A metamodel for 3D concrete printing

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Abstract

A recent ground-breaking approach to automate the construction process is the implementation of additive manufacturing (AM), i.e. three-dimensional (3D) printing, due to the development of printable concrete materials. Currently, AM is venturing in large-scale concrete construction with the development of large-scale 3D concrete printers, enabling the extrusion of structures and structural components without using formwork. However, challenges regarding digital data modeling of AM for concrete structures have been identified. The lack of knowledge on how the data triplet of geometry, process, and material information interrelate, together with information breaks along the digital information flow, limits 3D concrete printing to a rough process with a long trial-and-error learning curve and which is prone to redundancy, information loss, and inconsistencies in the digital data modeling. Consequently, there is a need to understand the information flow, the input parameters, and the relationships between parameters as a step necessary to standardize the digital data triplet into a unified digital data model. This paper proposes a metamodel, referred to as “printing information model”, for AM of concrete structures that defines the main input parameters and fundamental relationships between the data triplet. Using the metamodel as a formal basis, an approach based on building information modeling (BIM) is implemented and validated, incorporating all printing information into a single data model enabling a more efficient information flow to advance high-quality printed concrete structures. By instantiating the metamodel, AM main parameters and fundamental relationships are translated into a computer numerical control code, which is readable by a laboratory-scale 3D concrete printer. Validation tests are carried out showing adequate printing performances of small-scale concrete walls. As a result, it is demonstrated that a BIM-based approach to AM of concrete structures has the potential to improve the current data modeling that is implemented in order to produce high-quality printed concrete structures.

Keywords: Additive manufacturing, printing information modeling, 3D concrete printing, metamodel, semantic modeling, building information modeling.