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

AMC TRR277

A04

Integrated Additive Manufacturing Processes for Reinforced Shotcrete 3D Printing (SC3DP) Elements with Precise Surface Quality

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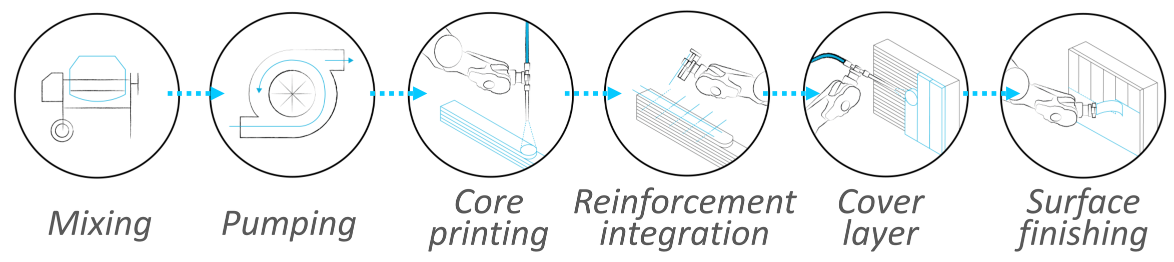
Project summary

The aim of this project is to investigate cooperative additive manufacturing processes for the production of material efficient, force-flow oriented, reinforced, load bearing concrete components with precise surface quality and geometry precision based on Shotcrete 3D Printing (SC3DP).

Workflow



Main outcome of 1st funding period

Material-process interaction
- High accelerator dosages result in weakening of layer bond strength
- Viscosity modifiers are increasing the precision of the layer geometry
- Layer geometry is systematically controllable by nozzle design

Reinforcement integration
- Force flow oriented reinforcement layouts increase flexural strength of reinforced beams up to 60 %
- Rotational thread pitch matched integration of short rebars (SRI) increases the bond strength by 68 % compared to a direct insertion
- Automated SRI with integration speed of 10 mm/sec and rebar magazine

Surface quality
- Geometrical precision (< 10 mm) and high surface qualities were achieved by subtractive processing in fresh-state with rotating tools

Key collaborations in 1st funding period

A05 – Integration of reinforcement strategies and the design of the final demonstrator

A07 – Wire Arc Additively Manufactured (WAAM) steel rebars

B03 – Simulation of SC3DP process and analysis of the particle speed

B04 – Simulation based path planning and sensor based process control

C05 – Manufacturing of specimens for experiments on jointing principles

C06 – Scanning technology for validating printed components and detailed process surveillance

AMC-MERCATOR-FELLOW
Prof. Dr. Nicolas Roussel

AMC-MERCATOR-FELLOW
Ass. Prof. Dr. Mariana Popescu

Material-process interaction

Interaction of main process parameters
- air volume flow
- concrete volume flow
- accelerator dosage
- traverse speed
- nozzle design

have been investigated

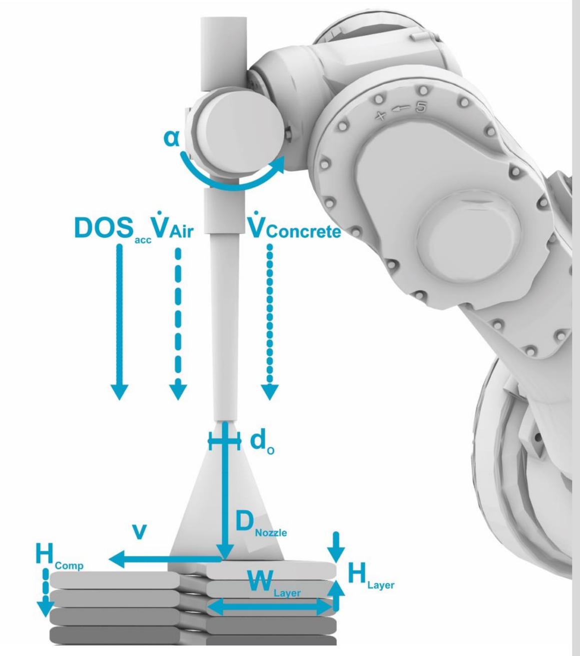


Fig 1: Parameter overview for SC3DP

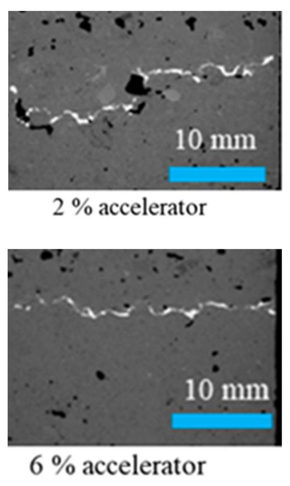


Fig 2: Influence of accelerator dosage, Source: Dressler et al. (2020)

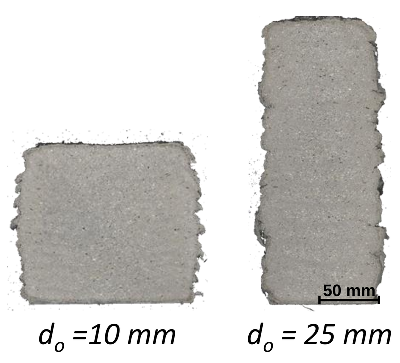


Fig 3: Results of nozzle outlet diameter, Source: David et al. (2023)

Reinforcement integration

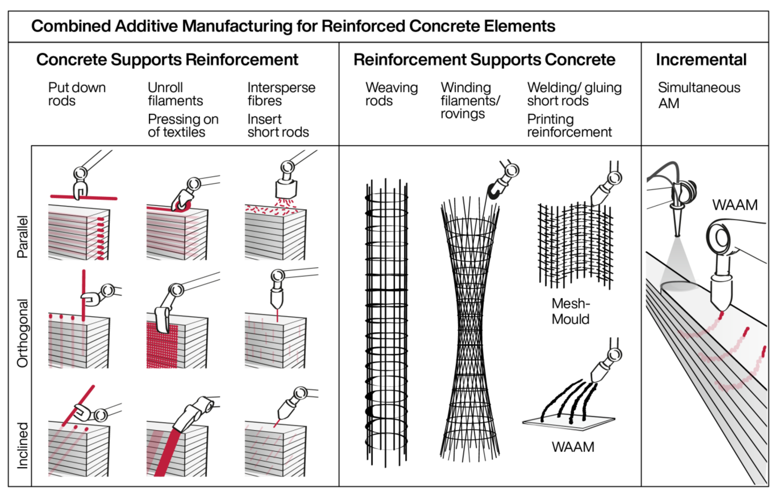


Fig 4: Characterisation of reinforcement strategies, Source: Hack et al. (2020)

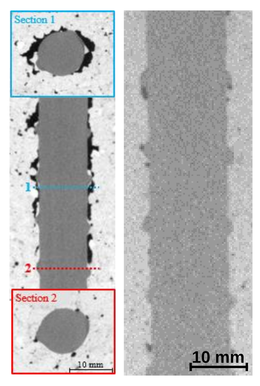


Fig 5: Bond zone of direct and screwed insertion of rebars, Source: Freund et al. (2020)

- Force-flow oriented reinforcement design was experimentally investigated
- Integration strategies and bond behaviour for rebars, fibers and fiber mats for interlayer reinforcement were evaluated
- Development of end effectors for the automated reinforcement integration
- Derivation of strategies for the manufacturing of structural construction elements

Surface quality

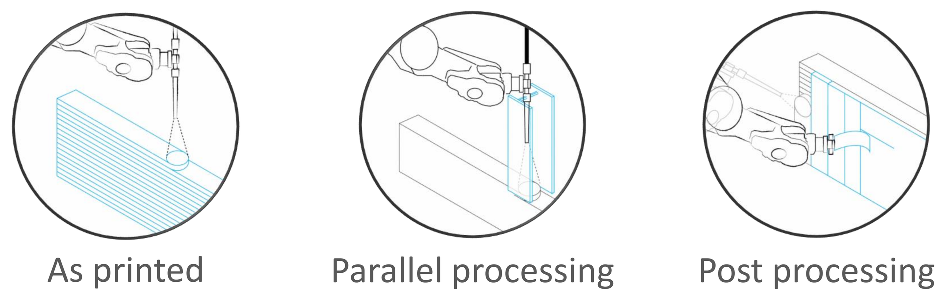


Fig 6: Characterisation of surface processing strategies

Evaluation of subtractive and formative post- and parallel processing with rotating tools/trowels for architectural surfaces on simple geometries

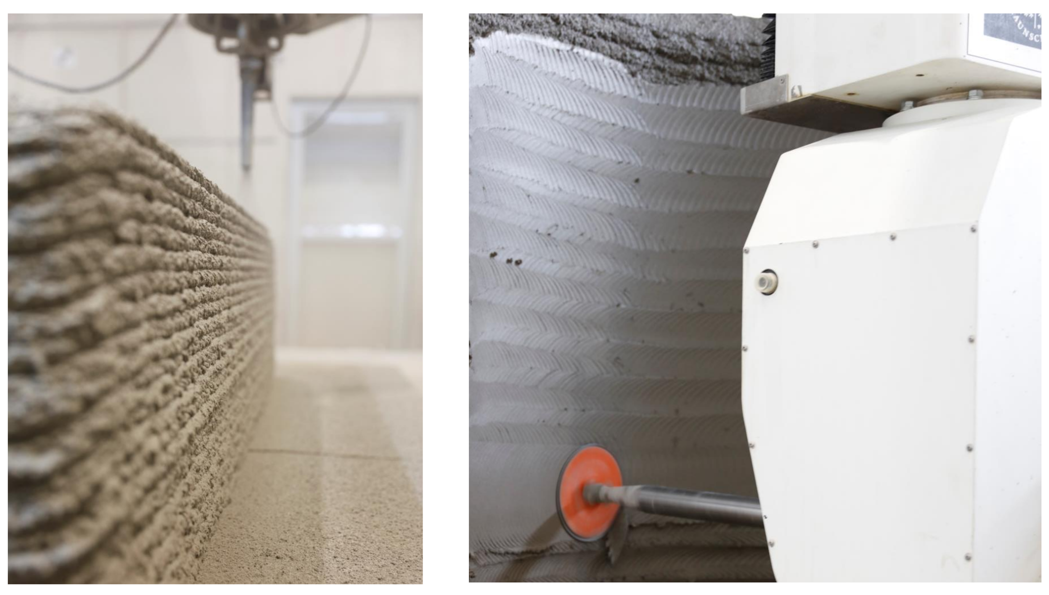


Fig 7: Results on surface processing strategies

Integrated reinforced SC3DP elements

- Large scale demonstration of automated processes
- Combination of several reinforcement strategies (interlayer reinforcement, automated short rebar insertion and fibre winding (A05))
- Integration of functional and technical elements (e.g. piping and heating)

Fig 8: Wall segments of final demonstrator in manufacturing environment

Large scale demonstrators

Fig 9: Shelltonics demonstrator

Shelltonics – in collaboration with:
- A05 - fibre winding techniques
- B04 - online process control
- C01 - force-flow analysis
- C03 - functionalisation concept
- C05 - concept for element jointing
- C06 - geometrical quality control / AR
- C07 - documentation / process analysis

Fig 10: Knitcrete bridge demonstrator

Knitcrete bridge – in collaboration with:
- A05 - design / fibre winding techniques
- B05 - process control / path planning
- C02 - design / force-flow analysis
- C06 - geometrical quality control / AR
- Mercator Fellow - Mariana Popescu – Concept and design / formwork structure

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