Selected aspects of influencing the workability of cement paste with power ultrasound

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Presentation Outline

- → Introduction
- → Characterization of power ultrasound
- → Material and Methods
- → Results
- → Perspective for Application in Concrete Production

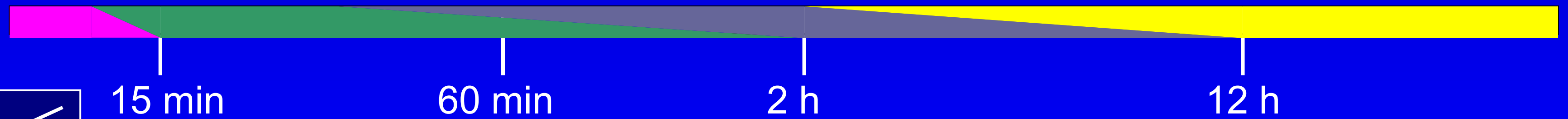
"Workability is that property of freshly mixed concrete witch determines the ease and homogeneity with witch it can be mixed, placed, consolidated and finished." [ACI- Std. 116R-90]

mixing	**placing**	**consolidating**	**finishing**
→ Mixing energy	→ Consistency	→ De aeration	→ Setting
→ Mixing time	→ Pumpability	→ Easy or	→ Hardening
→ Homogenizing	→ Stiffening	→ Self compaction	→ Curing
→ …	→ …	→ …	→ …

- → Intensiv mixer
- → Colloidal mixer (FML, GermanSucon)

- → Admixtures (SP)
- → Additives (fly ash)
- → ESC / SCC

- → Accelerater
- → Heat treatment



Characterization of power ultrasound

Power ultrasound: frequency 20 kHz – 100 kHz

Most important effect: cavitation (formation and implosion of cavities due to pressure fluctuations)

Industrial used…

→ Dispersing / homogenizing / milling

→ Sonocatalyses (catalytic transesterification, e.g. Biodiesel)

→ Sonochemistry, Sonocristallization:
influence on chemical reaktions and crystall growth

Cement chemistry…

→ Accelerate setting and early strength development of cement suspension

→ Changing properties of fresh cement suspensions

Material and Methods

Material…

→ CEM I 42,5 R (with different w/c-ratios)

Methodes…

→ Ultrasonic device (UIP 1000hd, Hielscher, Germany) amplitude: 43 µm; specific energy: 75 Ws/ml (intensity : ≈ 45 W/cm²)

→ Air void content (DIN EN 12 350 – 7)

→ Air void distribution (light optical microscopy on polished sections)

→ Mini slump flow (DAfStb SVB – RiLi)

→ Rheology (Viskomat NT, Schleibinger Germany); experimental setup with a basket probe

Results – *air void content*

Cement suspensions 20 min. after water addition

- Application of power ultrasound reduces air void significantly

Samples after 7d hydratation

Reference

Power ultrasound

- Power ultrasound treated sample contains less air voids than the reference
- Reference sample: air voids with diameter of 0.3 … 1.0 mm
  Sonicated sample: air voids less than 0.2 mm

Results – *mini slump*

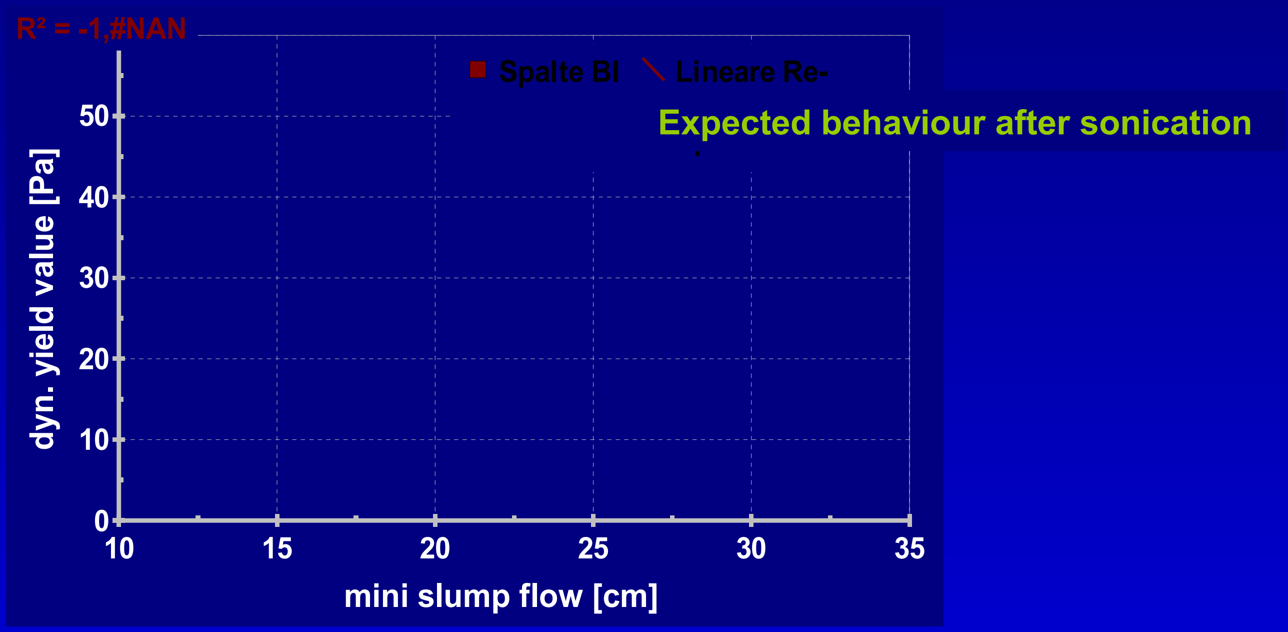
Cement suspensions 15 min. after water addition

- Higher mini slump values with power ultrasound application
- Advantage of consistency is equal to 5…10 M.-% water addition

Workability loss within 60 min. after water addition

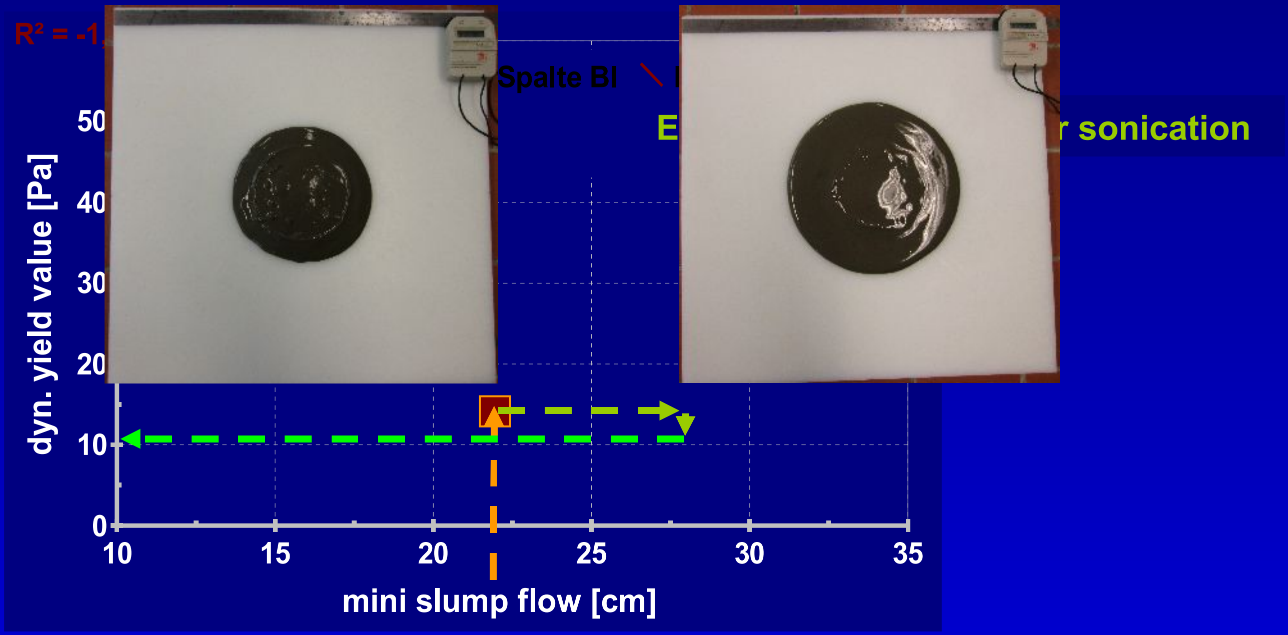
- Increased fluidity due to power ultrasound application is a temporary effect
- Power ultrasound effect is more significant at higher water content

Correlation mini slump flow vs. yield value



- Good correlation between mini slump flow and yield value in reference samples

Correlation mini slump flow vs. yield value



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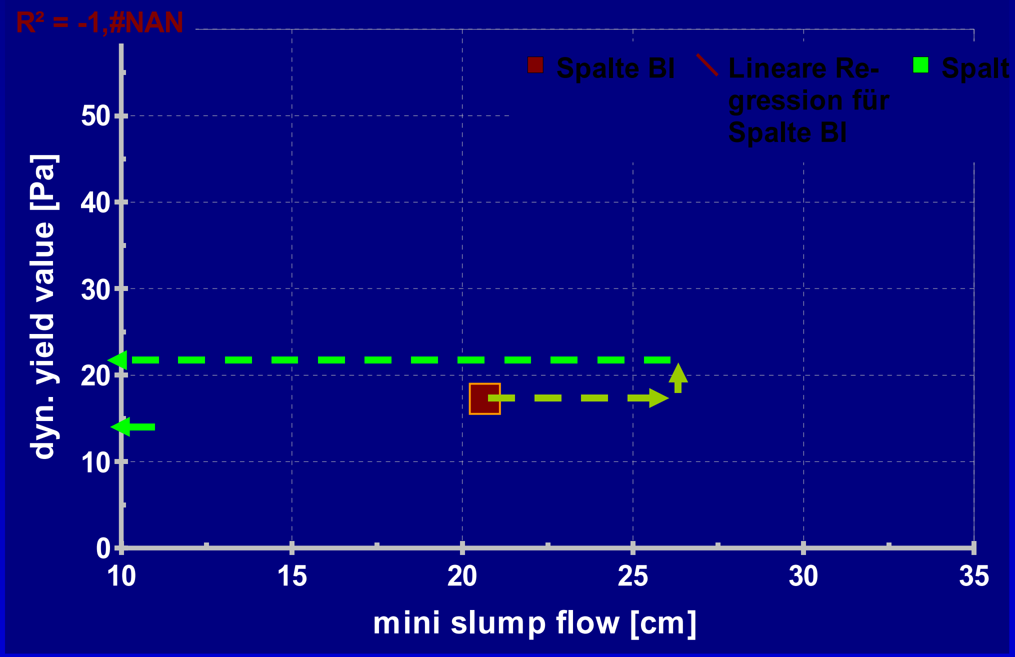
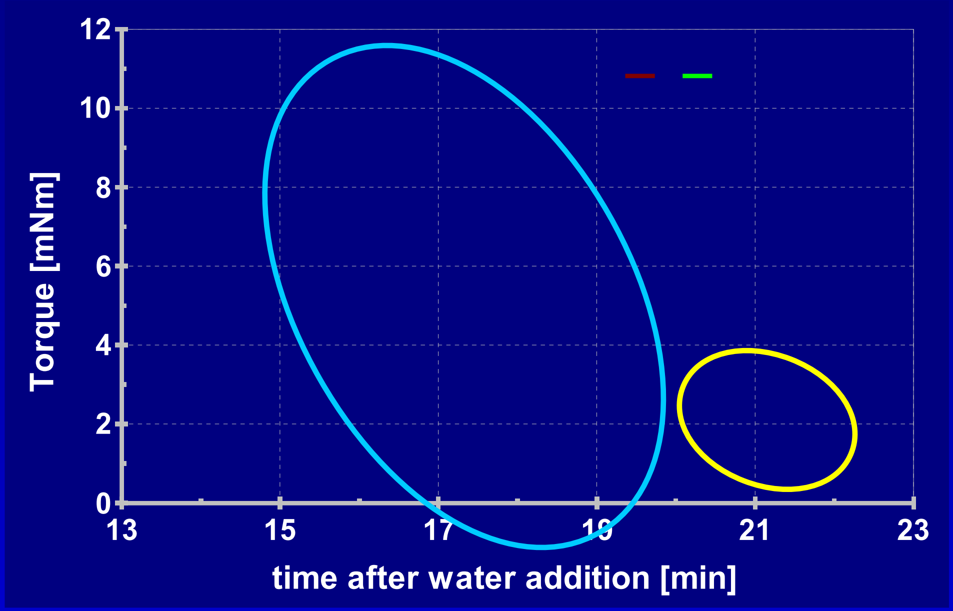
Correlation mini slump flow vs. yield value



- Despite higher mini slump values due to sonication (i.e. increased fluidity) samples show higher yield values

Results – *rheological measurements*

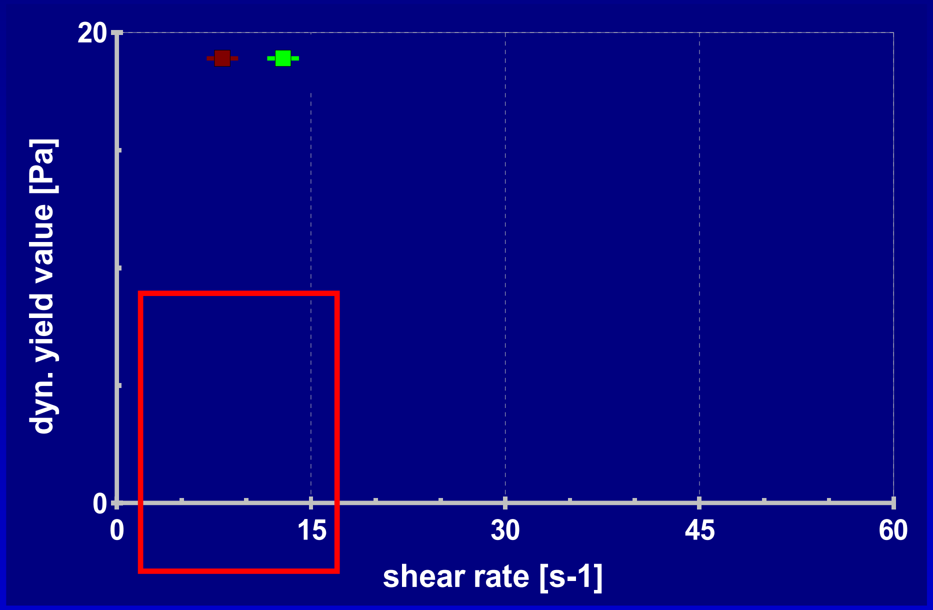
Shear profile w/c = 0,46



- Higher shear rates: structural interruptions / dispersion due to sonication
- lower shear rates: no significant chances due to sonication

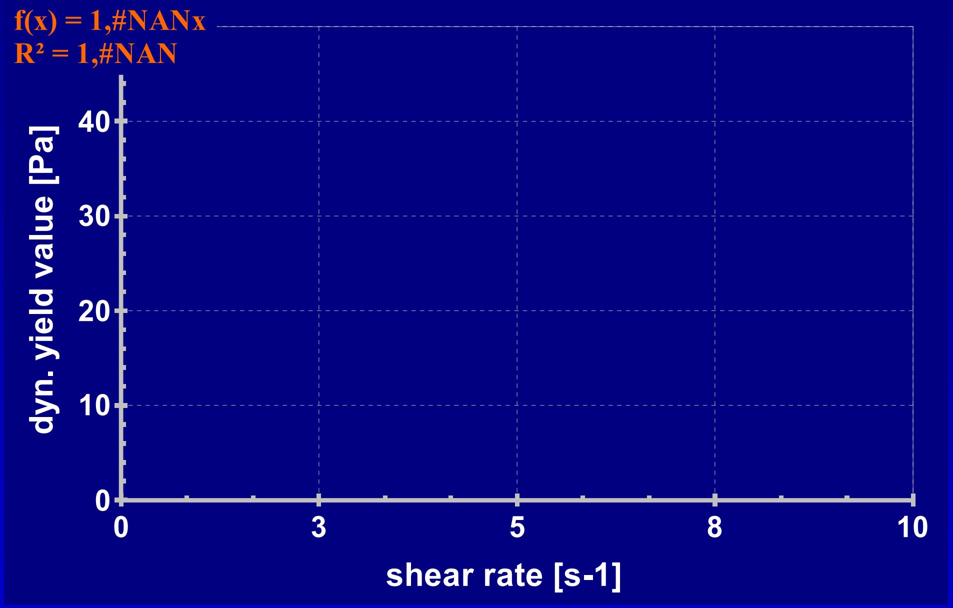
Results – *rheological measurements*

Flow curve w/c = 0,46



- Power ultrasound decreases viscosity at higher shear rates
- Lower shear rates used for calculation of Bingham parameter

Flow curve w/c = 0,46



- At lower shear rates no singnificant chance in viscosity
- Yield value increases due to sonication

Results

Power ultrasound application causes…

→ reduced air void content/ maximum pore size in fresh and hardened cement suspension

→ higher mini slump flow (i.e. improved consistency, temporary effect)

→ effectiv homogenizing / dispersion

→ significant reduction of viscosity at higher shear rates

→ trends to increased yield strenght

Workability affected by power ultrasound

mixing
- → Mixing energy
- → Mixing time
- → Homogenizing
- → …

placing
- → Consistency
- → Pumpability
- → Stiffening
- → …

consolidating
- → De aeration
- → Easy or
- → Self compaction
- → …

finishing
- → Setting
- → Hardening
- → Curing
- → …

- → Intensiv mixer
- → Colloidal mixer
- → Power ultrasound

- → Additives (SP)
- → Admixtures (Fly ash)
- → Power ultrasound

- → Accelerater
- → Heat treatment
- → Power ultrasound

Respektives – *Further investigations*

Influence of sonication on

→ superplasticizer containing mixtures

→ blended cement

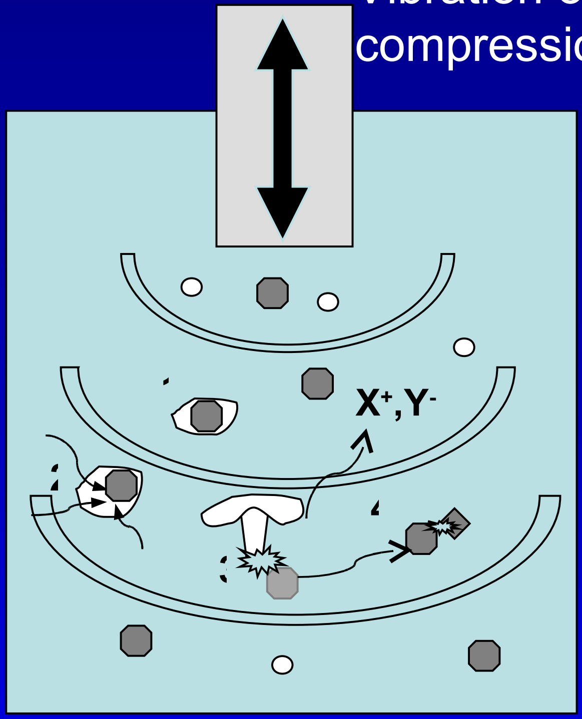
Deeper understanding of mechanism in

→ dispersing/ liquefying

→ cement hydratation

Thank you for your attention

Effects of power ultrasound on suspensions



Vibration of sonotrode (amplitude ca. 2 - 100 µm): compression and rarefaction of liquid

Cavitation:

1. Tensile strength of liquid is exceeded, cavities are formed
2. Vapor ingress in cavities
3. Compression causes cavities to implode, jet streams are formed
4. Liquid and particles are accelerated, particle collisions occur, diffusion is enhanced

➢ **Cavitation** leads to Degassing and bubble formation, temperature and pressure variations, accelerated crystallization processes