Technische Universität München
School of Engineering and Design
Department of Civil and
Environmental Engineering

Lehrstuhl für Massivbau

Univ.-Prof. Dr.-Ing. Dipl.-Wirt. Ing.
Oliver Fischer

Theresienstraße 90
Gebäude N6
80333 München
Germany

Tel +49.89.289.23039
Fax +49.89.289.23030

massivbau@tum.de
cee.ed.tum.de

Master's Thesis Project Proposal

Fiber Reinforced 3D Printable Concrete

Supervisors

Shengbo Cheng, M.Sc.

Room: N2611
Tel.: 089/289-23098
E-Mail: shengbo.cheng@tum.de

Dr. ir. Freek Bos

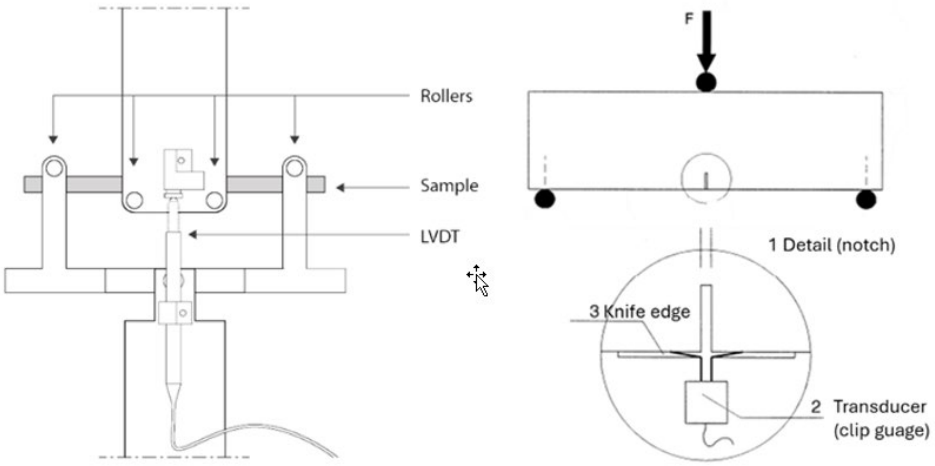
Room: N1602
Tel.: 089/289-23273
E-Mail: freek.bos@tum.de

Introduction and research objectives

Extrusion-based 3D concrete printing is a growing focus of research in the construction field. Due to its layer-by-layer deposition forming characteristics, incorporating fiber into material is one of the current mainstream methods for reinforcement.
To make the printing material efficient, a functional graded fiber reinforced printing system is under development. This system enables real-time changes in the length, content, and distribution of fibers during the printing process. However, it poses challenges in meeting the printability requirements while altering the above parameters. In addition, the variation pattern of the material's physical and mechanical (e.g. flexural capacity) properties in the transition areas still require further study. Therefore, the main objectives of this project are:

- To optimize the fresh material properties through fiber variation to achieve improved printability
- To explore the impact of variations in fiber type/length/content on the hardened properties of concrete

Some examples of 3DCP structures, from left to right: house in Eindhoven (the Netherlands), house in Beckum (Germany), bridge in Nijmegen (the Netherlands).



Setups for flexural tensile strength testing of fiber concrete, as found in literature (taken and reproduced from [1], [2]).

Methods

In order to achieve the objectives, it is expected the following research and actions are required:

- Literature study into 3D printed concrete, fiber reinforced concrete and the application of functional graded concrete
- Investigate the rheological properties of fresh concrete with different fiber types, lengths, and dosages
- Develop mix design strategies to balance extrudability, buildability, and fiber dispersion
- Conduct experimental testing on fiber reinforced concrete to assess flexural and compressive strength
- Evaluate the effects of fiber type, length and content on crack propagation and failure modes

The work is expected to take place in the LKI laboratory (Theresienstrasse, building N6) and/or Center of building material (Garching Campus) and/or TUM AMC Lab (Achering).
Depending on the quality of the work, the project may result in an academic publication (conference or journal paper).

Requirements

- Motivation and interest in this topic
- Knowledge of concrete structures
- Communication and academic writing in English

Literature

[1] A. L. van Overmeir, B. Šavija, F. P. Bos, and E. Schlangen, “Effects of 3D Concrete Printing Phases on the Mechanical Performance of Printable Strain-Hardening Cementitious Composites,” Buildings, vol. 13, no. 10, 2023, https://doi.org/10.3390/buildings13102483

[2] EN 14651 +A1 : Test method for metallic fibre concrete - Measuring the flexural tensile strength (limit of proportionality (LOP), residual), 2007.

[3] Z. Y. Ahmed, F. P. Bos, M. C. A. J. van Brunschot, and T. A. M. Salet, “On-demand additive manufacturing of functionally graded concrete,” Virtual Phys. Prototyp., vol. 15, no. 2, pp. 194–210, 2020, https://doi.org/10.1080/17452759.2019.1709009

[4] F. P. Bos, E. Bosco, and T. A. M. Salet, “Ductility of 3D printed concrete reinforced with short straight steel fibers,” Virtual Phys. Prototyp., vol. 14, no. 2, pp. 160–174, 2019, https://doi.org/10.1080/17452759.2018.1548069

[5] N. M. Andal and N. Kaviya, “Experimental Investigation of the Effects of Fly Ash on Functionally Graded Recycled Coarse Aggregate Concrete Beams Incorporating Fibers,” Lect. Notes Civ. Eng., vol. 346 LNCE, no. July 2023, pp. 371–384, 2023, https://doi.org/10.1007/978-981-99-2552-0_30

[6] G. Bai, G. Chen, R. Li, L. Wang, and G. Ma, “3D printed Ultra-High Performance Concrete: Preparation, Application, and Challenges,” Lect. Notes Civ. Eng., vol. 356 LNCE, pp. 53–65, 2023, https://doi.org/10.1007/978-981-99-3330-3_8

[7] J. F. Caron, L. Demont, N. Ducoulombier, and R. Mesnil, “3D printing of mortar with continuous fibres: Principle, properties and potential for application,” Autom. Constr., vol. 129, Sep. 2021, https://doi.org/10.1016/j.autcon.2021.103806

[8] S. Faustmann, M. Kronau, and O. Fischer, “Direct tensile tests on steel fiber reinforced concrete with focus on wall effect and fiber orientation,” Mater. Struct. Constr., vol. 57, no. 8, 2024, https://doi.org/10.1617/s11527-024-02463-2

[9] V. Mechtcherine et al., “A roadmap for quality control of hardening and hardened printed concrete,” Cem. Concr. Res., vol. 157, no. March, p. 106800, 2022, https://doi.org/10.1016/j.cemconres.2022.106800

[10] N. Roussel, D. Lowke, and R. Buswel, Digital Fabrication with Cement-Based Materials—The Rilem D.F.C. Technical Committee History, Strategy and Achievements, vol. 36. 2022, https://doi.org/10.1007/978-3-030-90535-4_1