Additive Manufacturing in Construction
2nd funding period: The Opportunity for Large Impact

AMC TRR277

New Project: Injection 3D Concrete Printing (I3DCP) – Material Efficient Lightweight Reinforced Concrete Structures Based on Spatially Complex Strut-and-Tie Models

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Project aims

The research project aims to fundamentally understand the two Injection 3D Concrete Printing (I3DCP) techniques Concrete in Suspension (CiS) and Concrete in Concrete (CiC) with regard to the underlying material and process interaction as well as its process applications and control. Physical and digital investigations set the basis for a robust and controlled process and are utilized to achieve the following aims:

- Develop rheologically suitable materials for the I3DCP process
- Establish a method for 3D path planning and structural design
- Integrate reinforcement
- Predict and model print stability
- Geometrically precise multi-strand-printing

Workflow

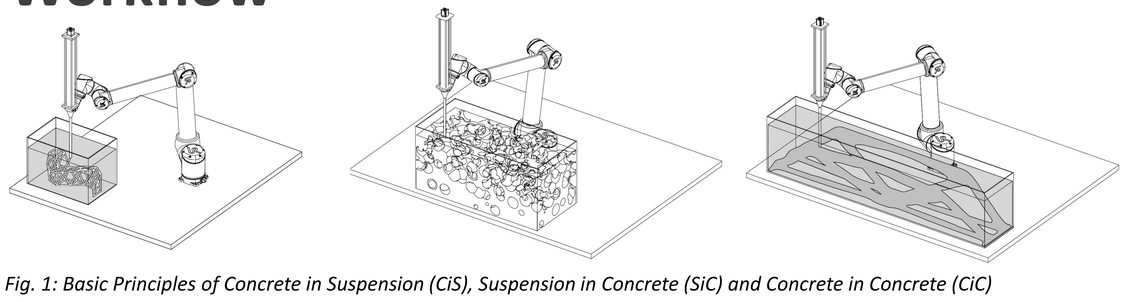
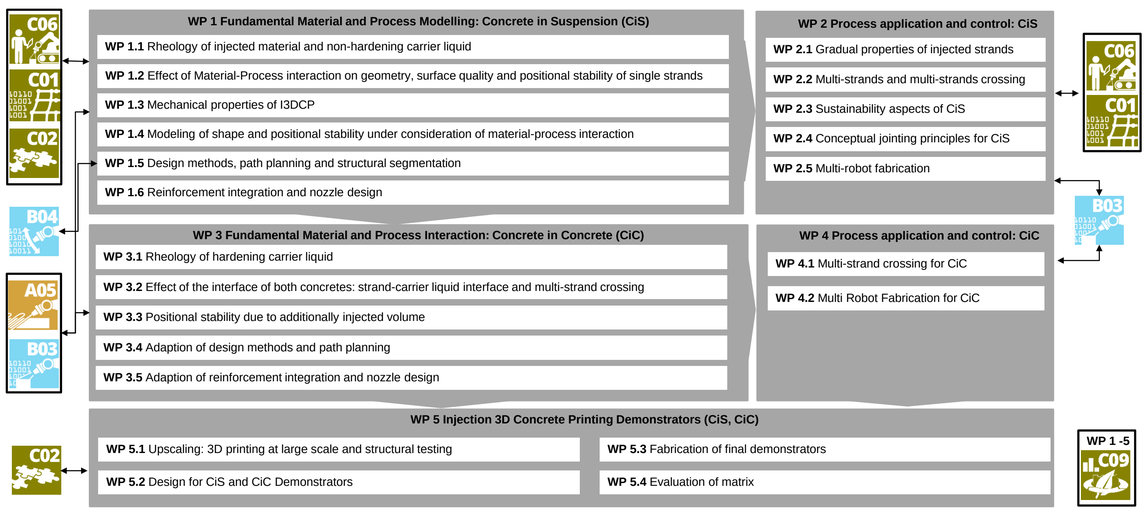


Fig. 1: Basic Principles of Concrete in Suspension (CiS), Suspension in Concrete (SiC) and Concrete in Concrete (CiC)

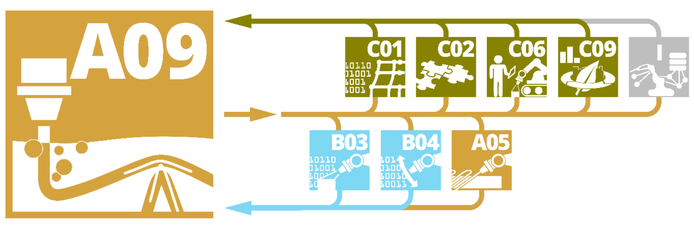
The basic principle of I3DCP is that a fluid of material A is robotically injected into another fluid of another material B and remains in a stable position. In general, I3DCP can be categorized into three sub-categories:

- Concrete in Suspension (CiS) – the injection of a fine-grained concrete into an inert non-hardening carrier liquid;
- Suspension in Concrete (SiC) – the injection of an inert non-hardening suspension into a fine-grained concrete; and
- Concrete in Concrete (CiC) – the injection of a fine-grained concrete into another concrete of different properties.

Work programme



Key collaborations



- C02: finding design and shape
- B04: 3D path planning
- B03: process and component modelling
- A05: reinforcement
- C06: (geometric) data acquisition after production
- C01: as-is-simulation
- C09: sustainability

Preliminary work

Own preliminary work in I3DCP is predominantly focused on CiS-technique. It was shown that even larger elements are printable but also current challenges were experienced. Besides, a proof of concept for the CiC-technique was demonstrated by applicants Mai and Hack.

Concrete in Suspension (CiS)

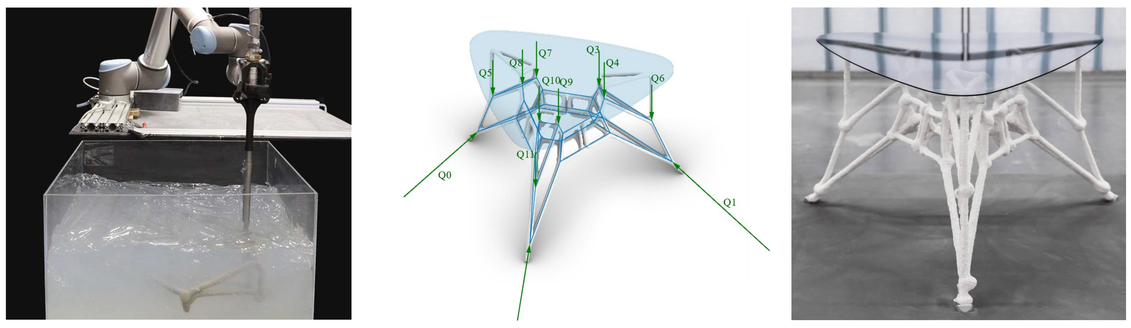


Fig. 2: Setup of Concrete in Suspension (CiS), Form diagram and printed object

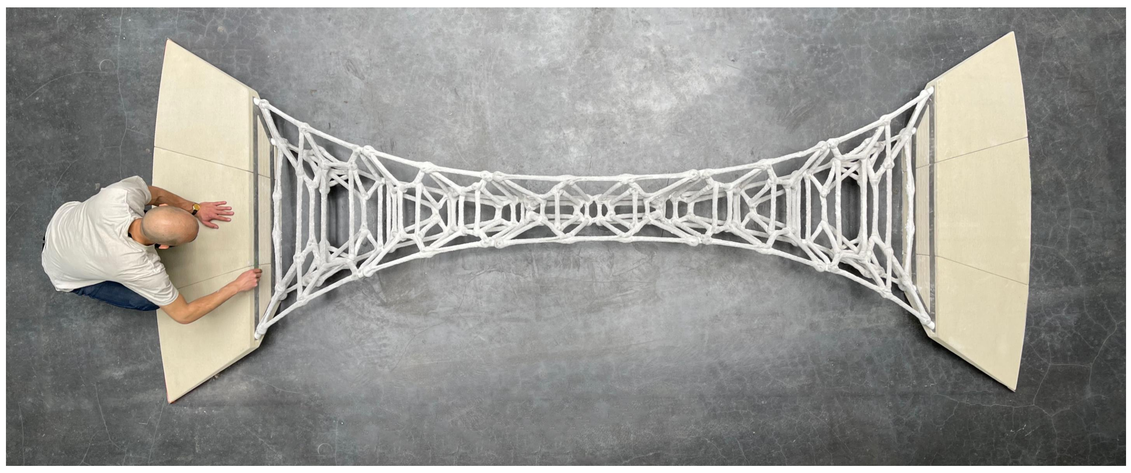


Fig. 3: CiS-demonstrator with a total length of 4.2 meters consisting of smaller elements

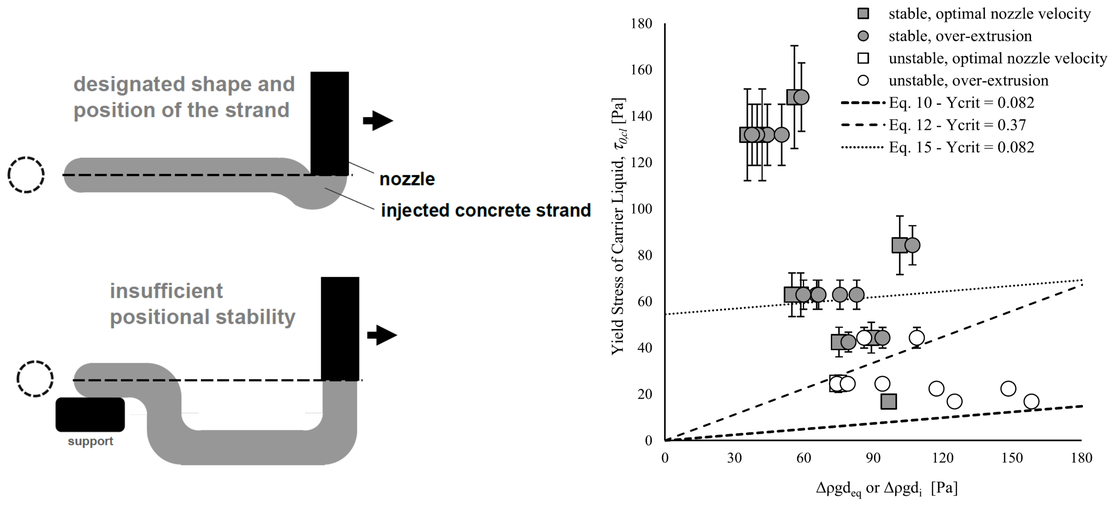


Fig. 4: Stable and unstable CiS-printed strands (left) and stable/unstable measured suspensions depending on the properties of the suspension (right)

Concrete in Concrete (CiC)

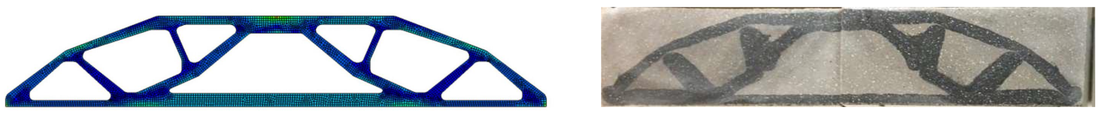


Fig. 5: Inspiration (left), Source: Deese et al. (2014); and fabrication (right) of a Concrete in Concrete (CiC)-demonstrator

Outlook

- enhancement of process control
- injecting other materials such as foam in order to achieve graded material properties
- Investigation of natural carrier liquids such as earth (Concrete in Earth)
- machine learning techniques in order to improve the printing result
- in depth investigation of the third technique in I3DCP, namely Suspension in Concrete (SiC)

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