# Zero-Waste Sand Formwork for Complex Spatial Concrete Structures

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## Abstract

Given the social and environmental situation, the concrete industry is challenged to increase production volumes while minimizing the consumption of natural resources, the emissions of greenhouse gases and the generation of non-recyclable waste [1]. This requires integrated solutions for design and manufacturing of lightweight components in the paradigm of circular production (i.e. fully recyclable and zero-waste). Concrete lightweight components are usually geometrically complex and, thus, require appropriate formwork, which production is until now usually cost- and waste-intensive. Recent research has shown great advances in digital manufacturing of complex formwork geometries by CNC-milling, 3D-printing or binder-jetting [2]. Also, significant advances have been made in the development of recyclable formwork concepts [3, 4].

This contribution presents an alternative method – *Hydroplotting* – that attempts to embrace the whole spectrum of requirements and constraints by combining sand material system with the advantages of digital fabrication to enable the zero-waste production of geometrically complex, even spatial geometries. This method is a continuation of research on recyclable sand formwork techniques initiated previously by the authors [4], where the premix of sand and binder is stabilized throughout formwork production, casting and hardening. After demolding, the formwork material is regained and reused in further production cycles. With *Hydroplotting,* the developments on material system were combined with the advantages of digital manufacturing resulting in a custom-made automated manufacturing unit where a water-soluble formwork geometry is produced by injecting water into a premix of sand and organic binder along predefined trajectories. *Hydroplotting* allows to produce a large variety of spatially complex formwork geometries. The potential of this method for lightweight concrete structures was explored on the fabrication of a spatially complex load-optimized functionally graded concrete beam.

This paper gives an overview of *Hydroplotting* with the focus on the production setup, the interdependence of material properties and fabrication parameters. Further, it is demonstrated how production parameters can be transferred into the geometric properties of formwork structure and further used in design of functionally graded concrete specimen. Finally, the whole design-to-production process is tested on the example of single-span beam to evaluate its potential for lightweight structures and discuss further development of the method.

## References

[1] W. Sobek, „Über die Gestaltung der Bauteilinnenräume“, In: Scheerer, S.; van Stipriaan, U. (Hrsg.): Festschrift zu Ehren von Prof. Dr.-Ing. Dr.-Ing. E.h. Manfred Curbach, Dresden: Institut für Massivbau der TU Dresden, 2016, S. 62 – 76.

[2] M. Aghaei-Meibodi, M. Bernhard, A. Jipa, and B. Dillenburger, “The Smart Takes from the Strong.” In: Fabricate, edited by B. Sheil, A. Menges, R. Glynn, and M. Skavara, 210–17. London: UCL Press, 2017.

[3] J. Mainka, H. Kloft, S. Baron, H.-W. Hoffmeister, and K. Dröder, “Non-Waste-Wachsschalungen: Neuartige Präzisionsschalungen aus recycelbaren Industriewachsen,” *Beton- und Stahlbetonbau*, vol. 111, no. 12, pp. 784–793, Dec. 2016.

[4] O. Gericke, D. Kovaleva, W. Haase und W. Sobek, „Fabrication of concrete parts using a frozen sand formwork“, Spatial Structures in the 21st Century, IASS Symposium, September 26-30, 2016, Tokyo.