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

S. Peters, M. Kraus, C. Rößler
Introduction – *What means workability?*

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

- **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 (FML, GermanSucon)
- Admixtures (SP)
- Additives (fly ash)
- ESC / SCC
- Accelerater
- Heat treatment

15 min | 60 min | 2 h | 12 h
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
Results – air void distribution

Samples after 7d hydration

- 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
Results – *mini slump*

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
**Results – rheological measurements**

Correlation mini slump flow vs. yield value

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

![Graph showing correlation between mini slump flow and yield value](image)

*Expected behaviour after sonication*
Results – rheological measurements

Correlation mini slump flow vs. yield value

- Good correlation between mini slump flow and yield value in reference samples
Results – *rheological measurements*

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 changes 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
Results – *rheological measurements*

Flow curve w/c = 0.46

- At lower shear rates no significant change 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)

→ effective homogenizing / dispersion

→ significant reduction of viscosity at higher shear rates

→ trends to increased yield strength
Workability affected by power ultrasound

- **Mixing**
  - Mixing energy
  - Mixing time
  - Homogenizing
  - ...  
  - Intensiv mixer
  - Colloidal mixer
  - Power ultrasound

- **Placing**
  - Consistency
  - Pumpability
  - Stiffening
  - ...  
  - Additives (SP)
  - Admixtures (Fly ash)
  - Power ultrasound

- **Consolidating**
  - De aeration
  - Easy or
  - Self compaction
  - ...  
  - Accelerater
  - Heat treatment
  - Power ultrasound

- **Finishing**
  - Setting
  - Hardening
  - Curing
  - ...
Respektives – *Further investigations*

Influence of sonication on

→ superplasticizer containing mixtures

→ blended cement

Deeper understanding of mechanism in

→ dispersing/ liquefying

→ cement hydration
Thank you for your attention
Characterization of power ultrasound

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