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

AMC TRR277

A02

Particle-Bed 3D Printing by Selective Cement Paste Intrusion (SPI) - Particle Surface Functionalisation, Particle Synthesis and Integration of WAAM Reinforcement

Prof. Dr.-Ing. C. Gehlen, T. Kränkel, A. Straßer
Prof. Dr.-Ing. A. Kwade, H. Zetzener, L. D. Hamilton
Prof. Dr.-Ing. M. F. Zaeh, S. Baehr, J. Schulz, F. Riegger

Chair of Material Science and Testing (cbm), TUM
Institute for Particle Technology (iPAT), TUBS
Institute for Machine Tools and Industrial Management (iwb), TUM

Project aims of 2nd funding period

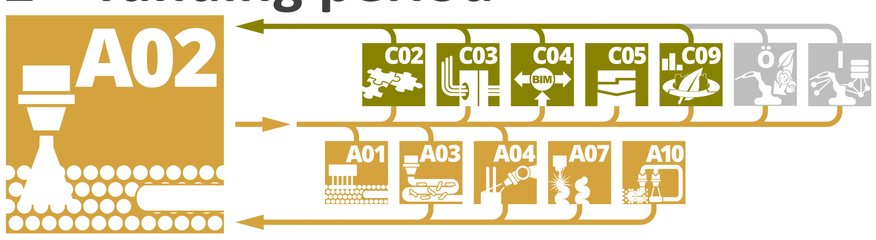
The two main objectives of A02 are:

1. Improvement of the environmental sustainability of the combined SPI + WAAM process
2. Acceleration of the process speed of the combined SPI + WAAM process

Three tasks were identified to achieve this goal:

a. Reduction of the ecological impact of the materials (aggregates and cement paste) used in the SPI process
b. Acceleration of the WAAM process by integrating stud welding (SW)
c. In-depth-studies on the influence of parameter and material adaptions on component properties

Key collaborations in 2nd funding period



- A03: Cement paste mixture / reducing clinker with supplementary cementitious materials (SCM)
- A04: Exchange on reinforcement integration
- A07: Exchange on welding processes
- C09: Life cycle assessment (LCA) / environmental sustainability evaluation of the process / sensitivity analysis

Work programme

WP 1 (C09)
Aggregate preparation

- **WP 1.1** Design of packing density
- **WP 1.2** Sensitivity of the aggregate function to the surface properties (C03)
- **WP 1.3** Aggregate customisation strategies (A01, A03)

WP 2 (C09)
Environmental concrete sustainability and durability

- **WP 2.1** Cement paste adjustment (A03, A10)
- **WP 2.2** Aggregates replacement
- **WP 2.3** Particle size and packing density

WP 4
Protruding reinforcement from particle bed

- **WP 4.1** Shadowing effects
- **WP 4.2** Particle bed levelling
- **WP 4.3** Contamination of the welding point

WP 3 (A04, C09)
Hybrid AM process for the production of reinforcements

- **WP 3.1** Interrelations of WAAM + SW (A07)
- **WP 3.2** Automatised path planning and simulation for WAAM + SW (C04)
- **WP 3.3** WAAM + SW material properties

WP 5 (C09)
Combined SPI + WAAM + SW process

- **WP 5.1** Effects of the building rate on the mechanical performance of reinforced concrete
- **WP 5.2** Methods for detecting and filling shadowed areas
- **WP 5.3** Implementation of WAAM + SW in SPI (C02, C04)

WP 6 (C02, C05, C09)
Final demonstrator

Fig. 1: Work package (WP) flowchart

Methods

Implementation of tailored, recycled aggregates:

- Surface as well as chemical analysis of recycled aggregates to determine their suitability for SPI and mechanical processing and material preparation for these aggregates (iPAT)
- Investigations of multi-modal aggregate size distributions for increased packing densities and determination of the equilibrium of adhesive/cohesive forces to prevent segregation (iPAT)

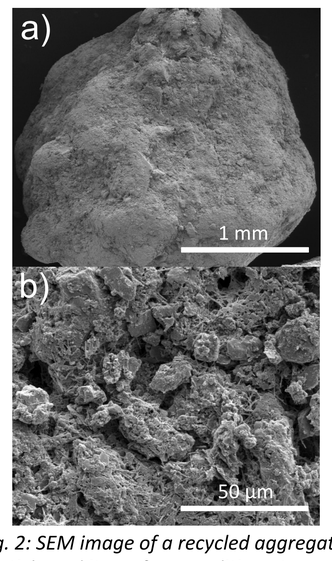


Fig. 2: SEM image of a recycled aggregate particle and its surface condition at magnifications of: a) 500 X and b) 10,000 X

Combination of WAAM with SW:

- Analysis of the process interrelations of WAAM + SW and determination of the material properties of the hybrid-manufactured steel components (*iwb*)
- Automated path planning by developing a computer-aided manufacturing (CAM) tool for WAAM + SW, which will interact with a thermal simulation of the WAAM + SW process (*iwb*)

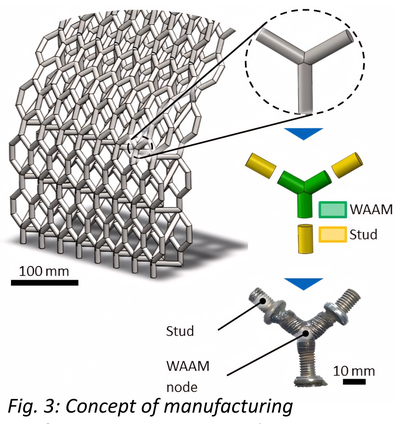


Fig. 3: Concept of manufacturing reinforcement structures with WAAM + SW

Environmentally sustainable construction materials and large-scale printing: Enhancing aggregates, cement paste, and WAAM/SPI printing

- Increasing the environmental sustainability of aggregates and cement paste by using for example SCM, recycled aggregates, and increased grain sizes (cbm, iPAT)
- Investigations on limitations by simultaneous WAAM and SPI printing (protruding WAAM bars, particle bed leveling, and shadowed areas) are conducted.
- Extending the large-scale printer based on the findings (cbm, *iwb*)

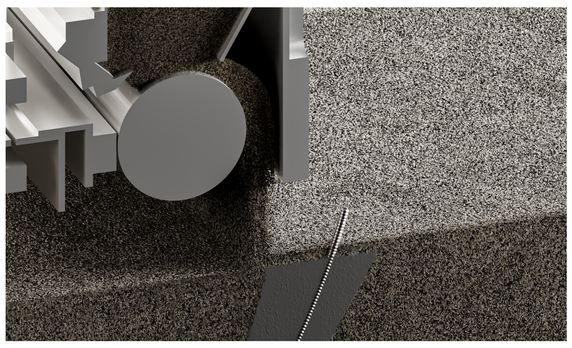


Fig. 4: Collision between a scattering roller and a protruding steel reinforcement

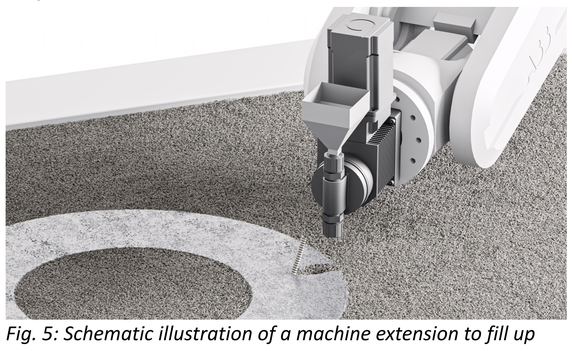


Fig. 5: Schematic illustration of a machine extension to fill up shadowed areas

Outlook 3rd funding period

- The extended large-scale printer will be capable of producing components with graded material properties and stud-welded reinforcements by WAAM.
- Fundamental research regarding the degree of automation and the building rate to transfer the hybrid process to industrial applications will be conducted.
- A large full demonstrator optimised in its structure, environmentally sustainable aspects, and the automation of the production process by the input of C02 and C09 will be produced.

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