# Influence of Power-Ultrasound on the Fluidity and Setting of Portland Cement Pastes

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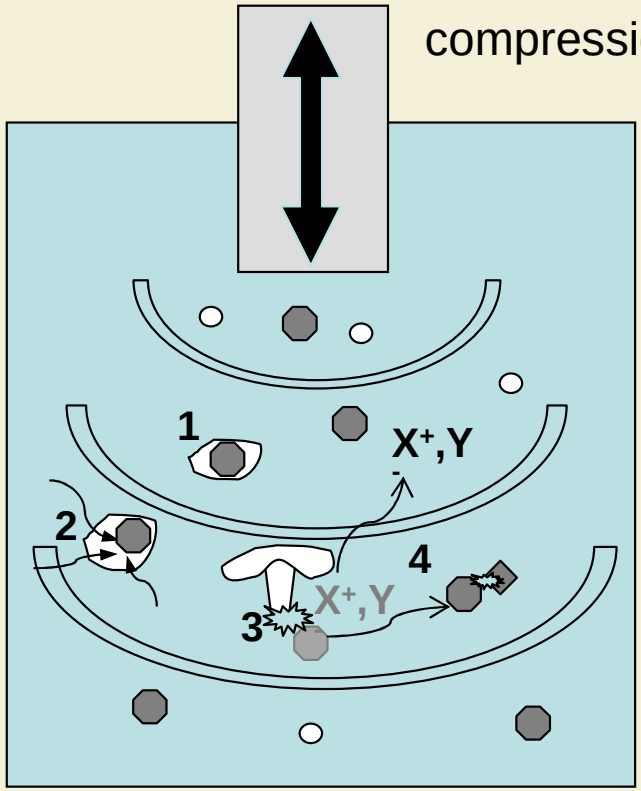
## Outline of presentation

- Brief description on effects of Ultrasound on suspensions
- Experimental setup
- Results
- Perspective for Application of Power-Ultrasound in Concrete Production



# Power-Ultrasound (PUS) in aqueous suspensions - phenomenon of acoustic cavitation

Power-Ultrasound: frequency 20 kHz – 1 GHz




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

Cavitation:

1. Tensile strength of liquid is exceeded, cavities form
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

PUS effects: degassing and bubble formation, temperature and pressure variations, crystallization processes are accelerated

## Study Objective

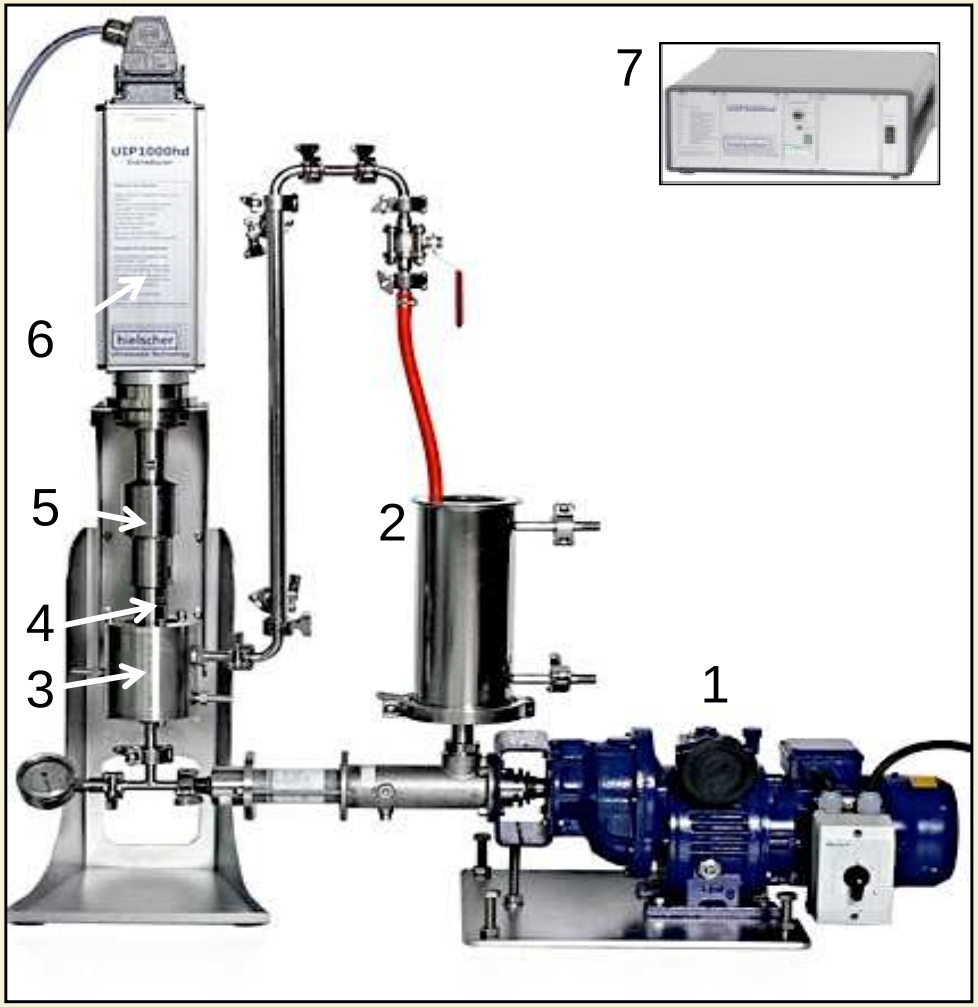
- To evaluate if PUS is a suitable method to accelerate hydration of alite in Portland cement pastes

- To measure impact of PUS on fluidity, setting behaviour, strength development and microstructure of cement pastes

- Outline a concept for implementation of PUS in concrete production



# Experimental Setup of Ultrasound Device UIP1000hd (Hielscher, Germany)




1. Pump
2. Sample storage container
3. Sonification vessel
4. Sonotrode
5. Booster
6. Transducer
7. Generator
8. Wattmeter

[www.hielscher.com]

## Experimental Setup

Mixture

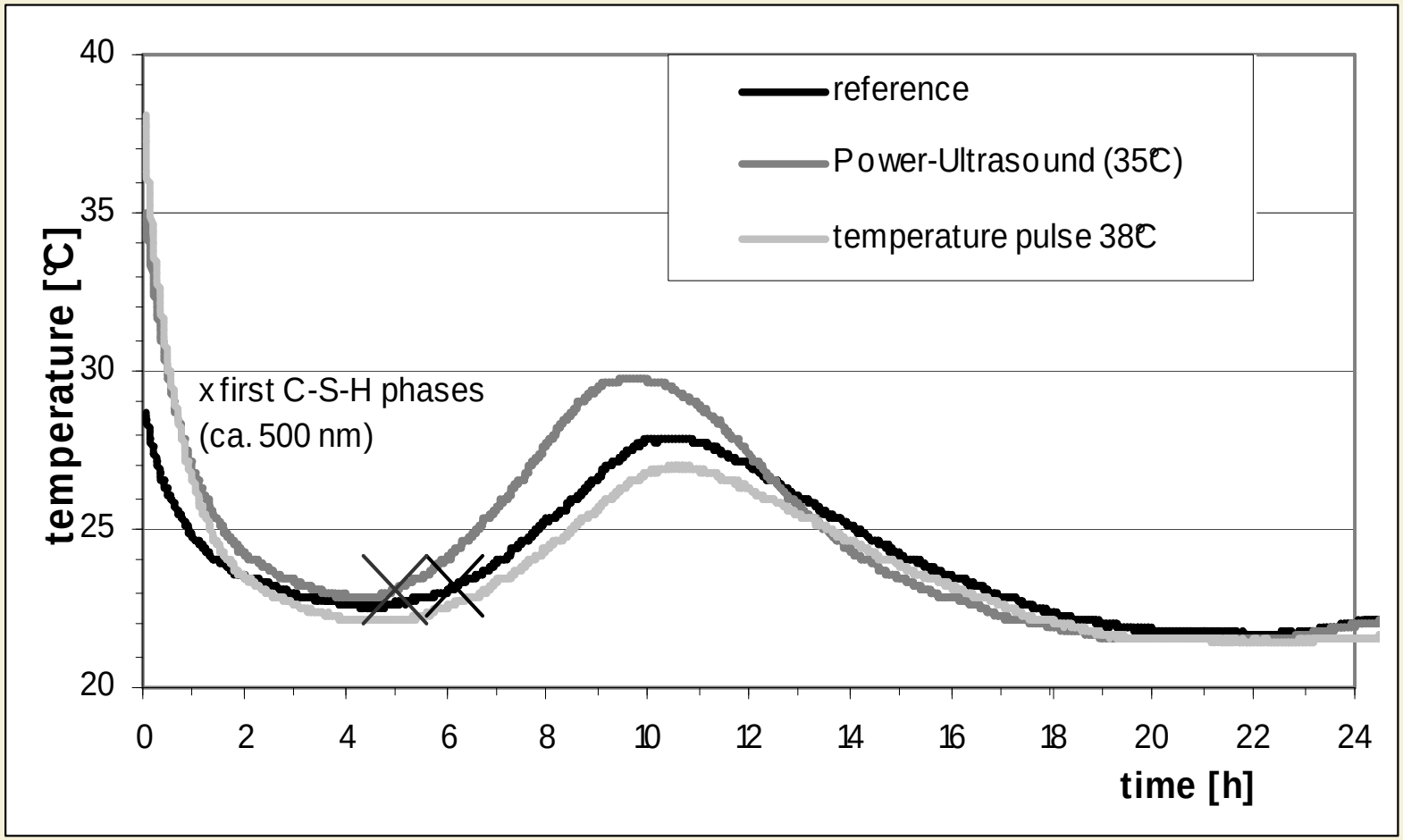
- CEM I 42. 5 R, w/c 0.37,
- Polyacrylate superplasticizer 0.1 % referred to the amount of cement

Methods

- Vicat Needle test, Non-destructive testing (ultrasonic pulse velocity), slump, temperature, Environmental SEM, compressional strength of mortar prisms



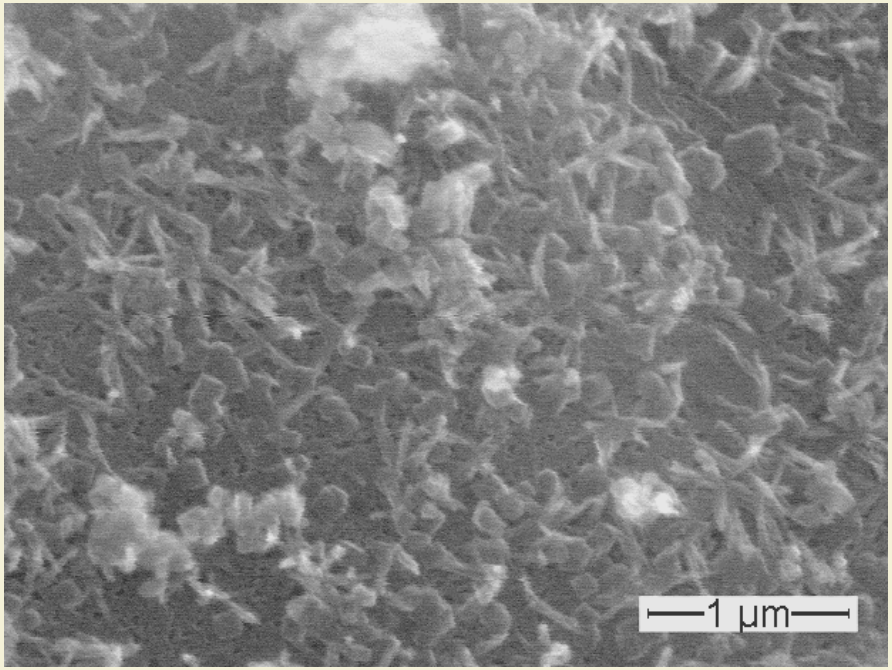
## Results: Time-Temperature curves of cement pastes in dependence of PUS application

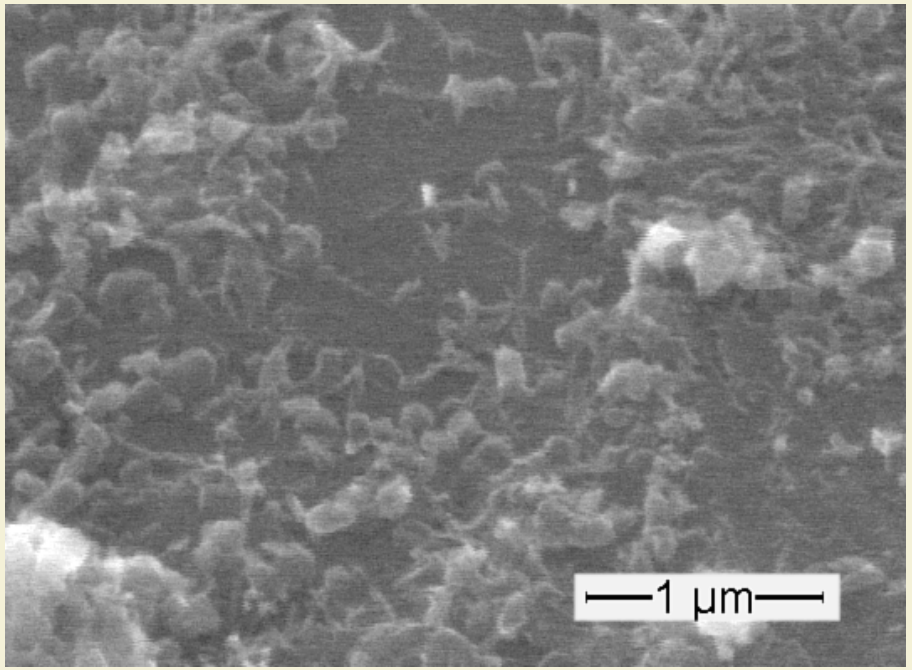



Main hydration period is accelerated by PUS.

## Results: Microstructure of cement pastes in dependence of PUS application

5 h Hydration (setting time)




Power-Ultrasound

Reference

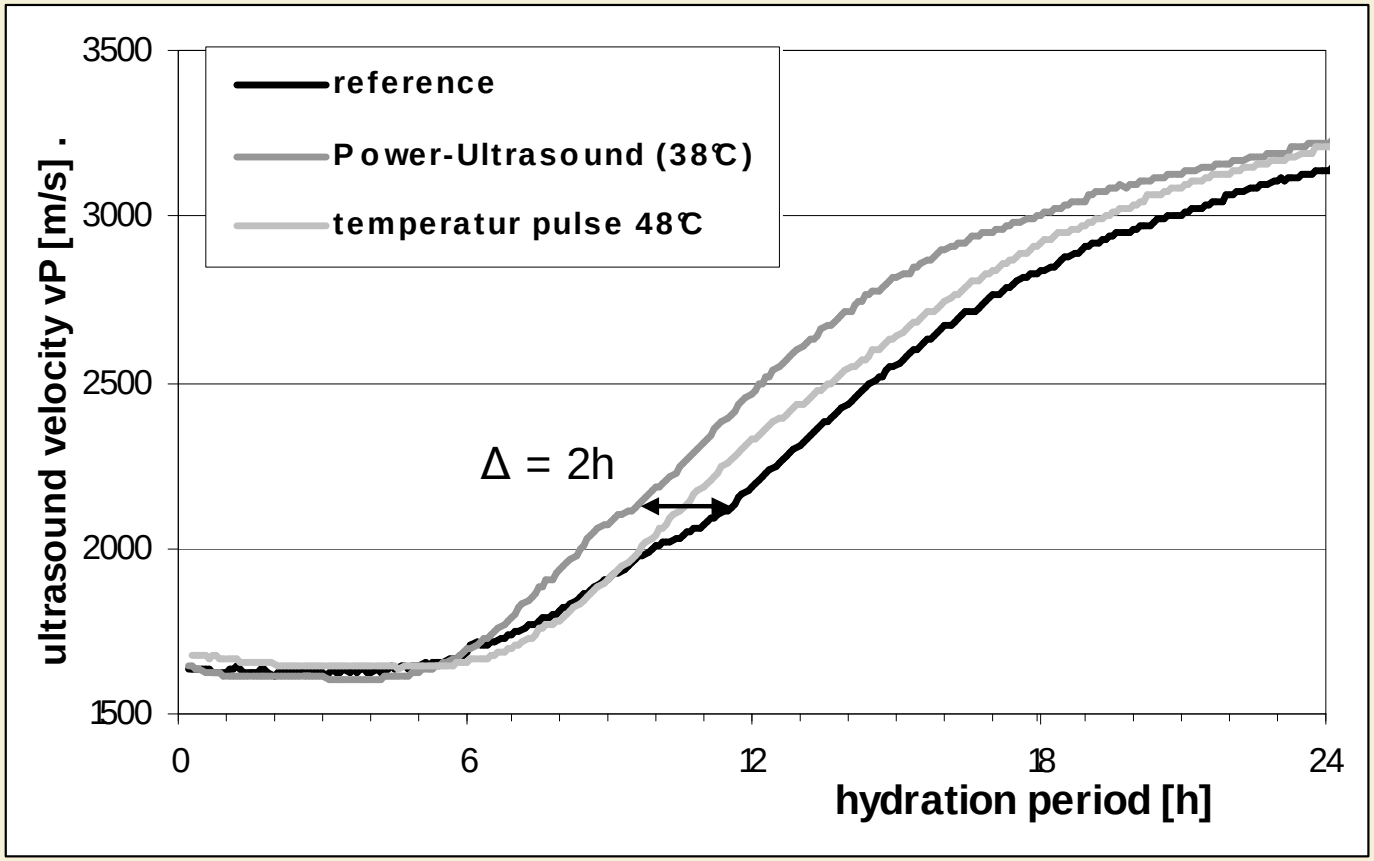
Larger C-S-H phases in PUS treated cement paste.

**Results: Set time and slump of cement pastes in dependence of PUS application (w/c 0.37, 0.1 % SP)**

| | **Reference** | **PUS** |
|---|---|---|
| **Initial Set** | 5 h 15 min | 3 h 45 min |
| **Final Set** | 6 h 45 min | 4 h 30 min |
| **Slump** | 122 mm | 158 mm |

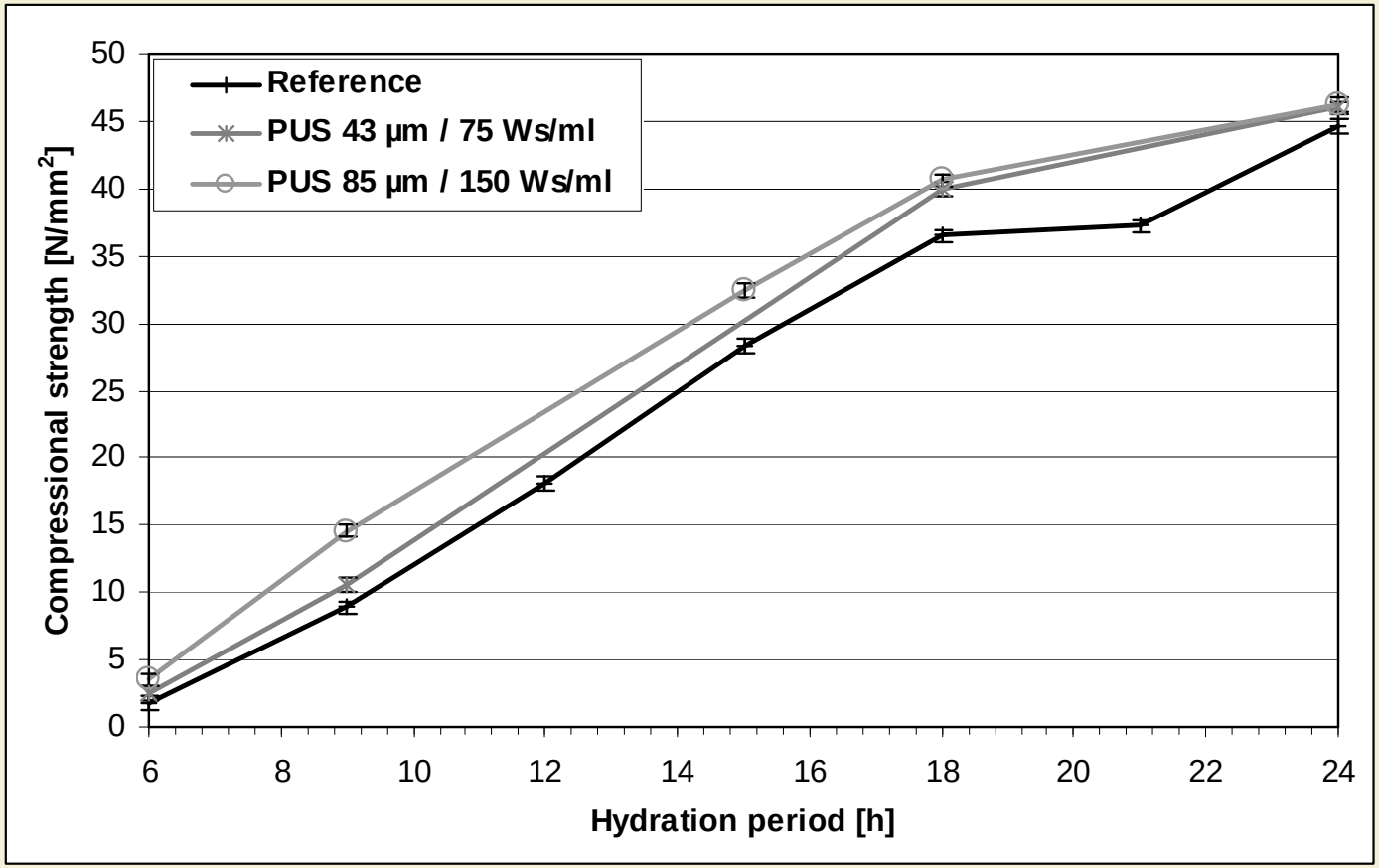
PUS application accelerates initial and final set of cement paste and increases fluidity.

## Results: Non-destructive testing of setting process - ultrasonic pulse velocity in dependence of hydration time and PUS application




Accelerated rigidification of PUS treated cement pastes, increased ultrasonic velocity after 24 and 72 h of hydration indicates higher strength of pastes.

# Results: Compressional strength of mortar prisms in dependence of hydration period and PUS application




Increased early strength in PUS treated cement pastes.

## Summary

- Power-Ultrasound is a useful technique to accelerate formation of C-S-H phases, setting and thus development of early strength of Portland cement pastes.

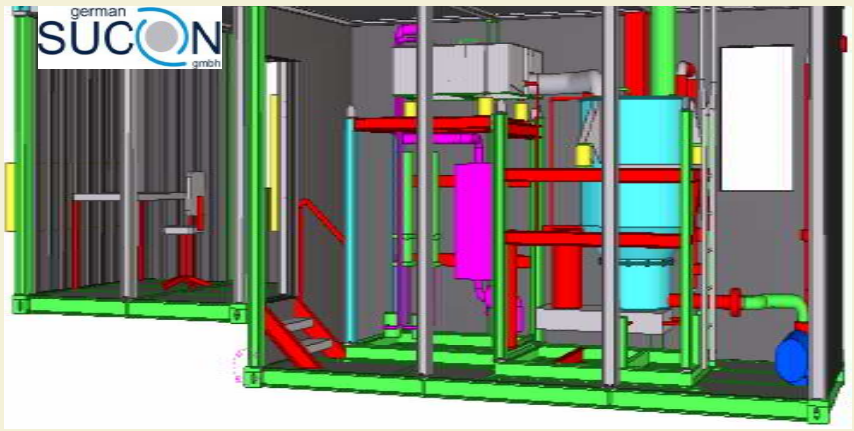
- It was shown that by an input power of ~ 10 kWh / $m^3$ cement paste (~ 2 - 3 $m^3$ concrete, ≤ 1 Euro / $m^3$ concrete) approx. 2 h acceleration of setting and early strength is achieved.

- Due to the possibility to increase fluidity by application of PUS, superplasticizer dosage can be reduced.

- Efficient input of PUS is only achieved for cement suspensions, thus mixing procedure of concrete has to be varied if PUS application is desired.

## Perspective / Vision

- Optimisation of ultrasound parameters (time and duration of PUS application, amplitude, pressure)
- Feasibility study for precast concrete plant
- Reduction of heating power in precast concrete production
- Implementation of Power-Ultrasound and alternative mixing process (for example suspension concrete, www.germansucon.com) in precast concrete plant.




Suspension concrete

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PUS

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Efficient mixing and hardening of concrete