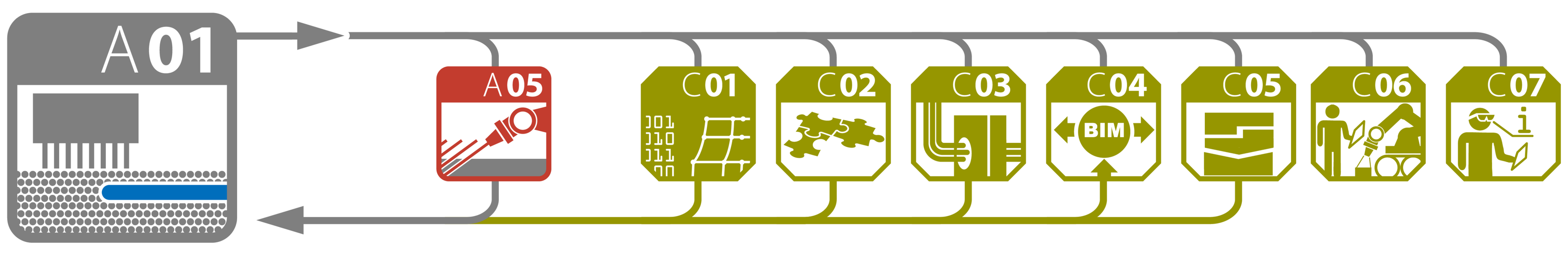
A01

Particle-Bed 3D Printing by Selective Cement Activation (SCA) – Particle Surface Functionalisation, Particle-Bed Compaction and Reinforcement Implementation

Prof. Dr.-Ing. Dirk Lowke
Prof. Dr.-Ing. Arno Kwade

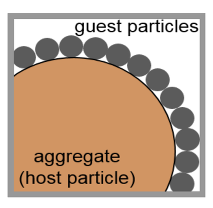
Institute of Building Materials, Concrete Construction and Fire Safety, TUBS
Institute for Particle Technology, TUBS

Summary



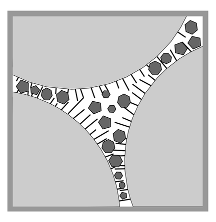
This project focusses on **high-resolution particle-bed 3D printing** of **reinforced cementitious composites** as a novel technology in the construction industry. To pioneer the understanding of governing mechanisms affecting the **material-process interaction**, basic interdisciplinary research addressing particle surface functionalisation, tailoring of particle size distribution, particle-bed compaction, liquid intrusion, interparticle and interlayer bonding, active structural build-up control of the matrix, high precision geometries as well as reinforcement integration will be conducted.

Approach and Goals



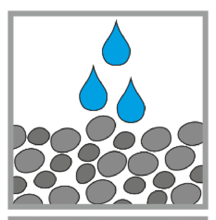
Particles – Tailoring of particles and particle bed
- Coating, chemical surface modification, particle shape and particle size distribution
- Application and compaction techniques

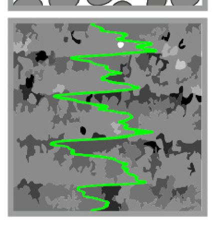
→ **Easy particle processability, high interparticle bonding, good liquid intrusion, high particle-bed compaction**



Microstructure – Active structural build-up control
- Binder composition and chemical admixtures

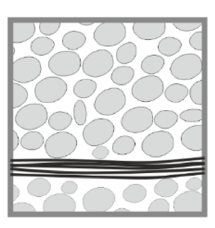
→ **High precision geometries**





Liquid – Intrusion behaviour and interlayer bonding
- Liquid dispensing technique
  pressure, pulse frequency, nozzle distance, nozzle diameter
- Liquid intrusion into the layer - penetration depth
- Micro-mechanical properties of the interlayer bond zone

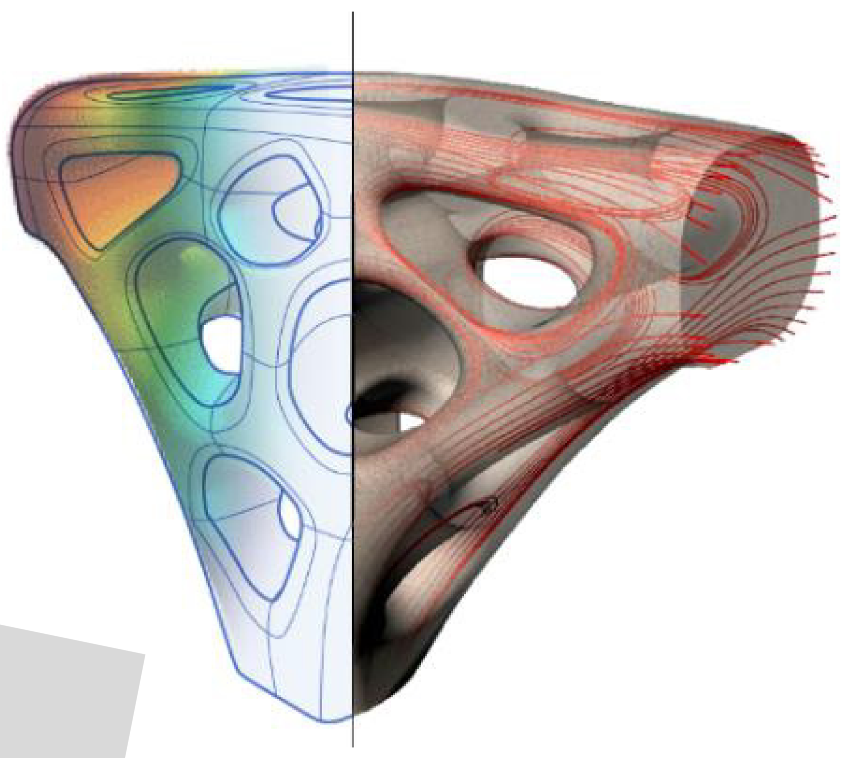
→ **Controlled liquid intrusion for high interlayer bonding, e.g. isotropic properties and high-strength**



Reinforcement – Integration and bonding
- Robot-assisted metal cord deposition in the layer plane
- Reinforcement pre-products in printed cavities with grout

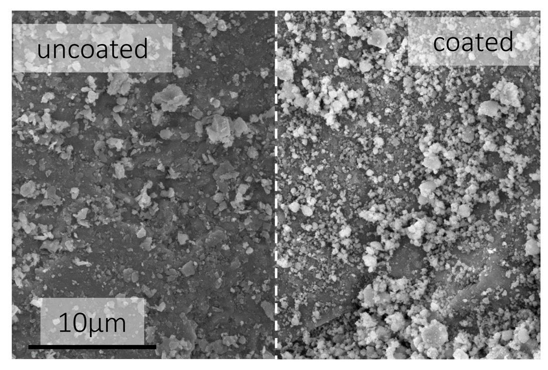
→ **Force-flow optimised reinforcement**

High strength and **high precision**
3D printed **reinforced** components

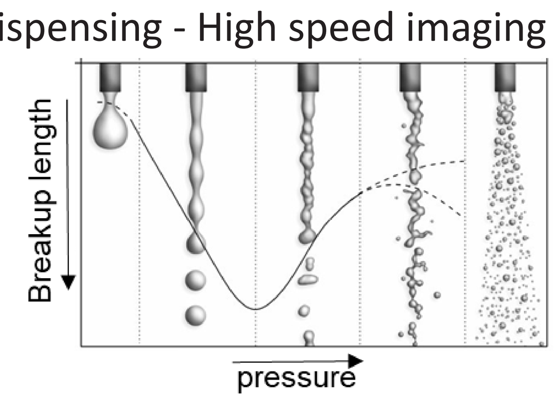


Exemplary Methods

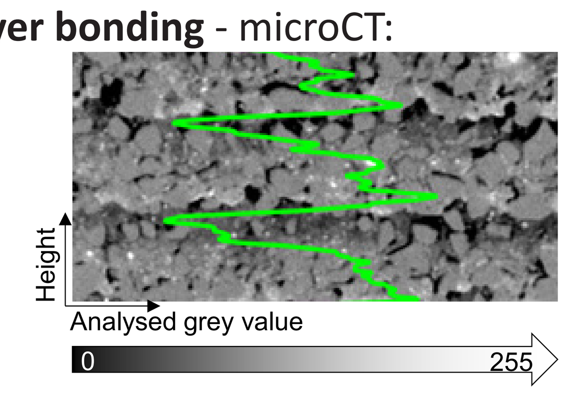
Particle coating and surface functionalisation



Liquid dispensing - High speed imaging



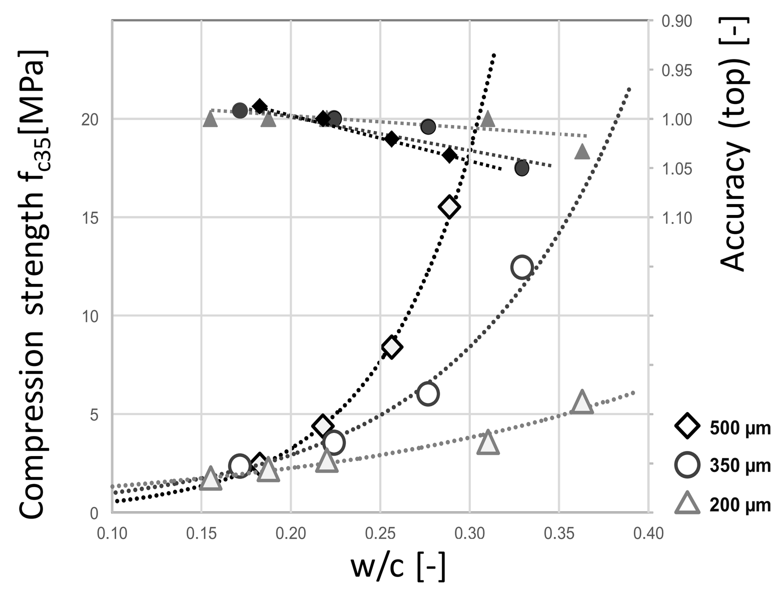
Interlayer bonding - microCT:

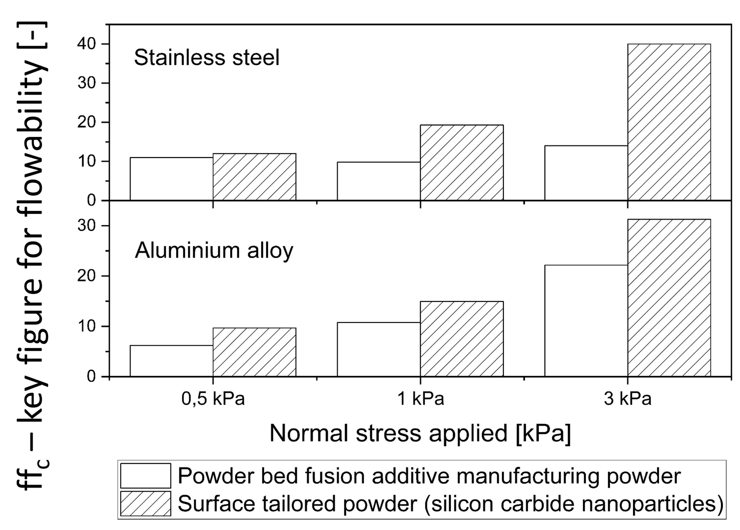


Preliminary Work

Basic material-process interactions of selective binding techniques using cementitious materials have been investigated [1,2]:

- Process technology overrides the usually governing concrete-technological relationships.
- Increase in water/cement ratio results in an increase in compressive strength.
- An opposite effect occurs on shape accuracy: it decreases with increasing water-content.
- Depending on maximum grain size compressive strengths of up to 16.4 MPa were achieved.





Particle functionalisation and modification for influencing surface and flow properties have been evaluated:

- Potential particles for particle-bed 3D printing (SiO_2-host particles) were coated with a monolayer of guest particles (fumed silica).
- Particle coating of different powder bed fusion feedstock materials results in enhanced flowability.
- Particle surface properties have an effect on processability and wettability [3].

Powder-bed application, resulting bed structure and its effect on part properties have been analysed [4]:

- Structural anisotropy of powder-bed leads to anisotropic part properties.
- Post-processing tools for evaluating data from microCT have been developed.

Outlook

- Ecological footprint and durability
- Integration of topologically optimised reinforcement in a simultaneous robot-assisted build-up welding process
- Gradation in cementitious matrix and reinforcement corresponding to the flow of force
- In collaboration: Numerical simulation of SCA process and structural behaviour

[1] Lowke: Particle-bed 3D printing in concrete construction. **Dig. Concrete**. 2018

[2] Lowke et. al: Particle-bed 3D printing in concrete construction. **Cem. Con. Res**. 2018

[3] Prziwara et. al: Impact of grinding aids on dry grinding performance, bulk properties and surface energy. **Adv. Pow. Tech.**, 2017

[4] Beitz et al.: Influence of Powder Deposition on Powder Bed and Specimen Properties. **Materials**, 2019