Specimen Design and Advanced Material Testing for 3D Printing Concretes

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Abstract

This paper deals with the design of concrete samples for the material testing of 3D-printable concrete mixtures. Due to the rapid advancements and increasing pilot projects in the field of 3D printing in construction, it is of great importance to develop standards and design principles that allow a comparison of different material compositions in cast and 3D-printed specimen forms. Starting from general theoretical background of concrete 3D printing and over all characteristics of concrete objects which are built up by multiple material layers, typical issues are identified. From theoretical correlations with the properties of the currently common 3D printing processes, an orthotropic material behaviour can be derived.

Keywords: 3D concrete printing, test specimen, test setups, material testing

1 Introduction

Due to the increasing level of automation on construction sites, innovative construction methods are coming into focus. Additive manufacturing of concrete components in particular is gaining in importance. This technology enables the efficient production of concrete components without the use of elaborate formwork, which in turn can lead to material savings and thus to the responsible use of resources. Since various international research projects show that material efficient and therefore sustainable production of structural concrete components using additive manufacturing is possible, it is essential to elaborate standards and design principles allowing to compare different material admixtures in casted and 3D printed specimen shapes.

For the additive manufacturing of concrete components, various processes can be employed, distinguished by their operating principles. These can be categorized into selective binding, extrusion methods, shotcrete processes, and slipform methods. Among these, extrusion methods represent the most well-known and extensively developed techniques in 3D printing. These are printing processes in which a pre-mixed material, such as a specially formulated concrete, is pumped through a controllable nozzle, the extruder, and pressed to form strands.

Due to the manufacturing process, an additively manufactured test specimen cannot be assumed to have a homogeneous cross-section. In the multi-layer extrusion process, individual strands of material are placed on top of each other in layers to create a three-dimensional object. Accordingly, joints or contact surfaces form between the individual layers, which are assumed to have a negative effect on the strength properties compared to a homogeneous body. In principle, a distinction can be made between two types of joints. On the one hand, there are horizontal contact areas between superimposed printing strands and, on the other hand, vertical contact areas between two adjacent printing strands.

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