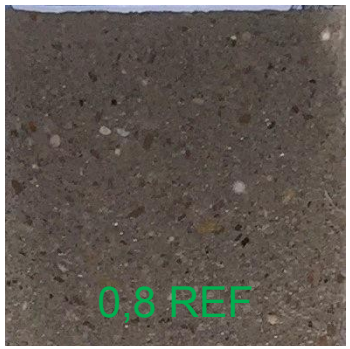


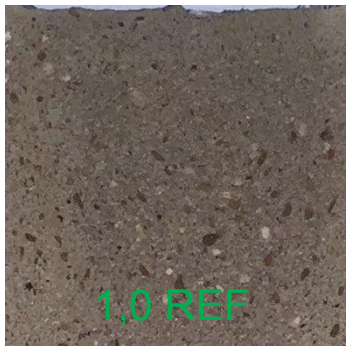


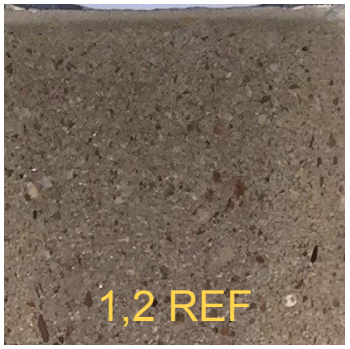
- **The stability of mortar under vibration depends directly on the viscosity and the residual interparticle structure of the paste.**
- **The yield stress has no mentionable contribution to the stability.**

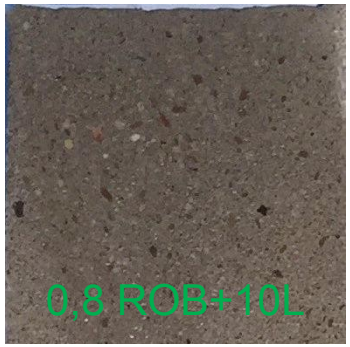
Stability Criteria based on Sedimentation of Mortar (vibrated)

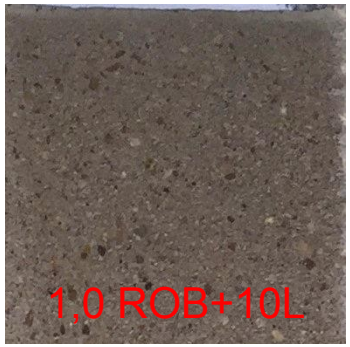


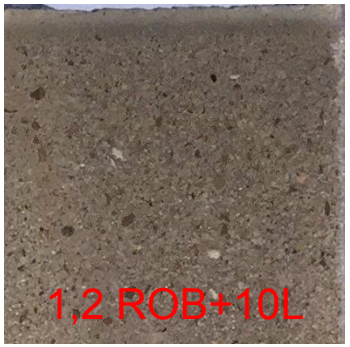


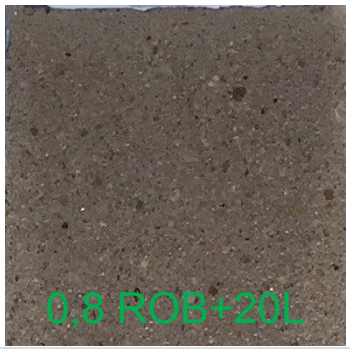


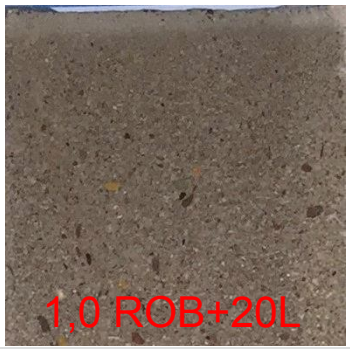


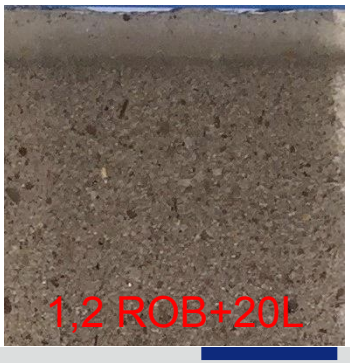












Green – stable zone
Yellow – critical zone
Red – No-go zone

Conclusions

- **The new measurement method makes it possible to determine the yield stress, viscosity and the thixotropic properties of cement based mixtures.**
- **Rheological investigations that are based on structural breakdown are adequate to explain dynamic stability of cement based materials.**
- **The stability properties of mortar compositions depends on the viscosity and the residual inter particle structure of the paste. The yield stress plays a no significant role.**
- **There exists a critical viscosity and inter particle structure that have to be maintained, so that the sedimentation under vibration remains tolerable.**

Thank you for your kind attention!