

# **Biomimetic Antifreeze Polymers: A Natural Solution to Freeze-Thaw Damage in Cement and Concrete**

**Mohammad Matar<sup>1</sup>, Shane Frazier<sup>2</sup>, and Wil V. Srubar III<sup>3</sup>**

<sup>1</sup>Department of Civil, Environmental, and Architectural Engineering, University of Colorado Boulder, ECOT 441 UCB 428, Boulder, Colorado 80309 USA, mohammad.matar@colorado.edu

<sup>2</sup>Materials Science and Engineering Program, University of Colorado Boulder, UCB 027, Boulder, Colorado 80303 USA, shane.frazier@colorado.edu

<sup>3</sup>Department of Civil, Environmental, and Architectural Engineering, University of Colorado Boulder, ECOT 441 UCB 428, Boulder, Colorado 80309 USA wsrubar@colorado.edu

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## **1 Introduction**

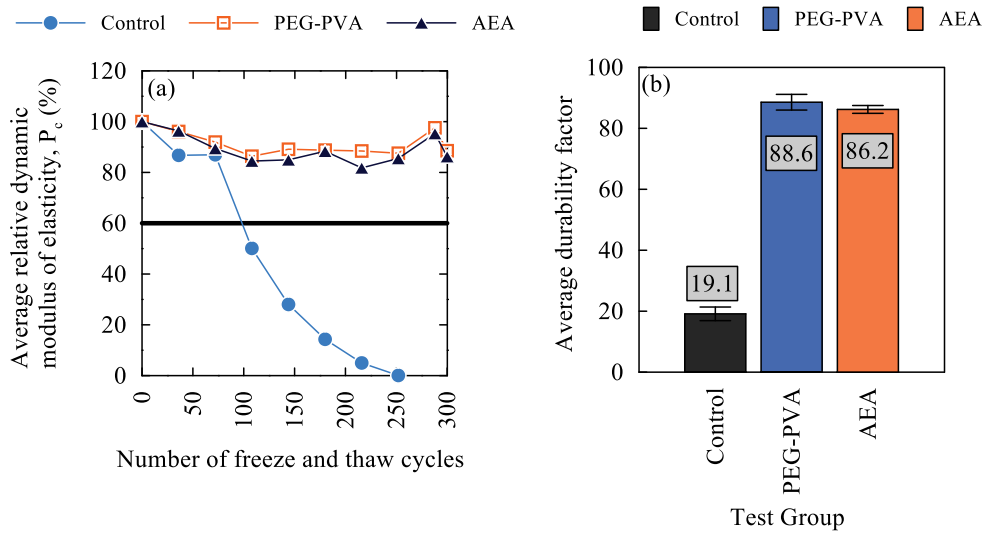
It is commonly accepted that freeze-thaw damage is a result of hydraulic, osmotic, and crystallization pressures developing when ice forms in the pore structure of concrete leading to internal micro-cracking (Powers, 1975; Scherer *et al.*, 2005). The default method to reduce freeze-thaw damage is *via* the use of air entraining agents (AEAs) but notable drawbacks include reduction in mechanical strength, increased permeability, and retardation of set time. Nature has provided an alternative approach with antifreeze proteins which have the ability to interact with ice and inhibit ice recrystallization (IRI). Polymeric materials that mimic the IRI activity have been analyzed including polyvinyl alcohol (PVA) (Congdon, *et al.*, 2013). Polyvinyl alcohol-polyethylene glycol graft copolymer (PEG-PVA) is more soluble in water and was recently shown to be IRI active (Frazier, *et al.*, 2020). To this end, it was hypothesized that PEG-PVA could be used for freeze-thaw mitigation in concrete.

## **2 Experimental Methods**

Unmodified concrete (Control), concrete containing 0.066% wt. of cement PEG-PVA (PEG-PVA), and concrete containing air entraining agent (AEA) were mixed with a w/c ratio of 0.5. Slump and fresh state air content were measured. After curing the compressive strength was measured, the hardened state air content was estimated by using micro X-ray computed tomography, and rapid freeze-thaw cycling was performed for 300 cycles.

## **3 Results and Discussion**

The unmodified concrete (Control) air content remained relatively unchanged at 2.1% and 2.7% in the fresh and hardened state. The air content of PEG-PVA-modified samples decreased from 4.2% in the fresh state to 2.3% in the hardened state indicating not all air voids were stabilized. The samples containing air entraining agent also saw a reduction in air content of 7.0% in the fresh state to 4.0% in the hardened state.



**Figure 1. (a)** Average relative dynamic modulus of elasticity ( $P_c$ ) of test groups. Horizontal line at 60%  $P_c$  indicates failure. **(b)** Average durability factor for each test group. Error bars indicate standard deviation for  $n=3$ .

Figure 1 shows the change of average relative dynamic modulus of elasticity ( $P_c$ ) and the average durability factor (DF) for each test group. The PEG-PVA and AEA modified specimens both maintained a  $P_c$  value above 80% and a DF greater than 85% indicating freeze-thaw resistance. As expected, the  $P_c$  and DF for unmodified concrete indicated poor performance compared to the PEG-PVA and AEA samples.

## 4 Conclusions

It was found that PEG-PVA provided freeze-thaw resistance comparable to air entrained concrete with a hardened state air content less than 3%. The low air content suggests that the freeze-thaw resistance could be attributed to something other than an entrained air system. It is hypothesized that the IRI activity of PEG-PVA results in the observed freeze-thaw resistance.

## References

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