Component additive approach to predict Cement paste Rheology considering Secondary Cementitious Materials and their special effect on thixotropy and concrete de-airing behaviour (CONCERT-CCAir)

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Funding body + grant number: SPP2005 DFG, SCHA 1854/4-1

Duration: March 2021—March 2024

Project leader: Univ. Prof. Dr. habil. Thorsten Schäfer

Personnel in charge: Steffen Hellmann

INTRODUCTION

The collaborative project **CONCERT-CCAir** within the DFG funded **SPP 2005** is a joint research project between the **Bauhaus University Weimar** (BUW; Prof. Horst-Michael Ludwig), the **Leibniz Universität Hannover** (LUH; Prof. Michael Haist) and the **Friedrich Schiller University Jena** (FSU; Prof. Thorsten Schäfer).

Close cooperation within **CONCERT** and the multi- and interdisciplinary **SPP 2005** consortium with researchers from **Physics, Chemistry, Materials Science, Civil Engineering** and **Mineralogy** offers unique prerequisites for transferring the findings from **basic research** into **applications**.

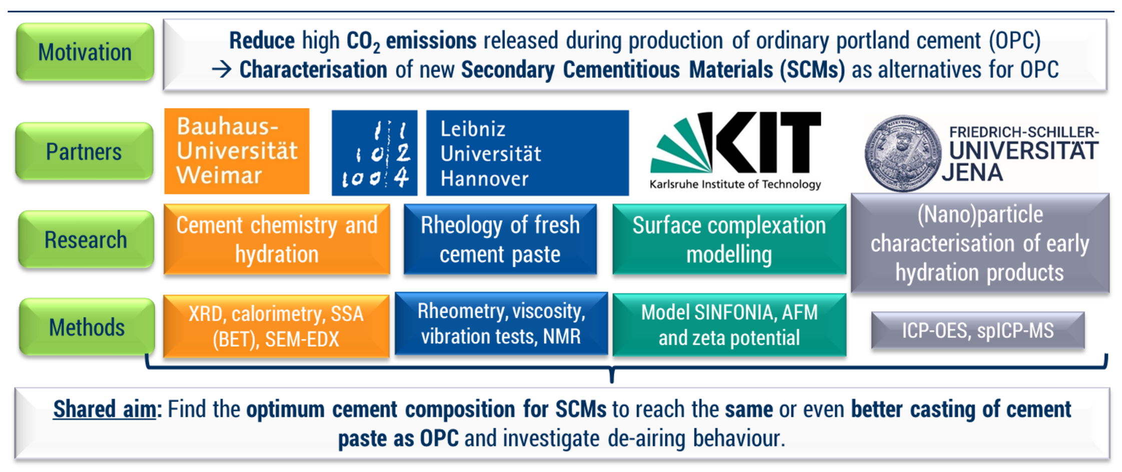

Figure 1 Project overview CONCERT-CCAir.

Whereas a reasonably clear picture of the mechanisms governing the **rheology of cement suspensions** made from **Ordinary Portland Cement (OPC)** starts to emerge, the knowledge of the effect of **Secondary Cementitious Materials (SCMs)** is still scarce. These materials, however, play an essential role in reducing the **CO_2 footprint of concrete** which is worldwide around **8% of global CO_2 emissions [1]**. The most relevant and promising alternatives for OPC are **calcined clays (CCs)** as well as **limestone powder (LSP)** which are both investigated within this project.
The "**hardening**" of cement paste is a **hydration reaction** which starts at the **nano-scale**. Therefore, early hydration products should be well characterised as **variations** in **cement composition** leads to different phases, which directly affects the **strengthening** and **workability** of **concrete**.

AIM AND APPROACH

The **goal** of this project is **(i)** to identify appropriate SCM that will allow to mold the concrete to the desired shape via extensive **characterization** of **surface** and **rheological properties** of cement paste and **(ii)** to understand their **impact** in **air-bubble entrapment**.
A special focus will be at the **SCMs,** particularly **CC's** and **LSP** as well as at the main **hydration product** of cement: **Calcium silicate hydrate (C-S-H)** phases but also at other hydration products such as **ettringites**.
For these topics of study, a series of approaches will be combined involving **sample characterization** (e.g., XRD, XRF, calorimetry, SEM-EDX, BET, ICP-OES, spICP-MS, etc.), the development of **surface complexation models** (i.e., by means of AFM-measurements and zeta-potentials), and quantification **of the rheological properties** of hydration products and cement systems (e.g., rheometer, NMR, vibration test systems, etc.).

METHODS AND RESULTS

SINGLE PARTICLE INDUCTIVELY COUPLED PLASMA - MASS SPECTROMETRY (SPICP-MS)

A promising method to **characterise the particle composition** of early hydration products at **nano and micro-scale** is the **spICP-MS** (Fig. 2).

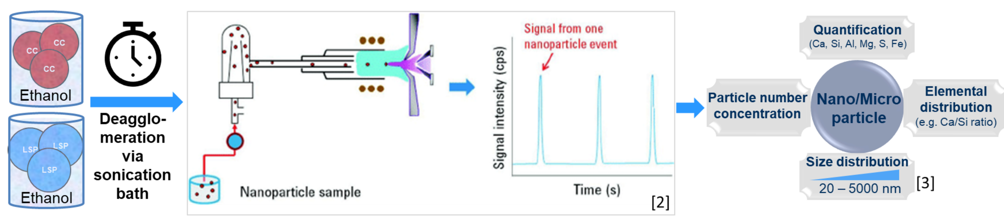

Figure 2 spICP-MS method.

The method allows to characterise particles regarding their **chemical composition, size** and **concentration**. The particles are analysed in **alcoholic suspension** to **stop the hydration reaction** and investigate **early-hydration products**. First results characterising C-S-H phases are shown in Fig. 3.

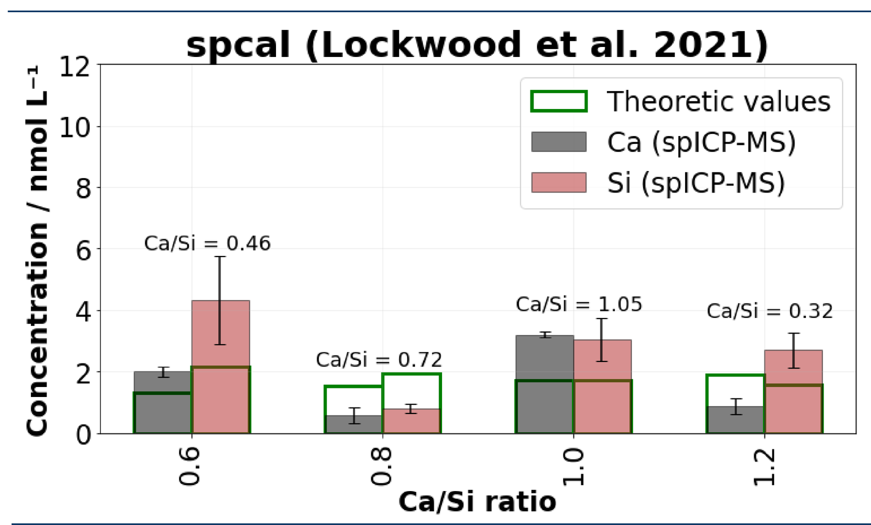

Figure 3 Peliminary results investigating C-S-H phases synthesised by BRGM (France) with well-defined Ca/Si ratios. The x axis represents the theoretical Ca/Si ratios and the plotted value shows the measured Ca/Si ratios.

Particle sizes measured by **spICP-MS** are based on a **spherical shape**. **C-S-H phases** are usually nearly **spherical** which allows a **good size characterisation** by **spICP-MS** which calculates particle sizes assuming **spherical geometry**.
Commercial C-S-H phases (**X-Seed 100 and 500**) were also investigated within this project using **Scanning electron microscopy with energy dispersive X-Ray diffraction (SEM-EDX)**. For the method **validation** of **spICP-MS**, these are valuable comparison values for the **Ca/Si ratios** as well as **sizes** and **shape** information (Fig. 4 and 5).

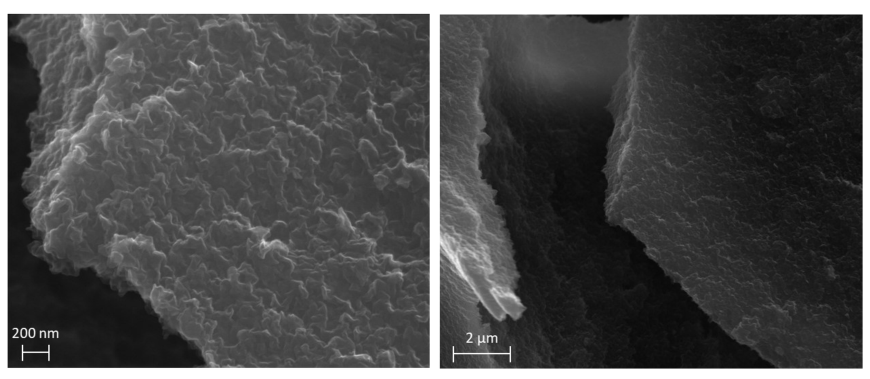

Figure 4 Scanning electron microscopy (SEM) record from the main cement hydration product (C-S-H phases) shown for a commerical product „X-Seed 100" at nano (left) and microscale (right).

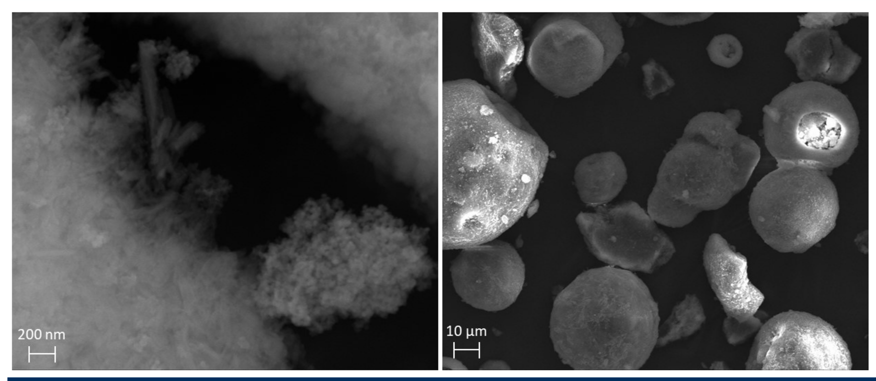

Figure 5 Scanning electron microscopy (SEM) record from the main cement hydration product (C-S-H phases) shown for a commerical product „X-Seed 500" at nano (left) and microscale (right).

SURFACE COMPLEXATION MODELLING AND DE-AIRING BEHAVIOUR

Given the analogous surface properties between **gold** and **air bubbles** (Fig. 6), experimental approaches with **AFM** measurements of **gold surfaces** in **different solution compositions** (Fig. 7) can shed light onto **air bubble affinity** onto **cementitions phases**.

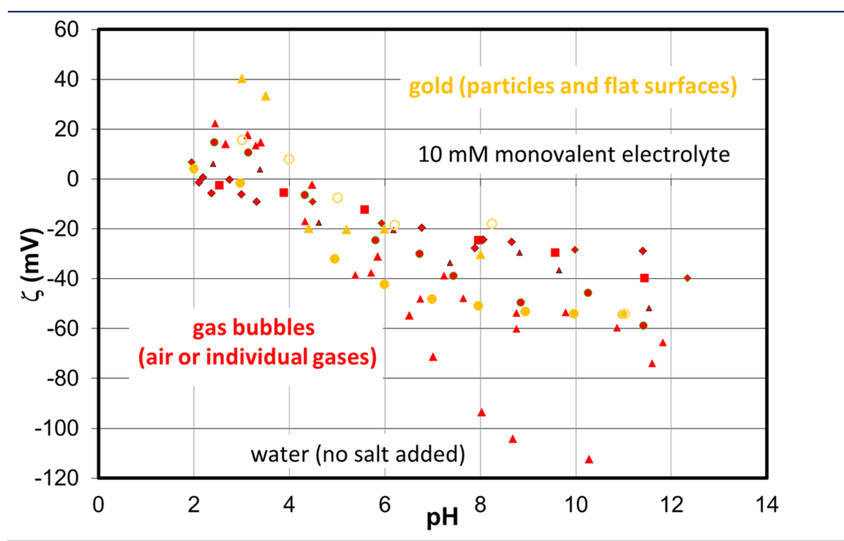

Figure 6 Experimental evidence of similar surface properties between gold and air-bubbles.

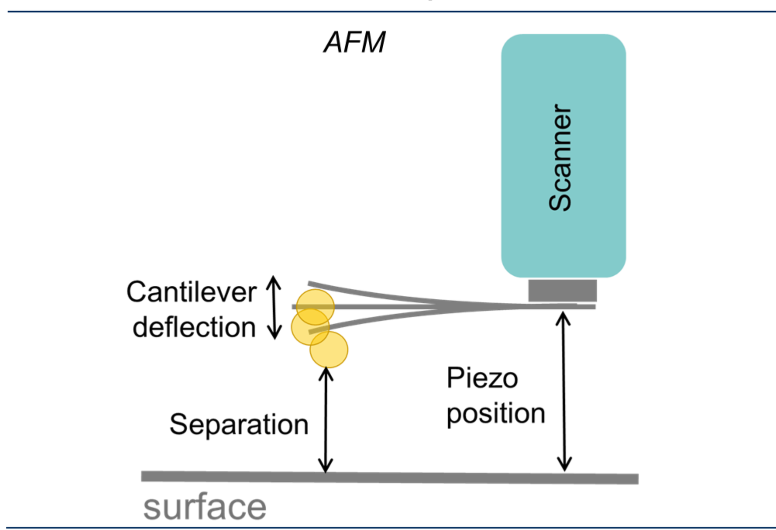

Figure 7 Experimental design of the atomic force microscopy (AFM) measurements: properties of air-bubbles by using gold nanoparticles as model.

These measurements will validate further development of **surface complexation models** of dissimilar surfaces (Fig. 8), as approached in [4].

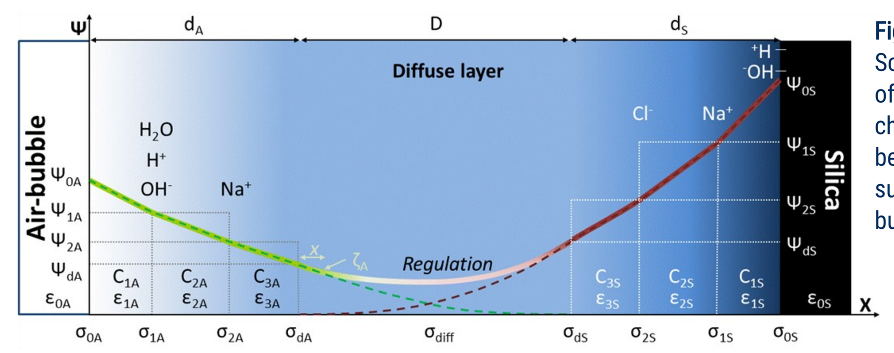

Figure 8 Schematic explanation of the physical-chemical interactions between dissimilar surfaces (e.g., air-bubble vs silica).

OUTLOOK

- **spICP-MS**: the method will be applied to investigate SCMs such as CCs and LSPs to characterise different cemntitious systems at nano and micro-scale.
- **Surface complexation modelling**: this approach will be applied to achieve the goal of understanding de-airing behaviour of cement paste when using alternative SCMs.

We believe that our research helps to better understand the **composition of cement particles** and their **interactions** in solution during the hydration process. The accurate **characterisation of SCMs** will show to which extent we can use them as future **building materials** to **reduce the CO_2 footprint**. The close **cooperation** of all partners allows us to combine our findings regarding **particle characterisation** and **surface-physics** with the insights of our partners regarding **cement chemistry, hydration, concrete rheology and de-airing behaviour**.

LITERATURE

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