

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

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Project aims of 2nd funding period

Environmental sustainability

- Reduction of carbon footprint on material, design and process level

Material properties and process interaction

- In-depth material characterisation in fresh and hardened state
- Online control of material parameters and extension of process control

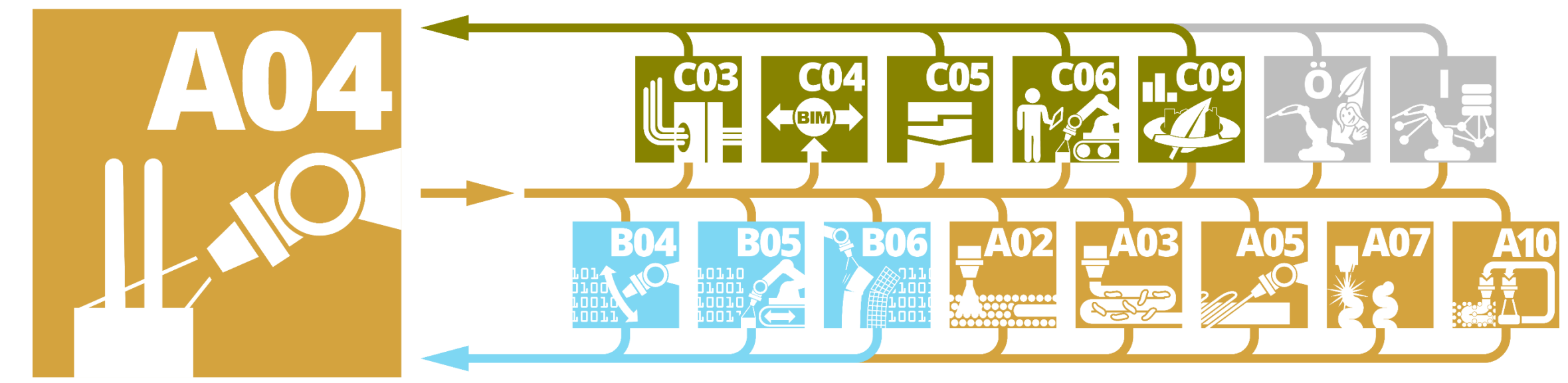
Reinforcement and surface

- Evaluation of new concepts for continuous 3D reinforcement structures
- Methods and tools for automated surface processing expanding the usability of SC3DP to free-form geometries

On-site SC3DP processes

- Influences of environmental conditions on SC3DP
- Concepts for mobile robots for on-site processes

Key collaborations in 2nd funding period



- Environmental sustainability (C09, A10, A03)
- Material design and process interaction (A10, B06, B04)
- Online-process control and mobile robots (B04, B05, C04)
- Reinforcement (A02, A03, A05, A07, C05)
- Surface design, functions and quality assessment (C03, C06)
- On-site processes for SC3DP (B04, B05, C06)

Work programme

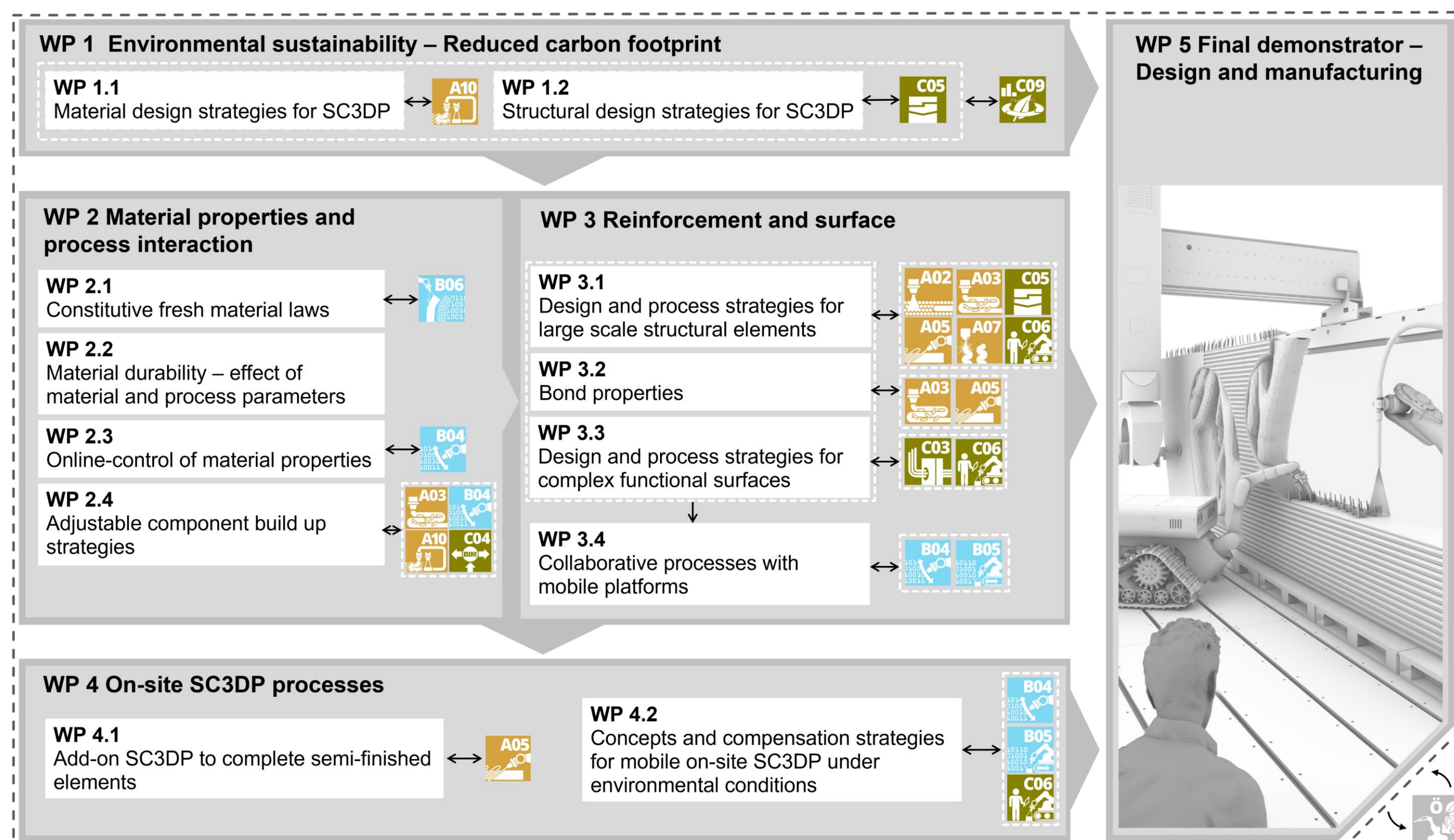


Fig 1: Work programme of 2nd funding period

Environmental sustainability

- Material level**
 - Substitution of cement
 - Increase of aggregate size
- Design level**
 - Reduced material use
 - Structural optimisation
- Process level**
 - Continuous and discrete material grading

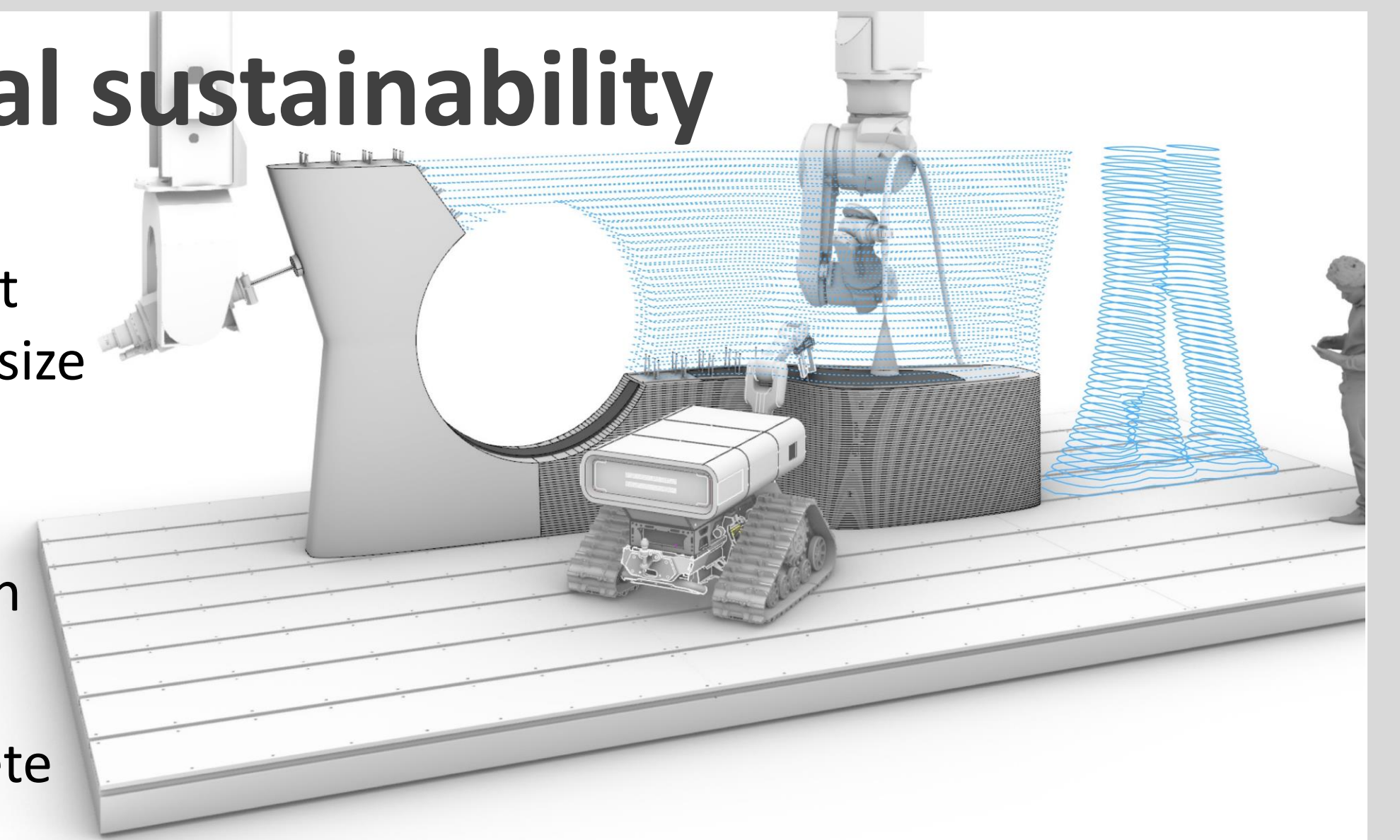


Fig 3: Reduction of CO₂ footprint on various levels

Material and process interaction

- Constitutive fresh material laws
- Material durability
- Online control of material properties
- Component build-up strategies
- Grading strategies for SC3DP



Fig 4: Chloride migration for SC3DP specimen, Credit: IBMB, TUBS

Methods

- Evolutionary algorithms for force flow compliant designs and reinforcement layouts
- Process and material monitoring with adaptive control algorithms
- Experimental investigation of mechanical fresh-state and rheological properties
- Experimental investigation of material durability
- Evaluation of combined reinforcement strategies based on design, component requirements and resulting bond behaviour
- Inventing end effectors for automated reinforcement integration and processing of free-formed surfaces

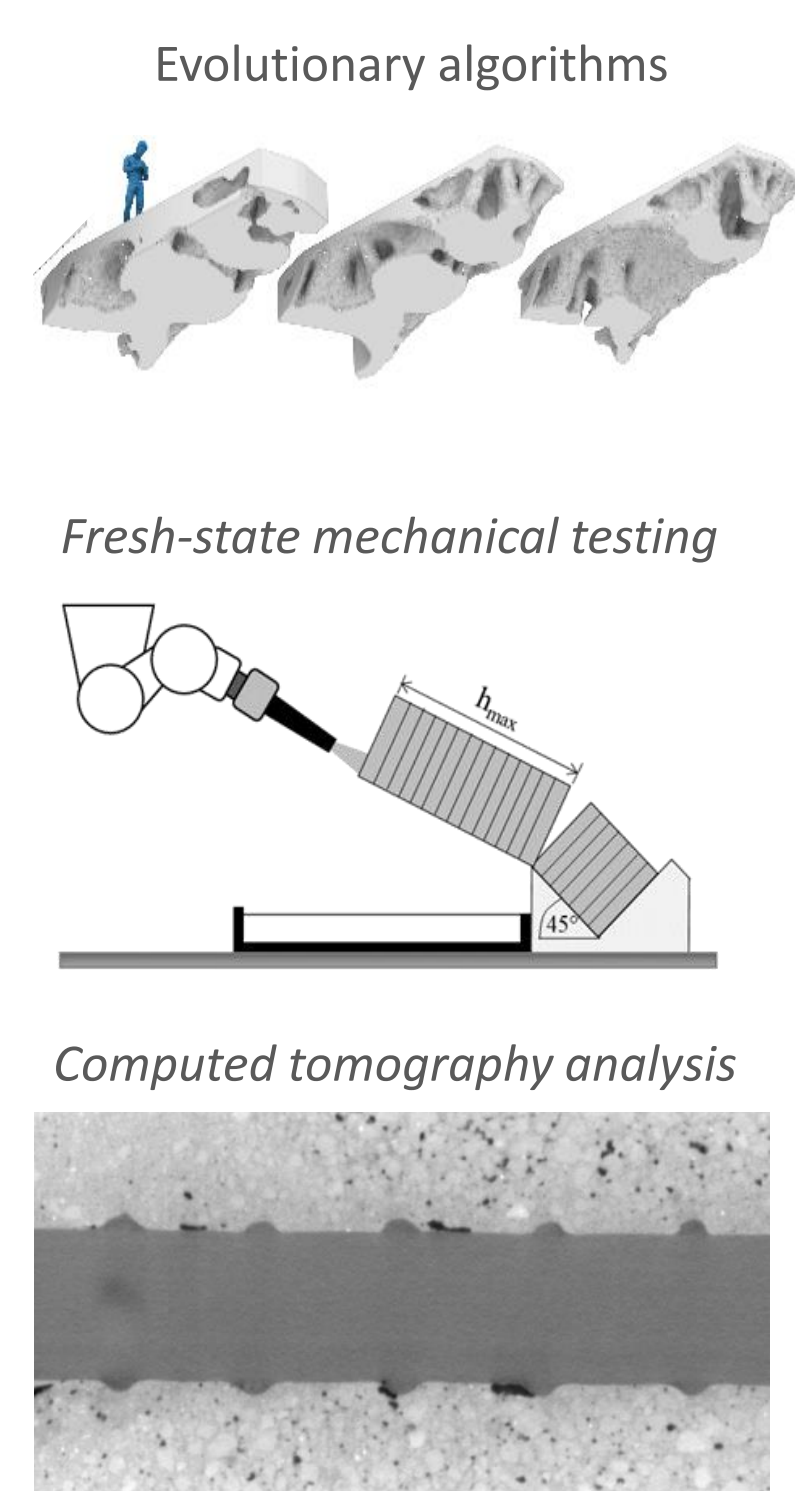


Fig 2: Selection of methods used within 2nd funding period

Reinforcement and surfaces

- Combination of reinforcement strategies and anchorage systems
- Strategies for complex three-dimensional reinforcement layouts
- Use of mobile robots for integration

Strategies for Reinforcement Integration					
Short Rebar Integration			Prefabricated Structures		
Screwed	Vibrated	Bond. Mortar	Rebars	WAAM	Fibres
Interlayer Reinforcement			Cover Layer Reinforcement		
Fibres	Rebars	Meshes	Fibres	Rebars	Meshes
Incremental					
Stud Welding	Clamping	WAAM			

Fig 5: Evaluation matrix for reinforcement integration in 2nd funding period

Tab 1: Evaluation matrix for surface processing

Design and Manufacturing Strategies for Surfaces		
As printed	Post-processed	
	Without coverlayer	With coverlayer
<ul style="list-style-type: none"> • Precision based on printing precision • Reinforcement integration during printing 	<ul style="list-style-type: none"> • Subsequent modification of surface • Functionalisation through texture modification • Reinforcement integration during printing 	<ul style="list-style-type: none"> • Subsequent modification of surface • Functionalisation through texture modification • Material-based functionalisation

- Strategies for free-form geometries regarding path planning and tools
- Three stage approach to improve surface quality and geometrical precision

Outlook 3rd funding period

- Use of local and recycled materials in SC3DP
- Constitutive material laws and durability
- Fully mobile SC3DP processes
- Combined automated SC3DP assembly strategies
- SC3DP for full-scale infrastructure
- Transfer of knowledge to industrial scale

On-site SC3DP

- Mobile robotic SC3DP
- Environmental influences
- Compensating strategies
- Add-on SC3DP

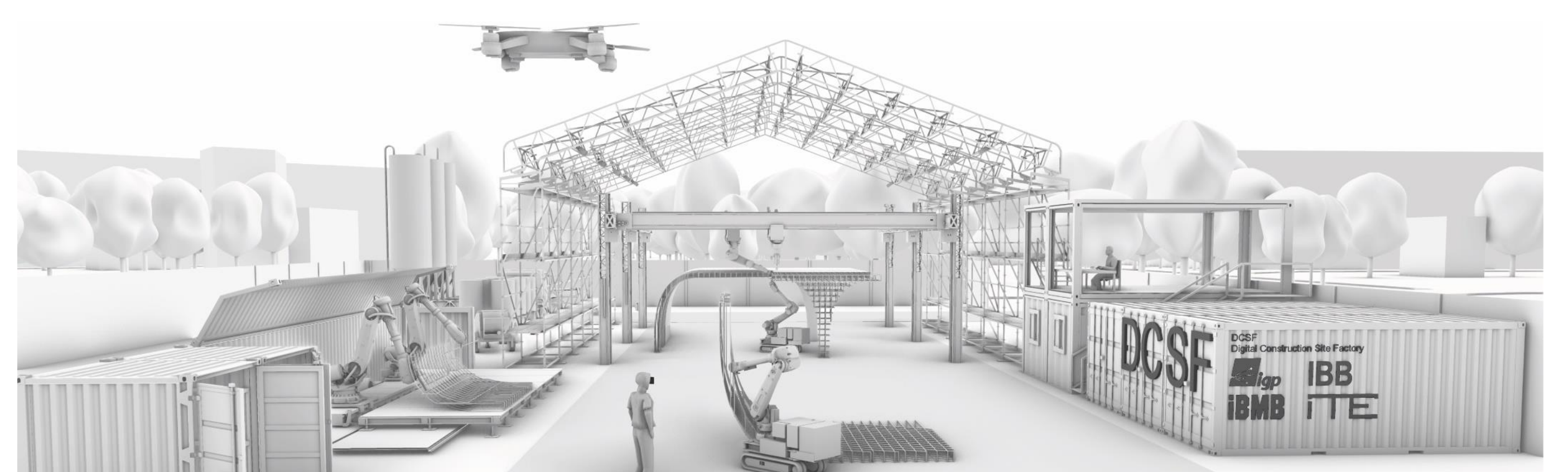


Fig 6: Mobile setup for an on-site SC3DP process, Source: Kloft et al. (2022)