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Effect of Printing Process on Mechanical Properties and Porosity of 3D Printed Concrete Strips

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Abstract : 3D concrete printing technology is a novel and highly efficient construction method that holds significant promise for advancing low-carbon initiatives within the construction industry. In contrast to traditional construction practices, 3D printing offers a manual and formwork-free approach, resulting in a transformative shift in labor requirements and fabrication techniques. This transition yields substantial reductions in carbon emissions during the construction phase, as well as decreased on-site waste generation. Furthermore, when compared to conventionally printed concrete, 3D concrete exhibits mechanical anisotropy due to its layer-by-layer construction methodology. Therefore, it becomes imperative to investigate the influence of the printing process on the mechanical properties of 3D printed strips and to optimize the mechanical characteristics of these coagulated strips. In this study, we conducted three-dimensional reconstructions of printed blocks using both circular and directional print heads, incorporating various overlap distances between strips, and employed CT scanning for comprehensive analysis. Our research focused on assessing mechanical properties and micro-pore characteristics under different loading orientations.Our findings reveal that increasing the overlap degree between strips leads to enhanced mechanical properties of the strips. However, it's noteworthy that once full overlap is achieved, further increases in the degree of coincidence do not lead to a decrease in porosity between strips. Additionally, due to its superior printing cross-sectional area, the square printing head exhibited the most favorable impact on mechanical properties.This paper aims to improve the tensile strength, tensile ductility, and bending toughness of a recently developed ‘one-part’ geopolymer for 3D concrete printing (3DCP) applications, in order to address the insufficient tensile strength and brittle fracture characteristics of geopolymer materials in 3D printing scenarios where materials are subjected to tensile stress. The effects of steel fiber content, and aspect ratio, on mechanical properties, were systematically discussed, including compressive strength, flexure strength, splitting tensile strength, uniaxial tensile strength, bending toughness, and the anisotropy of 3DP-OPGFRC, respectively. The fiber distribution in the printed samples was obtained through x-ray computed tomography (X-CT) testing. In addition, the underlying mechanisms were discussed to provide a deep understanding of the role steel fiber played in the reinforcement. The experimental results showed that the flexural strength increased by 282% to 26.1MP, and the compressive strength also reached 104.5Mpa. A high tensile ductility, appreciable bending toughness, and strain-hardening behavior can be achieved with steel fiber incorporation. In addition, it has an advantage over the OPC-based steel fiber-reinforced 3D printing materials given in the existing literature (flexural strength 15 Mpa); It is also superior to the tensile strength (<6Mpa) of current geopolymer fiber reinforcements used for 3D printing. It is anticipated that the development of this 3D printable steel fiber reinforced ‘one-part’ geopolymer will be used to meet high tensile strength requirements for printing scenarios.

Keywords : 3D printing concrete, mechanical anisotropy, micro-pore structure, printing technology
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