

Behavior of Shear Strength in 3D-Printed Concrete Beams with Bio-Inspired Lattice Reinforcement

1. Introduction

The potential for material efficiency, architectural design flexibility, and construction speed is enormous with the latest advancements in 3D concrete printing. However, not enough research has been done on structural performance, specifically the shear capacity of 3D-printed structures. In order to enhance shear performance, the current study recommends printing bio-inspired internal lattice reinforcement geometries (like honeycomb, trabecular, or spider-web-like structures) inside concrete beams. With little material, these reinforcements successfully mimic nature's ability to withstand stress.

2. Objectives

- Design & simulate bio-inspired lattice geometries for internal reinforcement of 3D-printed concrete beams.
- Create the beams with different reinforcement methods: unreinforced, conventional rebar, and three bio-inspired lattice structures.
- Evaluate the shear strength through numerical simulation and experimental tests.
- Observe the crack patterns, modes of failure and energy dissipation for each configuration.
- Validate finite element models with experimental data.

3. Methodology

3.1 Literature Review

- Survey existing 3D Concrete Printing (3DCP) technologies and their structural constraints, particularly under shear.
- Study biomimetic structural optimization and natural geometries that are renowned for load efficiency.
- Investigate historical uses of internal lattice reinforcement in polymer and concrete 3D printing

3.2 Design and Modeling

- Employ Rhino + Grasshopper + Karamba3D for parametric modeling of inner lattices.
- Simulate shear loading and identify optimal lattice geometries using FEM tools (ANSYS or Abaqus)

3.3 Fabrication

- Use 3D concrete printer to fabricate beams (e.g., 1000 mm × 150 mm × 200 mm) with:
 - No reinforcement (Control)
 - Traditional rebar
 - Honeycomb lattice
 - Trabecular lattice
 - Spider-web lattice

3.4 Testing

- Perform 4-point bending shear tests as per ASTM C78 or IS 516.
- Monitor strain using strain gauges and Digital Image Correlation (DIC).
- Measure ultimate load, first crack load, and post-cracking behavior.

3.5 Data Analysis

- Compare peak shear strength, load-deflection behavior, and crack propagation.
- Use image processing and data acquisition tools to track damage zones.
- Validate FEM results with experimental data.

4. Expected Outcomes

- Determining the most appropriate bio-inspired lattice arrangement for shear reinforcement.
- Data on the improved shear performance in lattice-reinforced beams.
- Improved understanding of crack behavior in 3D-printed reinforced concrete.
- A tested methodology that can be used for applications of biomimetic reinforcement in additive manufacturing in the future.

5. Novelty and Impact

This study is one of the first to experimentally explore the function of bio-inspired internal reinforcement geometries in 3D-printed concrete beams subjected to shear loading. It fills the gap between biomimicry, additive manufacturing, and structural mechanics and has the potential to redefine how we design shear reinforcement in the future.

References

1. Ahmed, Z. Y., & Bos, F. P. (2020). *Structural performance of 3D printed reinforced concrete beams*. *Construction and Building Materials*, 247, 118453.
2. Bendsøe, M. P., & Sigmund, O. (2004). *Topology Optimization: Theory, Methods, and Applications*. Springer.
3. Ding, L., Xiao, Y., & Wang, G. (2021). *Bio-inspired design and mechanical analysis of honeycomb and lattice structures*. *Materials & Design*, 198, 109285.
4. Perrot, A., Rangeard, D., & Pierre, A. (2016). *Structural build-up of cement-based materials used for 3D-printing extrusion techniques*. *Materials and Structures*, 49, 1213–1220.
5. Zhang, Y., et al. (2022). *Mechanical behavior of 3D printed concrete: State of the art and challenges*. *Cement and Concrete Composites*, 128, 104428.