Additive Manufacturing in Construction
1st funding period: The Challenge of Large Scale

AMC TRR277

A05

Integration of Individualized Prefabricated Fibre Reinforcement in Additive Manufacturing with Concrete

Prof. Dr. (sc. ETH) Norman Hack, Fatemeh Amiri, Stefan Gantner — Institute of Structural Design (ITE), TUBS
Prof. Dr.-Ing. Christian Hühne, Tom Rothe — Institute of Mechanics and Adaptronics (IMA), TUBS

Project summary:

In A05 the general process for robotic fabrication of individualised fibre reinforcement was developed, realised and tested in a laboratory setting. Different robotic integration strategies for wound fibre reinforcement were developed that are applicable to all additive manufacturing (AM) processes with cementitious materials investigated in TRR 277.

Main outcome of 1st funding period

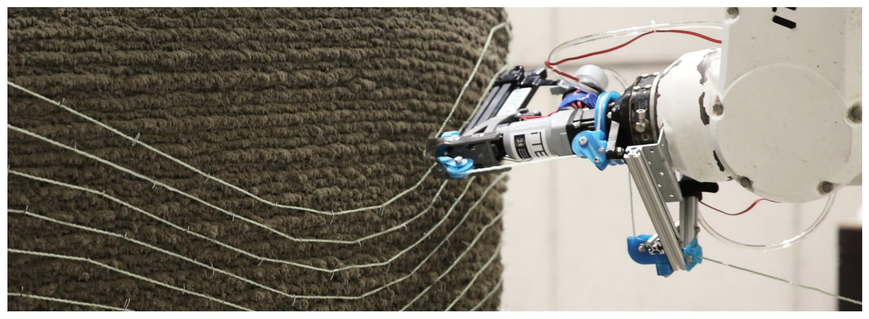


Fig. 1: Force-flow-oriented fibre application on a double-curved SC3DP wall-element

All components for automated winding, from the dynamic reinforcement production to robotic end-effectors and toolings have been developed for different sub-processes. This setup enabled the automated reinforcement of samples and demonstrators in a wide range of type and scale.

Workflow:

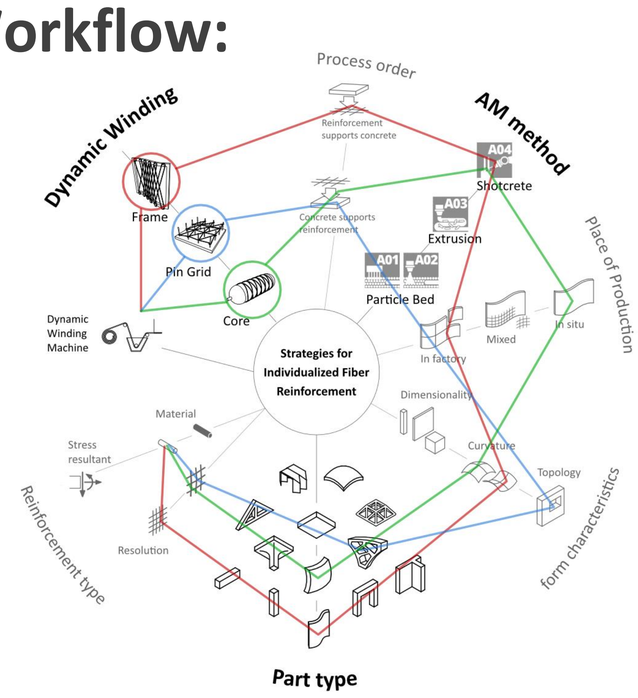


Fig. 2: Diagram allowing to trace a path in order to relate fabrication and design aspects

Individualized reinforcement production

Dynamic Winding Machine

A Dynamic Winding Machine (DWM) was developed, in which fibre material is consolidated to a strand and provided with a surface structuring.

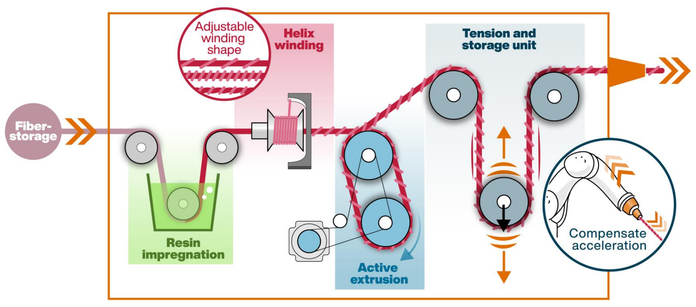


Fig. 3: Principal functionality of the Dynamic Winding Machine (DWM)

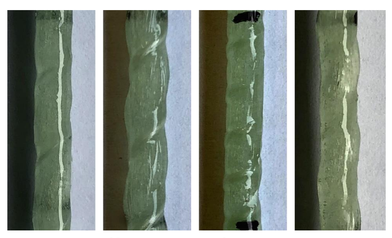


Fig. 4: Different reinforcement strands procduced by the DWM

Performance of integrated reinforcement strands

Reinforcement strands produced by the DWM have been tested in tensile and pull-out tests to characterize their mechanical behaviour. The results show comparable mechanical properties to commercial rebars.

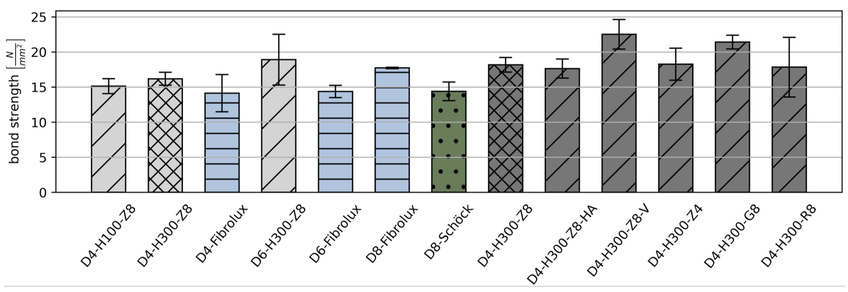


Fig. 5: Pull-out testing of reinforcement strands. Two test series have been conducted. First series with strands produced by the DWM (light grey) and commercial rebars. Second test series with strands produced by the DWM with modified surface structuring (dark grey).

Fig. 6: Test setup for pull-out testing

Key collaborations in 1st funding period

A05 has a close cooperation with A04 and is using the Shotcrete 3D Printing (SC3DP) process for several reinforcement strategies.

A05 is providing reinforcement inlays to A01, which are integrated into the SCA process.

A05 is collaborating with B04 in terms of adjusted robot path-planning for the reinforcement production and integration.

A05 is supported by C06 in sensing and determination of printed structures and pins for winding.

AMC-MERCATOR-FELLOW Prof. Dr. Mariana Popescu (Knitcrete Bridge)

Case study demonstrators

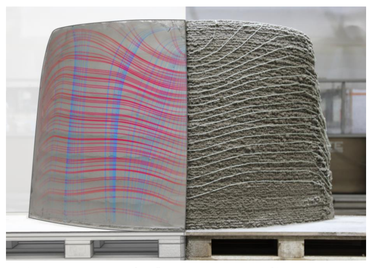


Fig. 8: Example for Core Winding

Core Winding:
- Reinforcement on concrete core
- Freely orientable (Force-flow)
- Embedding: SC3DP cover-layer

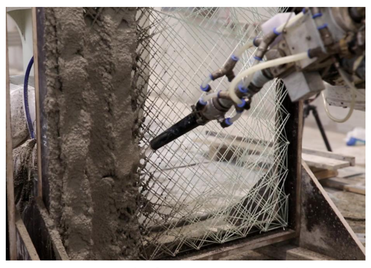


Fig. 9: Example for Frame Winding

Frame Winding:
- Reinforcement supports concrete
- SC3DP for fibre mesh penetration
- Synchronised shield formwork

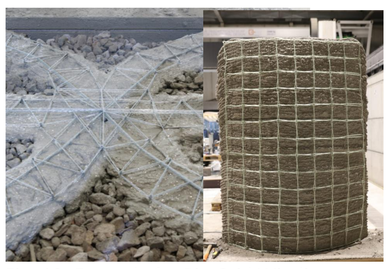


Fig. 10: Example for Pin Grid Winding

Pin Grid Winding:
- Inlays on reusable formwork
- Flat and slightly double-curved
- Applied to SCA, SPI and LP3DCP

Conceptual process design

Reinforcement strategies for Particle Bed Printing, Shotcrete 3D Printing and Extrusion Printing have been developed conceptually. The build-up logic of each AM-process has been taken into account in order to develop methods for fibre integration. This allows to reinforce the structure across layers and in a non-orthogonal force-flow oriented manner.

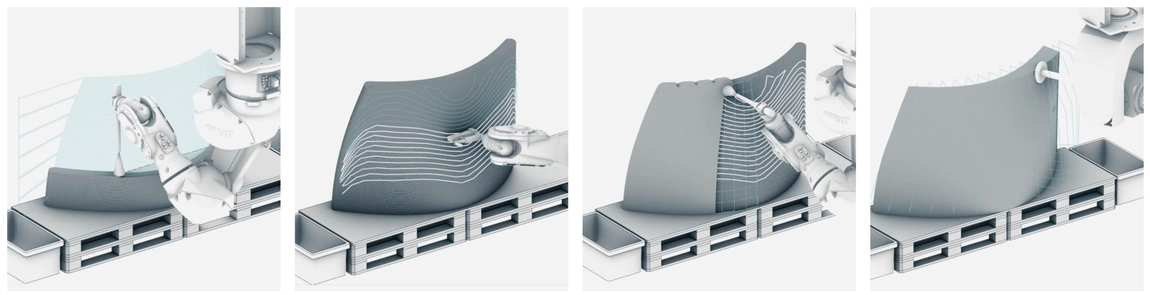


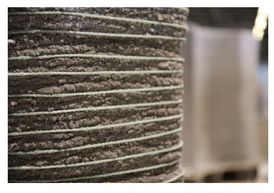
Fig. 7: Fabrication steps for the concept of Core Winding: SC3DP with subsequent fibre integration

Large scale demonstrators

Fig. 11: Robotic fibre integration in large scale fabrication

Knitcrete Bridge
- Unique process combination: SC3DP, Knitcrete, Fibre Winding
- Adapted Pin Grid Winding derived from integral design.

Shelltonics (column)
- First winding application within a multi-element-system
- Challenging trade-off: Complex design, reinforcement conventions and digital fabrication.



Funded by
DFG Deutsche Forschungsgemeinschaft
German Research Foundation

Technische Universität Braunschweig
Technical University of Munich