

ADVANCING PERFORMANCE OF CEMENT-BASED MATERIALS THROUGH BIO-INSPIRED APPROACH ENABLED BY ADDITIVE MANUFACTURING

ABSTRACT

The advancement of sustainable, high-performance materials is essential for the future of innovative civil infrastructure. 3D printed (3DP) concrete has emerged as an innovative technique with the potential to revolutionize construction practices by enabling advanced and novel material performance characteristics. This dissertation focuses on addressing the key challenges associated with 3DP concrete while exploring opportunities to develop innovative, high-performance materials by leveraging the unique capabilities of additive manufacturing technology, such as design flexibility and controlled internal architecture. The research presented in this work focuses on three aspects of 3DP concrete: the development of sustainable materials for 3DP concrete with enhanced rheological properties, the evaluation of mechanical performance and anisotropic behavior in 3DP fiber-reinforced mortars, and the investigation of mechanical responses of 3DP elements featuring bio-inspired designs. The first part of the research tackles the challenge of mixture formulation of 3DP concrete, focusing on improving rheological properties and sustainability by incorporating cellulose nanomaterials and supplementary cementitious materials. This study aims to enhance the performance of the material while concurrently reducing the environmental impact of 3DP concrete, making it more viable for practical applications. Furthermore, this dissertation contributes to understanding the role of fiber reinforcement in 3DP concrete, particularly its influence on the anisotropic behavior of the material. Lastly, the research introduces a novel, nature-inspired approach by taking advantage of this intrinsic anisotropy, coupled with flexibility in filament architecture design, to develop 3DP concrete with exceptional mechanical properties that are challenging to achieve through traditional casting methods. We have demonstrated the ability to make concrete both stronger and more energy-absorbing than its cast counterparts by combining clever architectures inspired by extreme animals in nature with 3D concrete printing technology.