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

AMC TRR277

C02

3D structural puzzle – Numerical Multi Scale Shape and Topology Optimisation Methods to Additively Manufacture Optimal Structures from Optimised Pieces

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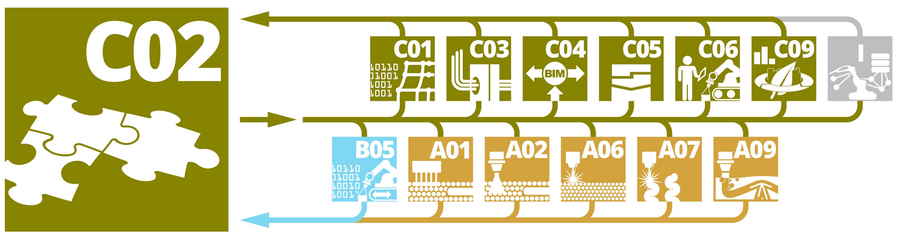
Project aims of 2nd funding period

Formalisation of a Holistic Design Framework (HDF) based on:

- **Multi-fidelity**: bi-directional coupling of Discrete Optimisation Approach (DOA) and Continuum-based Optimisation Approach (COA).
- **Multi-scale**: concurrent design of optimal structural forms (global scale) and segmentation into structural components (local scale).
- **Multi-material**: adaptability to different material models and opportunity for material grading.
- Integration of specific **AM-process-related** constraints and objectives.
- Development of dedicated **interfaces to other AEC disciplines** (building physics, building informatics, construction management, life-cycle assessment).

Key collaborations in 2nd funding period



- A01 - adapt HDF to SCA
- A02 - adapt HDF to SPI
- A06 - adapt HDF to LPBF
- A07 - adapt HDF to WAAM
- A09 - adapt HDF to I3DCP
- B05 - adapt HDF to MCE
- C01 - integrate advanced structural analysis
- C03 - integrate building physics
- C04 - interface to BIM
- C05 - refine joints of structural pieces
- C06 - integrate construction sequence
- C09 - integrate LCA

Work Programme

WP 1 Formulation of th Holistic Design Framework (multi-fidelity, multi-scale, and multi-material approach)

- **WP 1.1:** Extension of existing methods of Discrete Optimisation Approach (DOA)
- **WP 1.2:** Extension of existing methods of Continuum-based Optimisation Approach (COA)
- **WP 1.3:** Integration of DOA and COA into the HDF
- **WP 1.4:** Segmentation in structural pieces (3D puzzle)

WP 2 Integration of AM constraints and objectives

- **WP 2.1:** Formulation and modelling of AM-specific constraints and objectives ↔ A01, A02
- **WP 2.2:** Integration of direct design variable-related AM constraints and objectives in the Holistic Design Framework (HDF) ↔ A06, A07
- **WP 2.3:** Integration of primal-related AM constraints and objectives in the HDF ↔ A09
- **WP 2.4:** Multi-fidelity integration of the AM-specific constraints and objective ↔ B05
- **WP 2.5:** Refinement of structural pieces for AM (structural 3D puzzle) ↔ C05

WP 3 Extension to other Architectural Engineering Construction (AEC) disciplines

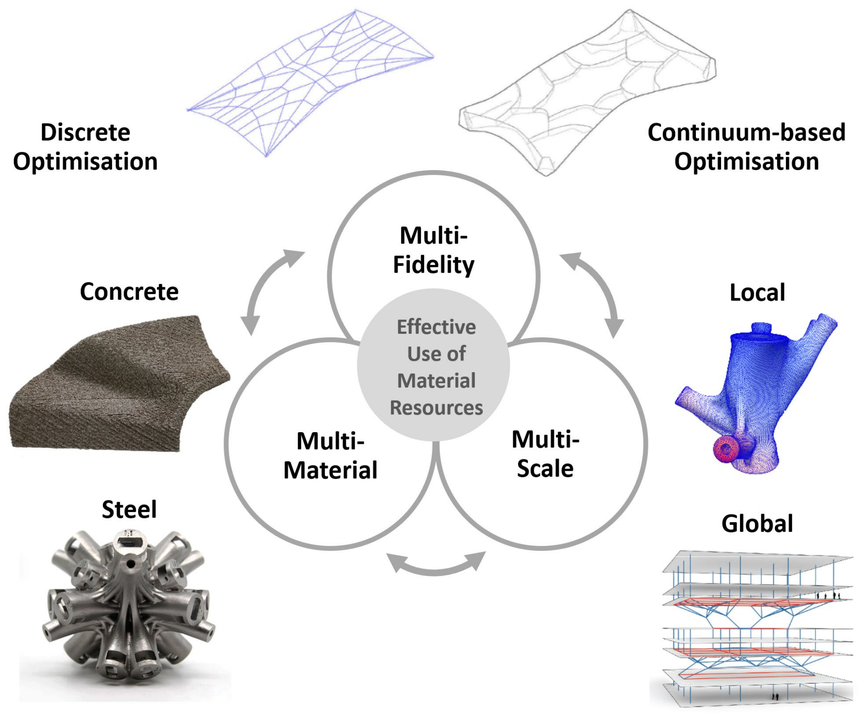
- **WP 3.1:** Interface to specialized structural analysis methods ↔ C01
- **WP 3.2:** Development of interface for BIM ↔ C04
- **WP 3.3:** Extension to building physics ↔ C03
- **WP 3.4:** Implementation of the construction sequence ↔ C06
- **WP 3.5:** Integration of life cycle assessment ↔ C09

WP 4 Implementation of the HDF into the design and construction of demonstrators

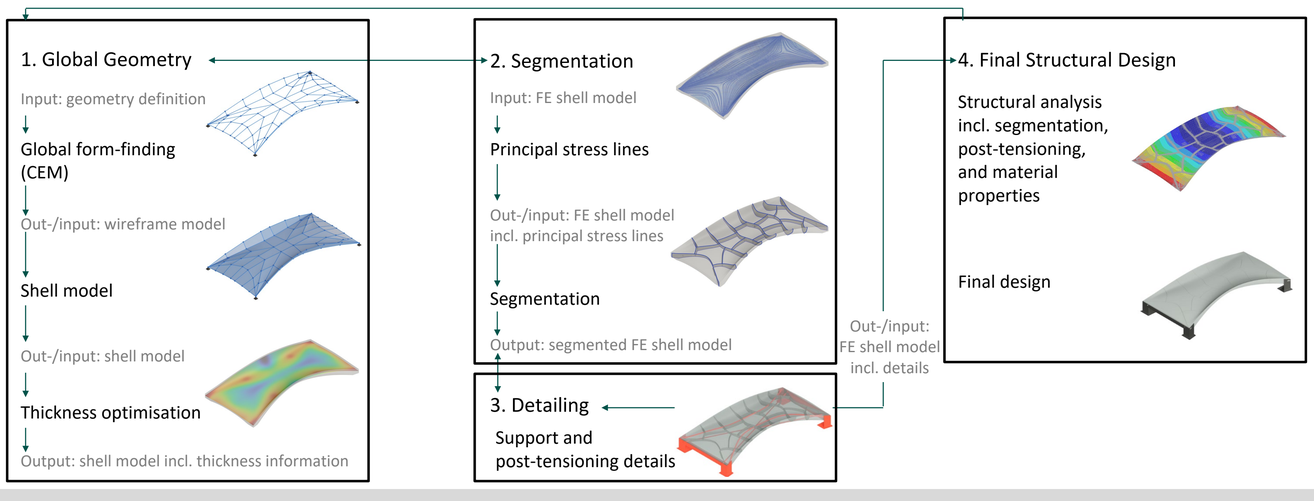
Methods

The HDF used in this project will combine the low-fidelity Discrete Optimisation Approach (DOA) and the high-fidelity Continuum-based Optimisation Approach (COA):

- The DOA for structural form-finding is based on **Vector-based Graphic Statics (VGS)** and **Combinatorial Equilibrium Modelling (CEM)**.
- The DOA operates on discrete equilibrium-based models subject to only tensile and compressive axial forces.
- The COA is built on finite element discretisation of solid structural geometries with a node-based parametrization for structural optimisation.
- **Vertex Morphing (VM)** in combination with complex FEM allows for the extension of the approach to arbitrary design variables.



Workflow



Outlook 3rd funding period

The goal for the 3rd funding period is to advance further the methods and tools formulated in the 2nd funding period to enhance the flexibility of the HDF via:

- Formulation of a **Multi-Disciplinary Design Framework (MDDF) for Additive Manufacturing in Construction**,
- Inclusion of the building life-span variable in the MDDF,
- Implementation of the MDDF into the demonstrators at the architectural scale.

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