Bioinspired Design of Novel Reinforced Concrete Elements

Robert Ciotti and Simone Williams; Advisor: Dr. Nima Rahbar
Worcester Polytechnic Institute; Department of Civil and Environmental Engineering

BACKGROUND

- There still exists a concerning number of structural issues when it comes to using rebar and other metal barring to strengthen cement: moisture enters the cracks of the concrete, creating a battery-like condition where the steel begins to rust; and rusting can cause for the rebar to expand up to four times its size.
- From examples in nature (wood, bones, and sea sponges), man has developed metallic foams, which take the design from the foams and bubble formation, and use a stronger material – typically aluminum, nickel, copper, or steel – to produce an incredibly strong, low-density material.
- Metal fibers refer to thin metal objects with diameters of one micron to 100 microns. They have excellent mechanical properties including high-thermal corrosion resistance, and high electrical and thermal conductivity, and compensate the weaknesses of concrete to form a composite material with superior mechanical and chemical properties.

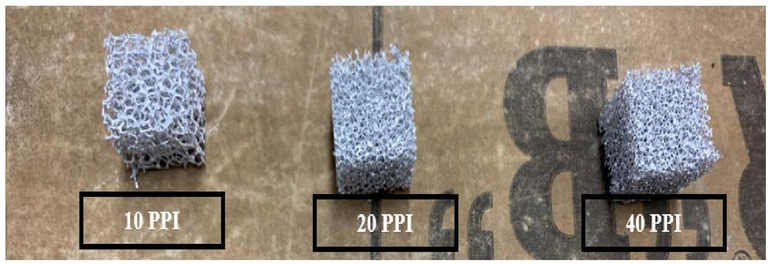

Fig 1. Images of the Duocel Aluminum 6061-T6 foams (top) and the Intramicron stainless steel A16 fibers (left).

OBJECTIVE

To create a cement composite structure with metallic foams and fibers that is stronger and more ductile than traditional reinforced concrete material.

METHODOLOGY

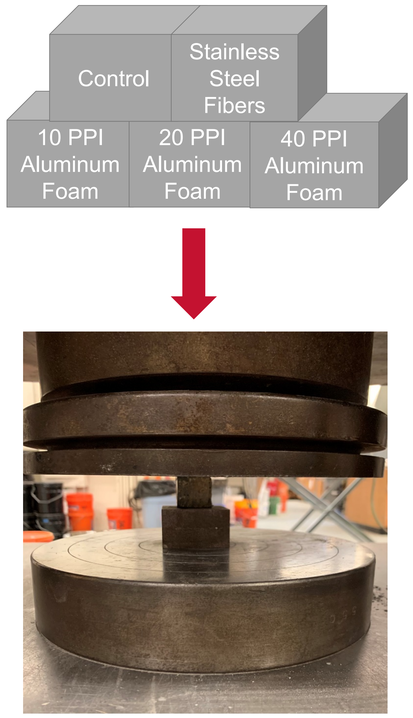

Fig 2. Image of an aluminum foam reinforced sample being tested in the Instron.

- 15 Control, 12 stainless steel fiber reinforced, 12 - 10 PPI aluminum foam reinforced, 17 - 20 PPI aluminum foam reinforced, and 12 - 40 PPI aluminum foam reinforced cement paste samples were made. All had a water to cement ratio of 0.5 and cured for 14 days before testing.
- The samples were tested in compression on an Instron machine. The control and steel fiber samples were tested until failure. The aluminum foam reinforced samples were tested until they were compressed by 75%.

RESULTS

Table 1. Average Maximum Compressive Strengths of the Samples

Sample	Max Comp Strength. (psi)
Control	3348.12
10 PPI foam	2568
20 PPI foam	1238
40 PPI foam	1156
Steel fibers	2909.17

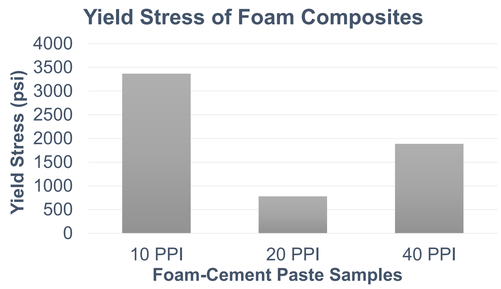

Fig 3. Yield Stress of Foam-Cement Paste Samples

ALUMINUM REINFORCED CEMENT PASTE COMPOSITE IN BUILDING DESIGN

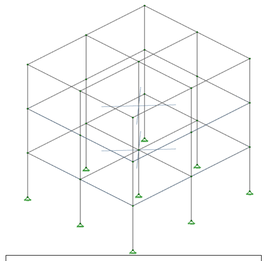

Fig 4. Risa 3D model of three-story building.

- Calculations were conducted on an 8” x 8” column that was reinforced with 10 PPI aluminum foam and one that was traditionally reinforced with 4 #6 rebars for a simply loaded three-story building.
- 41% of the load that the column is subject to is carried by the aluminum reinforcement. The foam reinforcement allows for the column to withstand three times more force than it is currently subjected to.
- 18% of the load is carried by the steel reinforcement. The steel reinforcement allows for the column to withstand a little less than twice the force than it is subjected to.

FINDINGS AND CONCLUSION

- The aluminum foam composites were found to not reach a failure point. As such, the foam-cement paste composites were compressed and a yield compressive strength was identified. Of the three composites tested, the 10 PPI foam sample performed the best, with an average yield compressive strength of 3363 psi.

Fig 5. Image of compressed aluminum foam reinforced composite.

- The steel fiber composite samples ultimately failed due to cracking and exhibited an average yield stress comparable to the foams but risks cracking.
- Based on the promising results from the composite samples, further research is encouraged to explore the ideal porosity, material, and microdesign of foams to be used in reinforced concrete structures.

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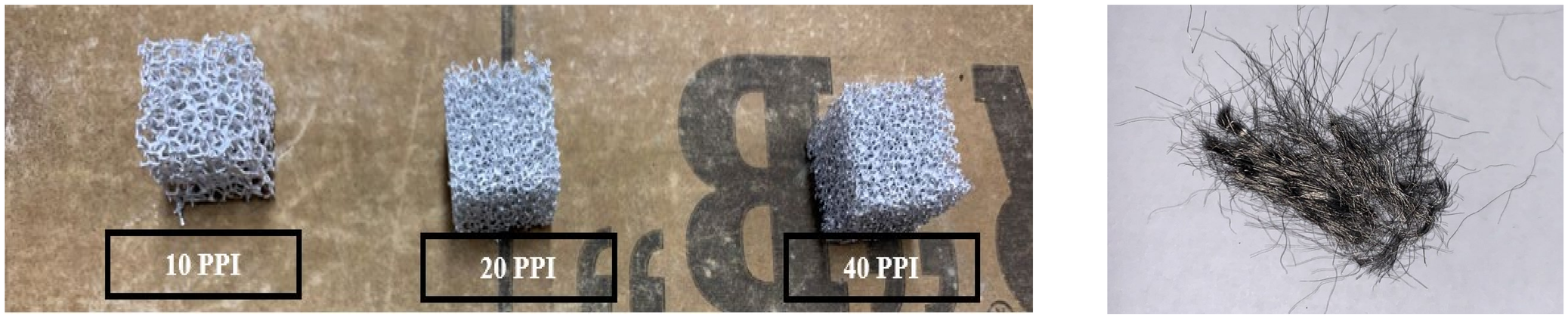

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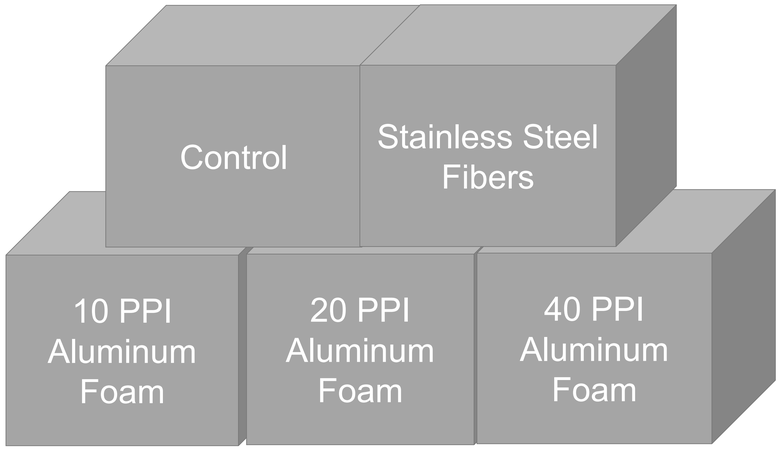

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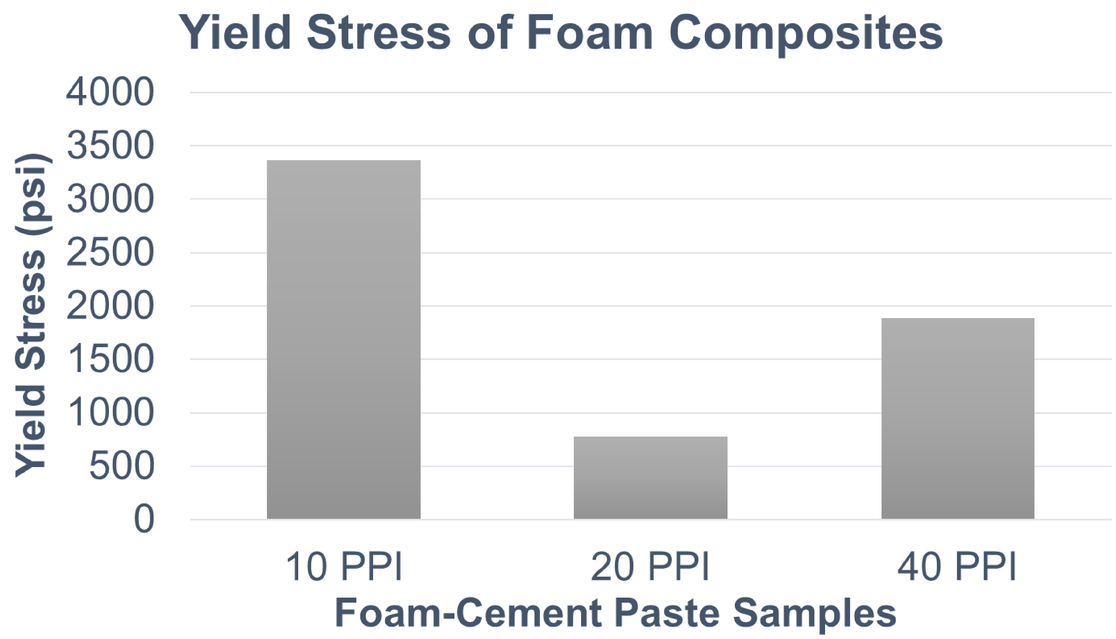

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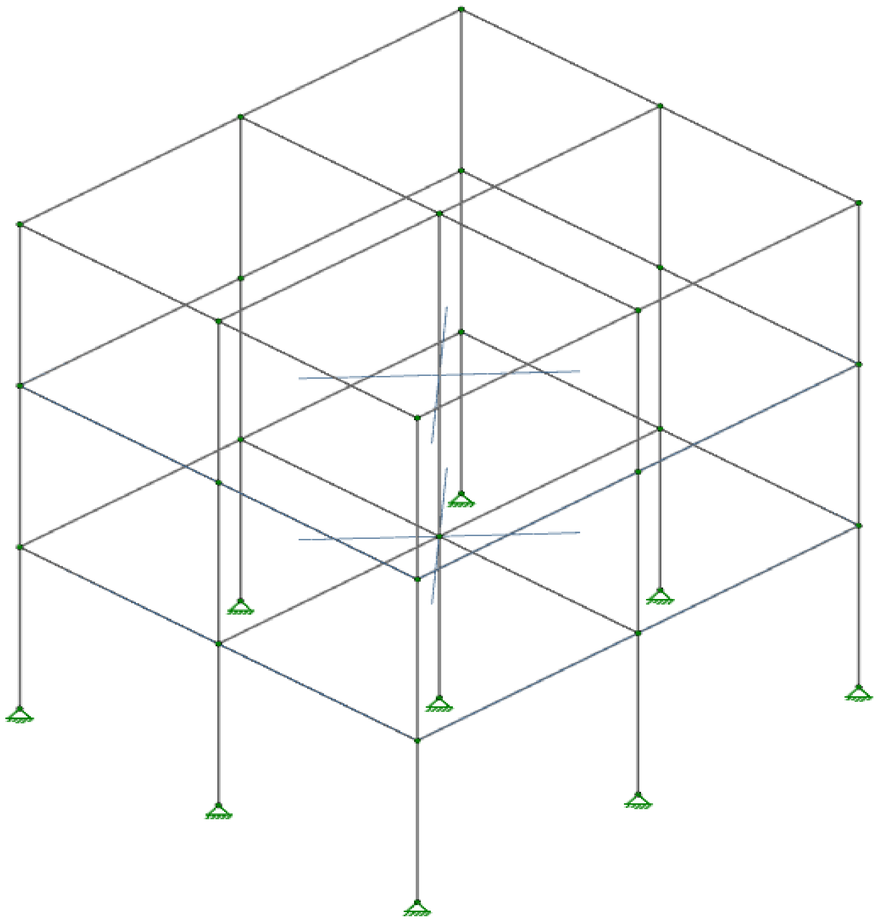

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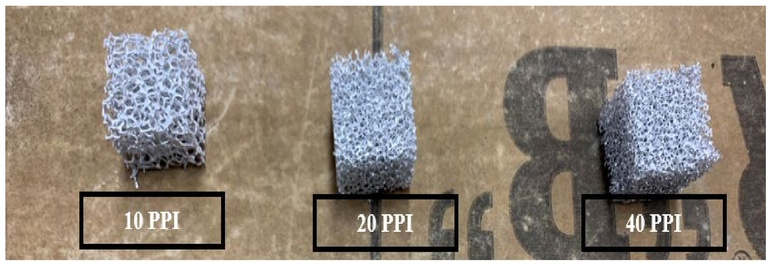

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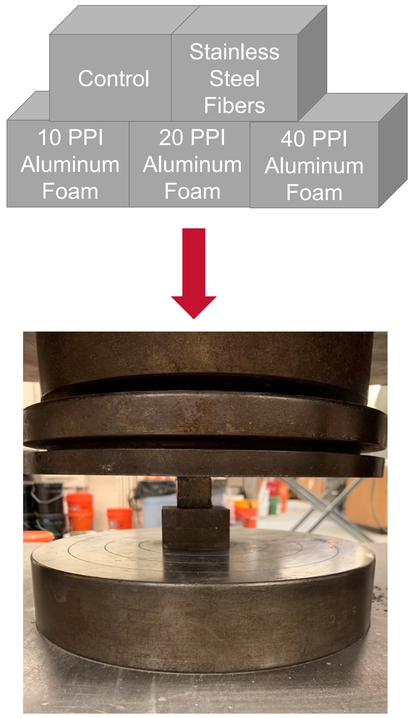

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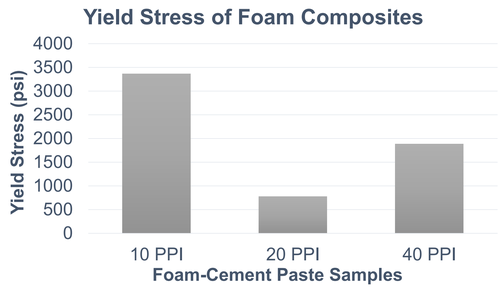

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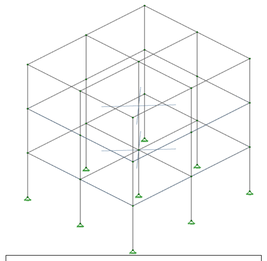

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