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Proposed topic for Master's Thesis

Optimisation of the material composition of ultra-high-strength concrete formulations with carbon short fibres for application in the additive manufacturing process

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General:

High-performance concretes achieve their high strengths, among other things, through a very dense, high-strength hardened cement paste matrix. In order to achieve this, investigations are often carried out during the formulation stage to increase the packing density of the granular starting components. In addition to the cements, other concrete additives (inert or reactive, e.g. rock powder, fly ash, micro- or nanosilica) are usually used in order to achieve a filler effect and thus an increased solids concentration through their particle size distribution, which differs from that of the cement. The addition of carbon fibres improves the behaviour under tensile load, but makes the material more difficult to process.

Based on a concrete recipe developed at the Chair of Solid Construction and the literature known to date, the UHPC recipe is to be further developed in terms of compressive strength, tensile and flexural strength, the maximum processable carbon fibre content is to be increased and its suitability for use in additive manufacturing by means of extrusion processes (green strength, pumpability) is to be optimised. The extrusion process straightens the fibres, which increases the bending tensile strength. For this purpose, test specimens are to be manufactured and tested in accordance with DIN EN 196-1. This is to be represented in the tests in a suitable manner.

Initially, possible optimisation parameters are to be researched, which can be used to increase the suitability of ultra-high strength fibre-reinforced concrete according to the aspects listed above. Based on this, an own optimised UHPC formulation is to be designed and continuously updated throughout the work.

The aim is to achieve consistently good workability and concrete quality (pore volume, surface texture, setting behaviour, etc.) in addition to high strengths through scientifically based parameter studies at high fibre contents > 2 % by volume. The documentation and further development should be carried out in such a way that a large number of different variations of the developed basic formulation are available for subsequent material tests.

Initial tactile tests (**design space exploration**) will show which material composition and mixing process best meet the criteria. This recipe will then be used as the basis for optimisation.

At the end of the work, the influences of the optimisations are to be highlighted and potentials for further developments are to be estimated.

Procedure

- Literature study on the composition of UHPC with the addition of fibres
- Chemical and physical description of the documented phenomena
- Transfer of the findings into own UHPC formulations
- Optimisation, further development of recipes under variation of different, potentially decisive parameters
- Preliminary tests to determine the final recipe
- Creation and implementation of an experimental programme
- Evaluation and interpretation of the various results and dependencies

Previous knowledge

- Motivation and interest in the topic
- Fundamentals of materials science in construction
- Basics of concrete / reinforced concrete

Literature

- Schmidt, M.; Fehling, E.; Geisenhanslücke, C. : Ultra High Performance Concrete (UHPC). In: Schriftenreihe Baustoffe und Massivbau Heft 3 (2004).
- A. Bentur and S. Mindess, Fibre reinforced cementitious composites. 1990.
- Fröse, J: Optimierung der stofflichen Zusammensetzung von ultrahochfesten Betonrezepturen zur Steigerung ihrer thermischer Beanspruchbarkeit. Master thesis at the Chair of Solid Construction TUM, (2018).