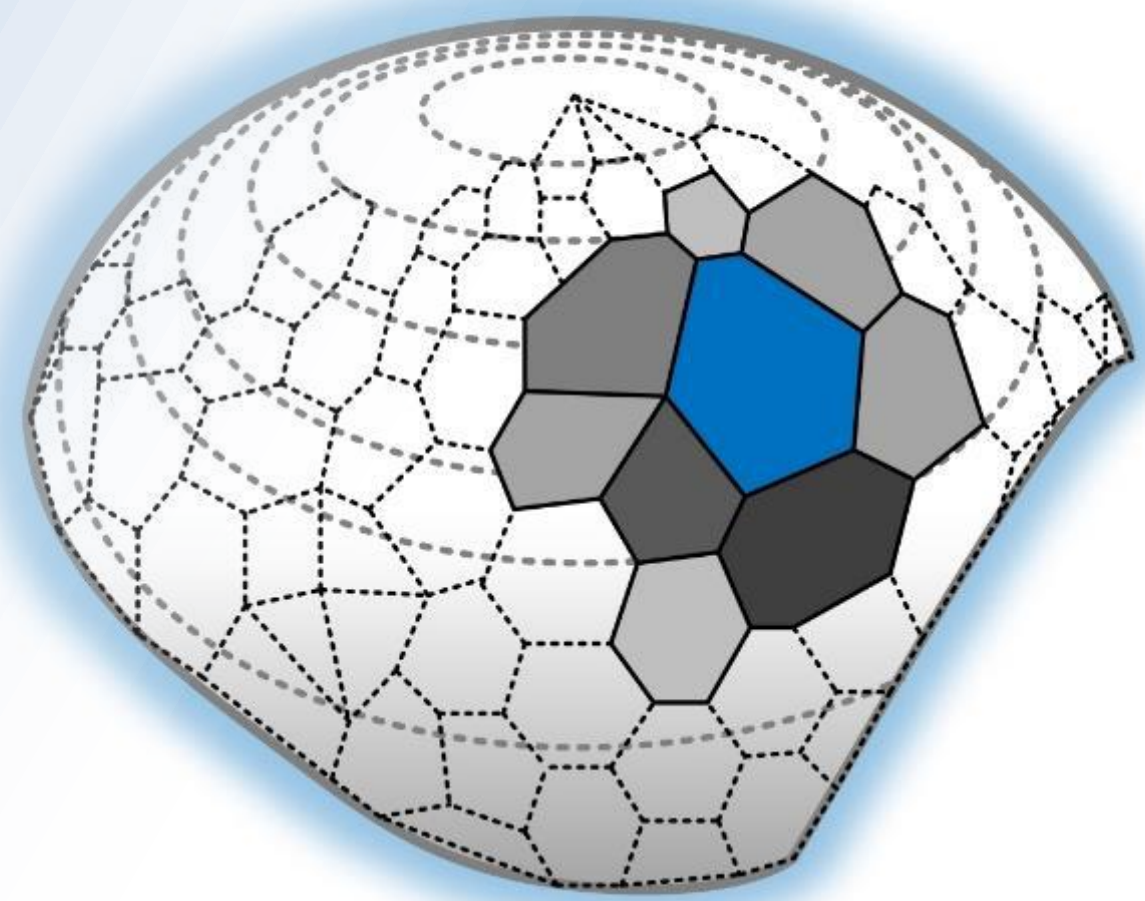


TP 12: Fabrication of modular lightweight concrete components with fully recyclable formwork systems

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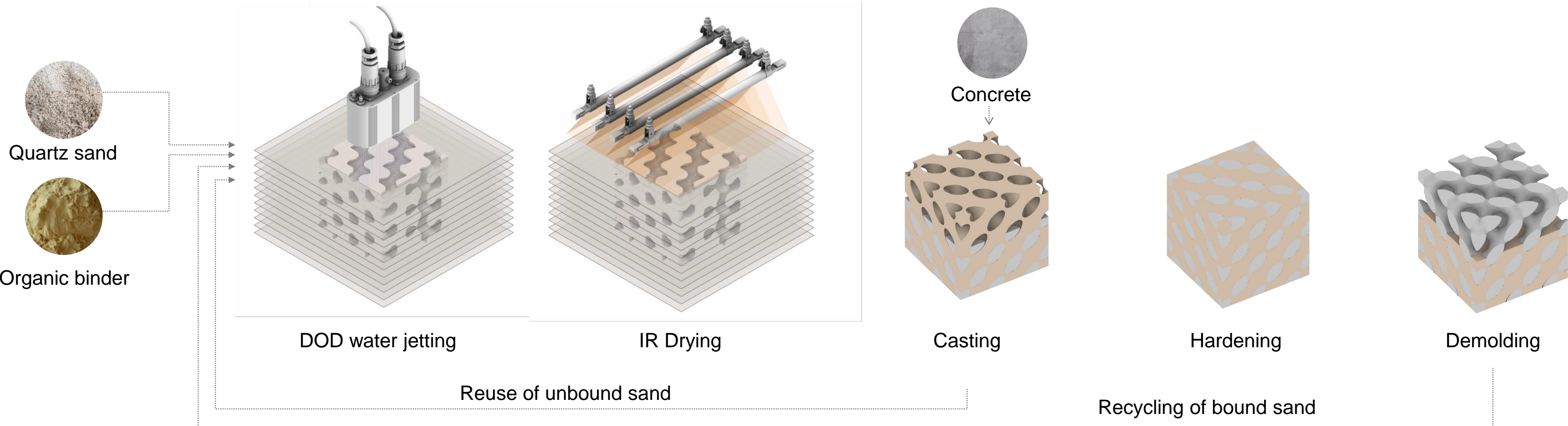


SPP 2187

Methods

Water-soluble sand formwork

Within the framework of SPP this subproject deals with circular production strategy for lightweight concrete structures, focusing on zero-waste formwork technology. To achieve fast and precise production of complex formwork geometries, typical for shape- and topology-optimized lightweight concrete structure, the mixture of sand and organic binder (corn starch) is combined with powder bed-based additive manufacturing technique. The binder, premixed with sand, is getting activated by water-jetting and binds sand particles when water is evaporated during infrared drying. Resulting formwork can sustain concrete hydrostatic pressure but is water-soluble and all formwork material can be reused in further production cycles.

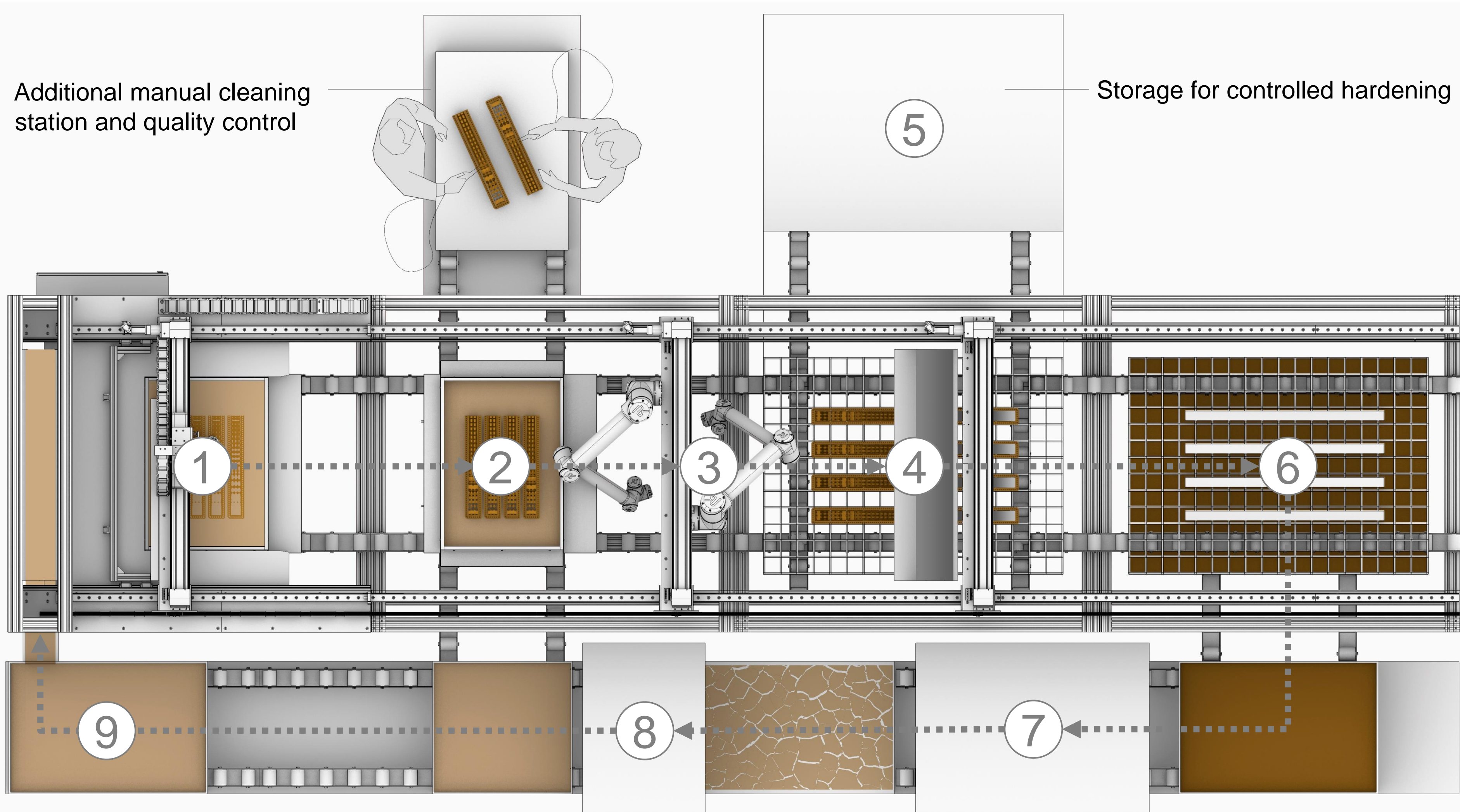


Circular production process

In the first project phase (until December 2022) the focus is set on development of modular production unit for formwork 3D printing (marked as 1 on the production line diagram). The module is extendable and can be integrated into flow line by adding new modules along its X-axis. During the first project phase the full production cycle including production of concrete components as well as the recycling of formwork materials is conceptualized and is illustrated on the diagram.

Production + Recycling diagram legend:

- 1. 3D Printing of formwork
- 2. Demolding of formwork blocks
- 3. Assembling of formworks element, positioning of reinforcement and connections
- 4. Casting
- 5. Hardening
- 6. Demolding
- 7. Drying of sand and binder
- 8. Crushing of sand and binder
- 9. Reloading of sand

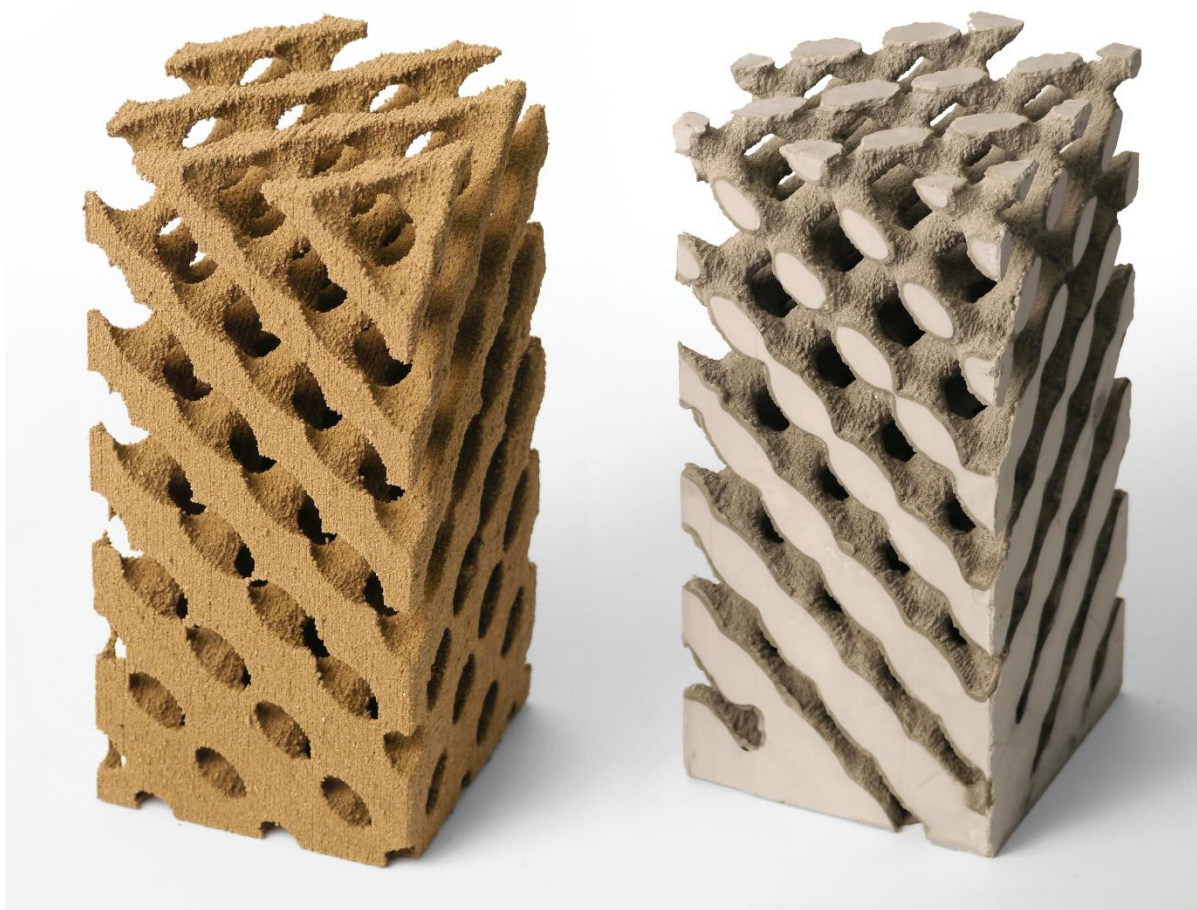
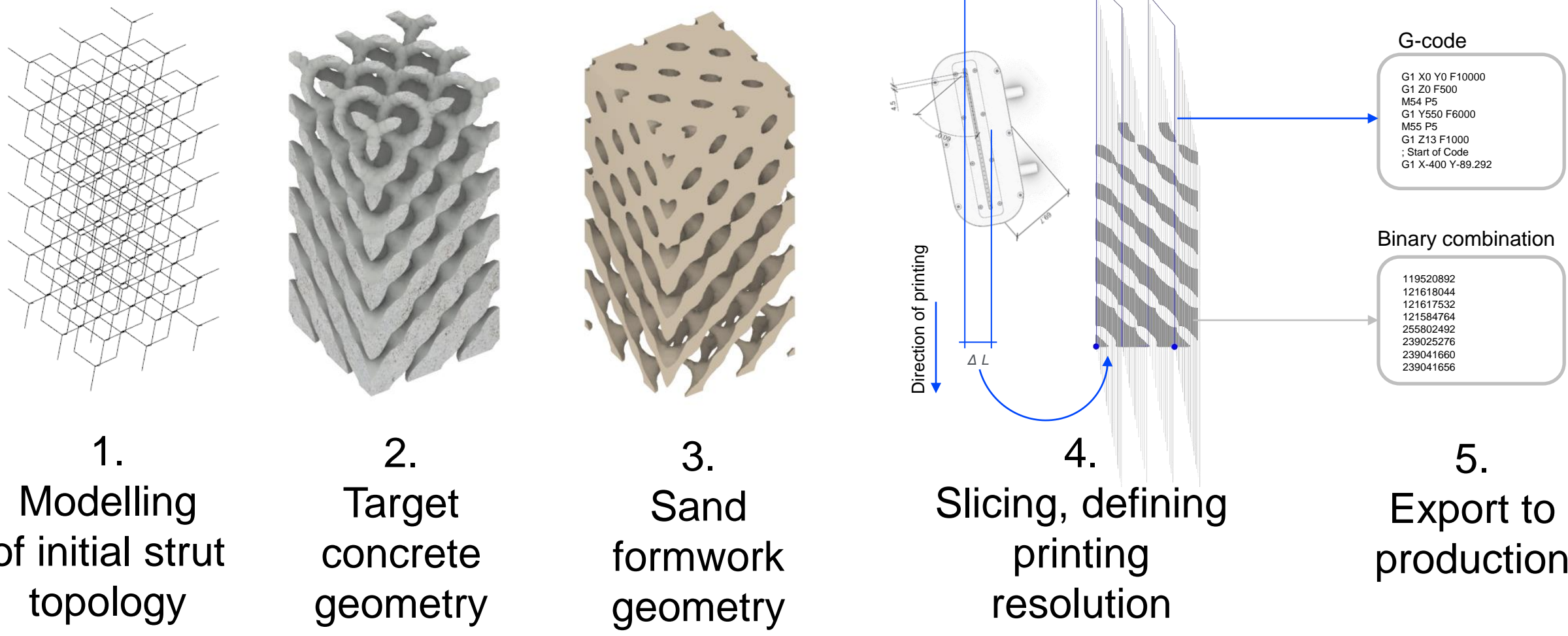


Results

Integrated design-to-fabrication chain

The interrelation between design and fabrication is key for the development of the method. Design intention to produce geometrically complex spatial formwork structures defines the choice of material system and manufacturing technique. Production instead puts constraints onto design of producible concrete and formwork parts. Concrete components should be designed appropriately, so that all areas of formwork should be castable and all formwork material should be possible to take out without much expense. During the modelling, first the target concrete shape and topology is geometrically of numerically modelled, then the opposite formwork geometry is generated. Further, it is processed through slicing procedure where the necessary resolution of printing is assigned .

Design-to-production chain of spatially graded concrete block

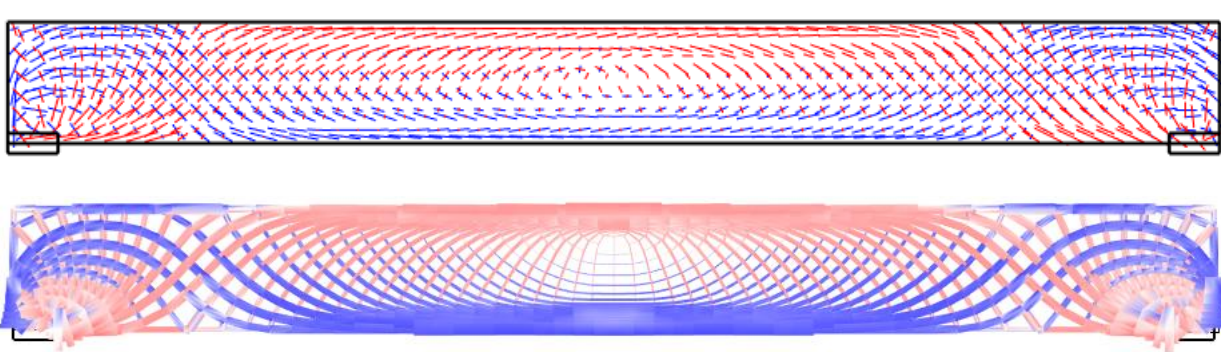


Production of lightweight structural elements

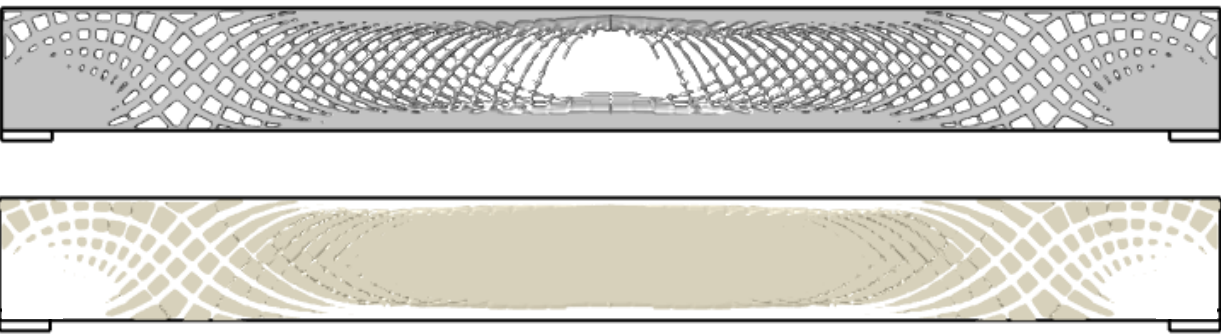
Several design-to-production iterations were carried out to check the design possibilities and constraints, as well as the speed, accuracy and stability of the production process.

The design started with the analysis and modelling of graded concrete structure within the design domain. Based on the fabrication constraints, such as concrete viscosity, grain size and formwork printing resolution, the target concrete geometry and corresponding formwork geometry were modelled. On the next step, formwork was separated into individual parts to fit the powder bed working area. Then, the formwork parts were printed layer-by-layer and dried immediately to achieve ready-to-cast formwork elements in one production step. Further, individual formwork parts were assembled, reinforcement was placed, and self-compacting concrete was poured to eliminate the excessive shaking. After hardening, the formwork was washed out by running water until all the sand was extracted. The sand was collected and dried in the oven until all water was evaporated. On the last step, the sand was pulled through industrial crusher and grinded to the required fraction to be used in further production cycle.

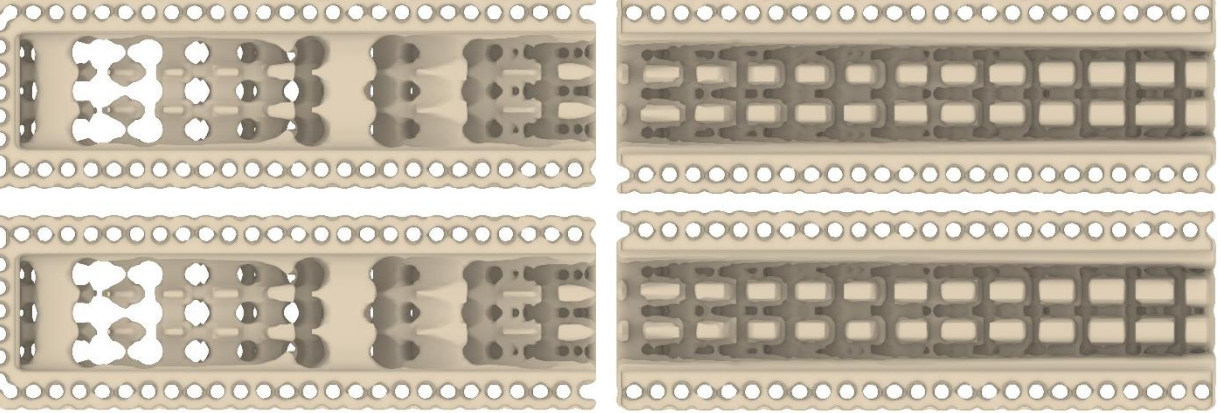
1. Structural analysis and assignment of required cross-sections



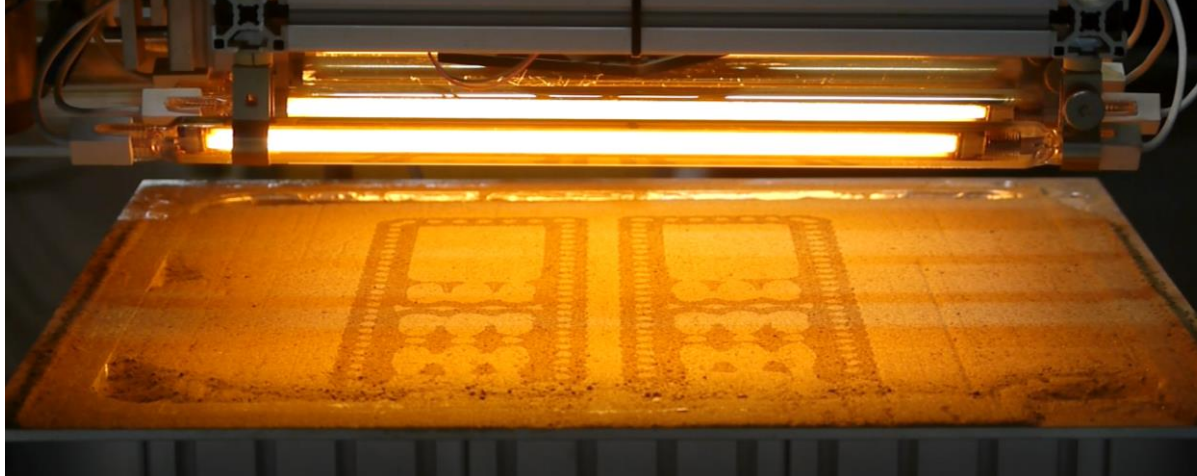
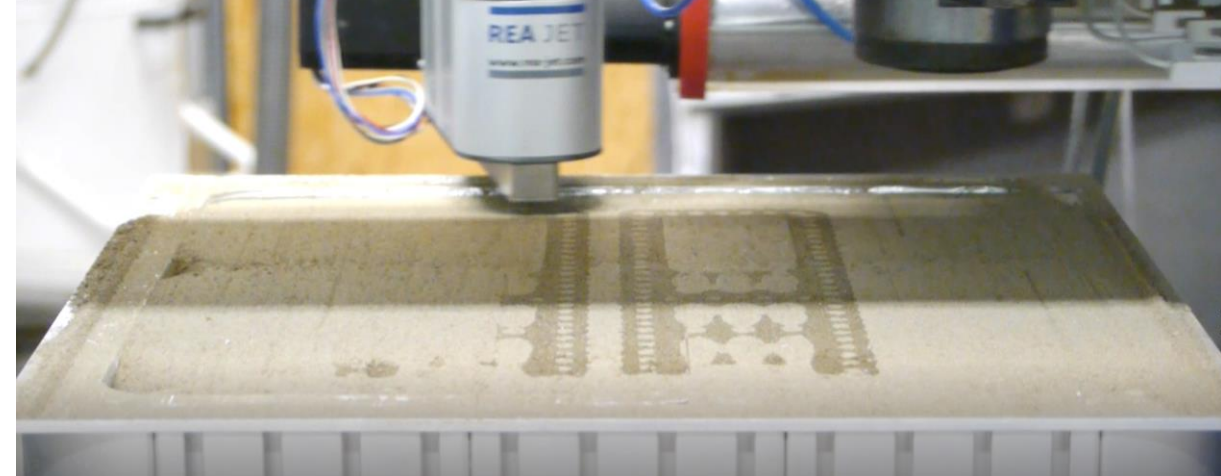
2. Modelling of target concrete structure and corresponding formwork structure



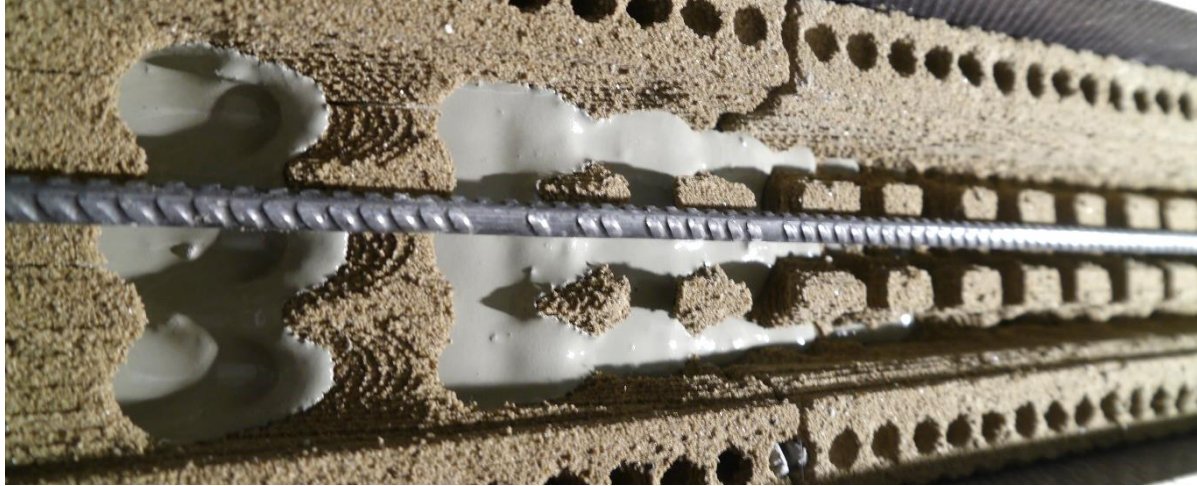
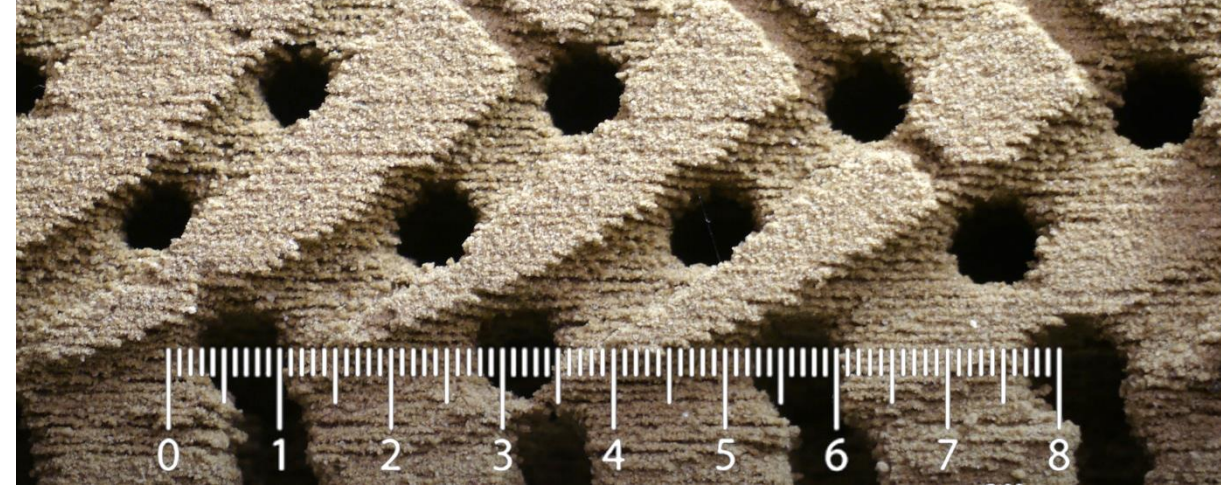
3. Segmentation of formwork for production



4. 3D printing of water-soluble formwork



5. Assembling and casting



6. Demolding

