Mechanical testing of Polymeric Lattice-Reinforced Mortar

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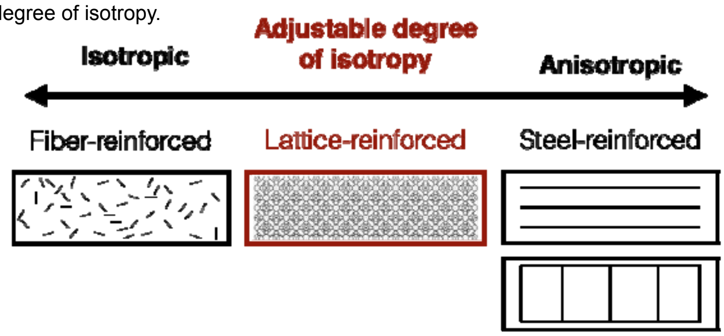
Motivation

We developed a technique for creating lightweight structures with a controllable degree of isotropy.

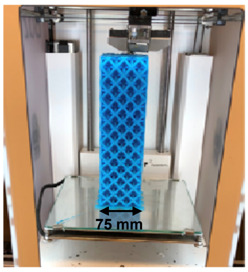


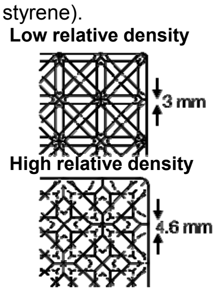
This was achieved with an octet lattice structure, but the methodology can be applied to other designs. The octet is stretch dominated, which results in a high specific strength and high specific stiffness.

Methods – beam fabrication

3D polymeric lattices were printed using a fused deposition modeling process. Polylactic acid (PLA) was utilized because it can print these overhanging structures without the need for support material, and it experiences low thermal warping (especially compared to acrylonitrile butadiene styrene).

Two configurations of the octet lattice were designed – one with a low relative density and one with a high relative density – by altering the member diameter.

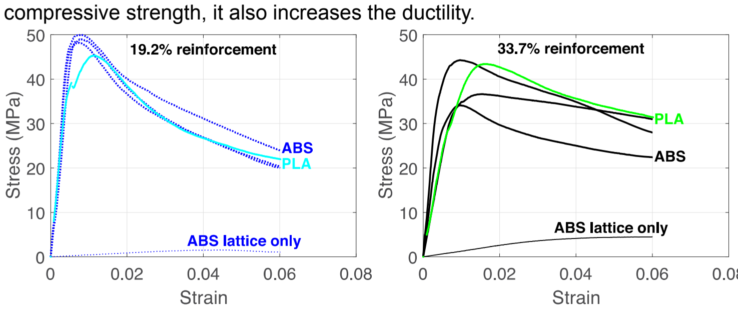




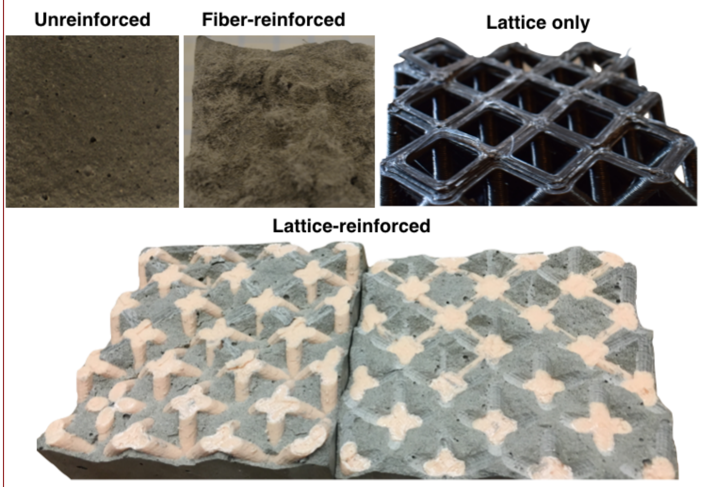
The lattices were placed into rectangular molds, infiltrated with a portland cement-based mortar, and vibrated. The infiltrated beams were stored in a fog room.

Results – compressive properties

We similarly created 50.8 mm cubes reinforced with polymeric lattices (some with ABS reinforcement and some with PLA reinforcement), infiltrated with ultra high performance concrete, and tested under compression. Specimens with PLA reinforcement performed similarly to those with ABS reinforcement and exhibited high ductility. While the higher reinforcement ratio lowered the compressive strength, it also increases the ductility.



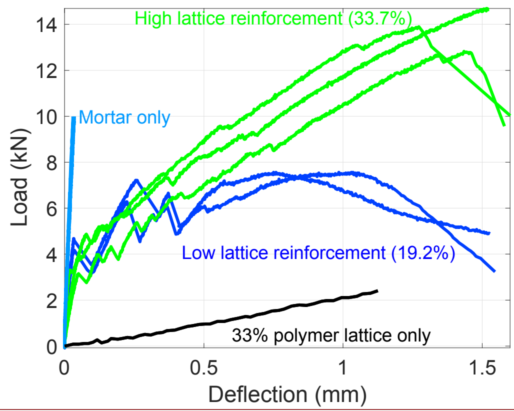
Results – fracture surfaces



Beams without reinforcement have flat brittle fracture surfaces, and beams with 2.8% by volume polyvinyl alcohol (PVA) fiber-reinforcement have tortuous fracture surfaces. An octet beam of PLA only (no mortar) shows cleaved fracture surfaces, as the crack was able to propagate through the interface between the 3D printed layers. The lattice-reinforced mortar beams show textured fracture surfaces, in which the dominant crack had to take a long tortuous path before fracture occurred.

Results – beam flexural properties

We tested beams under four-point bending. Beams with a high amount of lattice-reinforcement (33.7% by volume) exhibit higher toughness and higher peak loads than beams with a lower amount of lattice-reinforcement (19.2% by volume). This means that beam mechanical properties can be tuned by adjusting the amount of lattice reinforcement. The high lattice-reinforcement beams show similar toughness values as the PVA fiber-reinforced beams, while achieving a higher net deflection at peak load. Lattice-reinforced beams exhibit multiple cracking.



Conclusions

- Lattice reinforcement is easy to infiltrate and provides high ductility.
- Mechanical properties are tunable, by varying the polymer reinforcement.
- Lattices allow for smaller volumes of concrete, and lightweight structures.
- For high volume production, polymeric lattices can be injection molded.

Reference

Salazar B., Williams I., Aghdasi P., Ostertag C., Taylor H. (2018) Bending and Crack Characteristics of Polymer Lattice-Reinforced Mortar. In: Taha M. (eds) International Congress on Polymers in Concrete (ICPIC 2018). ICPIC 2018. Springer, Cham. https://doi.org/10.1007/978-3-319-78175-4_32

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