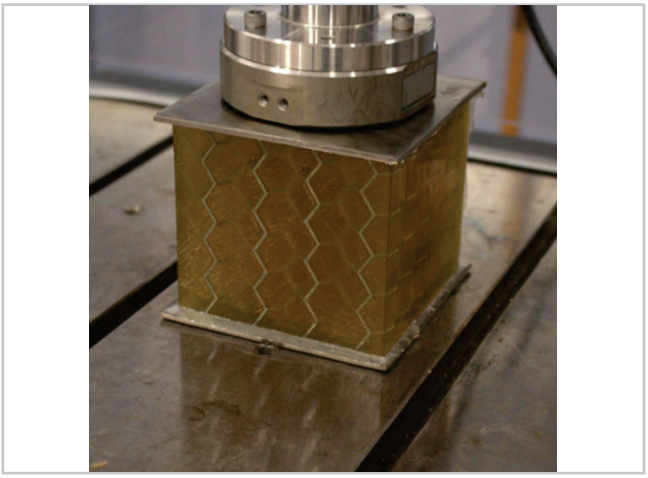
Research Summary

3D Printed Lattice Based Structures for Next Generation Bridge Bearings and Bridge Isolation Bearings

Research Need

Bridge bearings must transfer vertical loads while accommodating rotations and horizontal movements. Conventional elastomeric bearings provide limited ability to tailor axial and shear stiffness independently. Additively manufactured lattice reinforcement may allow these properties to be controlled through geometric design, creating new opportunities for customizable bearing systems for future bridge applications.



Goals/Objectives

The project evaluated the laboratory feasibility of elastomeric composite bearing prototypes reinforced with additively manufactured pentamode lattices. The primary objective was to determine whether lattice geometry could influence axial and shear stiffness through geometric design. The study also aimed to design and fabricate stainless steel lattice configurations using laser powder bed fusion, develop a reliable process for casting elastomer around the complex lattice geometry, and characterize the selected prototype elastomer. Additional objectives included measuring the small strain axial and shear response of the composite specimens, evaluating their behavior under progressively increasing cyclic shear displacements, and comparing experimental trends with preliminary numerical predictions. Finally, the project identified important material, interface, testing, manufacturing, and modeling limitations requiring further investigation before full scale bridge applications can be considered.

Methodology

Periodic representative volume element models were used to explore how pentamode lattice geometry affects composite axial and shear properties. Three stainless steel lattice configurations were selected and fabricated using laser powder bed fusion. The lattices were embedded within a cast polyurethane elastomer selected for prototype manufacturability. The elastomer was characterized through standardized compression and tension testing. Composite prototypes were then evaluated under small strain axial and shear loading, followed by progressively increasing cyclic shear displacement. Experimental results were compared with numerical predictions to evaluate qualitative trends and identify modeling limitations.

Key Findings

The prototypes were successfully fabricated and tested. Lattice geometry produced substantial differences in measured axial stiffness, while shear stiffness varied within a narrower range. Cyclic response and interface behavior also differed among the configurations. The results demonstrate laboratory proof of concept, but additional testing is required before the system can be considered for bridge implementation.

Use of Findings

The findings provide a foundation for developing customizable lattice reinforced bridge bearings. The results demonstrate that lattice geometry can influence the axial and shear response of elastomeric composite prototypes and identify interface behavior, elastomer selection, specimen confinement, and boundary conditions as important design considerations. The initial numerical models can guide future design exploration but require calibration before they can predict full specimen behavior. The current prototypes are not ready for deployment on MassDOT structures. Future research should include full scale testing under simultaneous vertical compression and cyclic shear, use of elastomers that satisfy bridge bearing requirements, calibrated finite element modeling, fatigue and dynamic testing, environmental exposure, corrosion and aging studies, and evaluation of manufacturing and lifecycle costs. Additive manufacturing may eventually allow bearing geometries to be customized digitally without developing unique internal reinforcement tooling for every application, potentially improving design and prototyping efficiency. These potential time and cost benefits require validation through full scale manufacturing studies.

Project Information

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