Development of a Steel-PVA Hybrid Fiber SHCC

Alok A. Deshpande, Dhanendra Kumar, Anandharam Mourougassamy & Ravi Ranade

Department of Civil, Structural and Environmental Engineering
University at Buffalo, The State University of New York

Introduction

- Benefits of PVA SHCC at elevated temperatures

  Easier escape of moisture => Retention of compressive strength

- Benefits of Steel FRC at elevated temperatures

  High melting-point => Retention of tensile strength

- Motivation

  Combining benefits of PVA & Steel = Hybrid fiber SHCC

- Research significance

  Development of robust solutions for applications in elevated temperatures

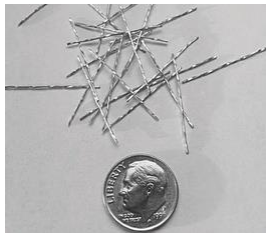
Materials and mixture proportions

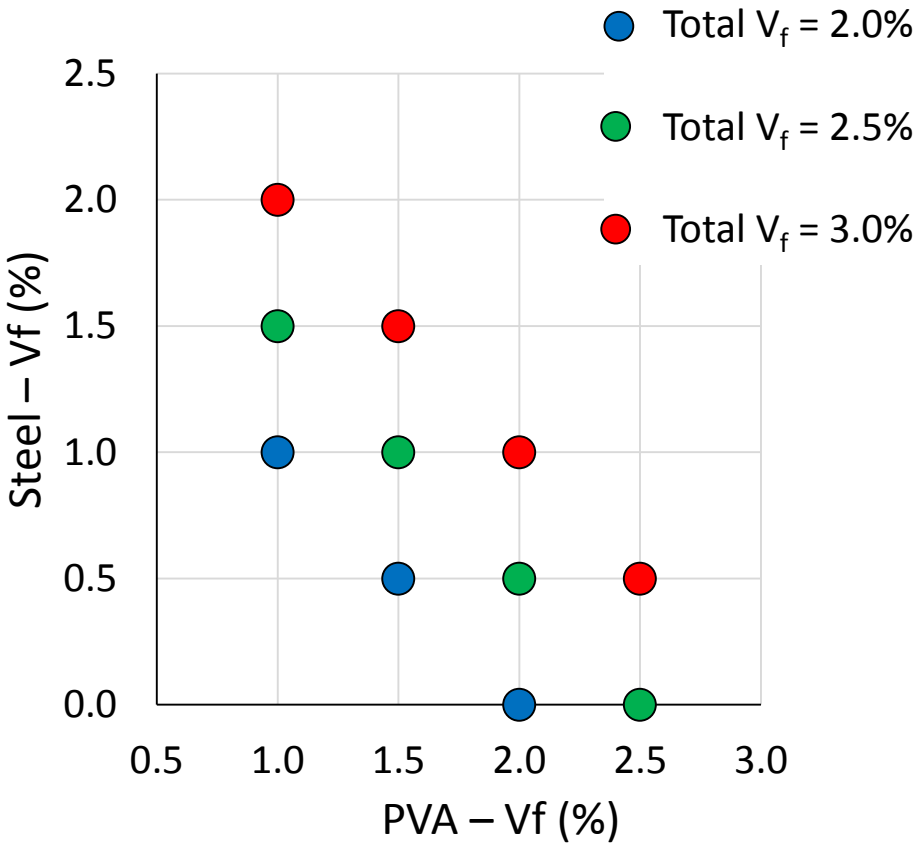
Matrix proportions*:

FA/C	Sand/C	w/cm	HRWR/cm	VMA/cm	PVA-V_f
1.2	0.8	0.29	0.35%	1.1%	2%

Fiber properties:

Fibers	Dia. (μm)	Len. (mm)	Density (kg/m^3)	Yng's Mod. (GPa)	Ten. Stren. (MPa)	Elong-ation (%)	Melt. Point (°C)
PVA	39	12	1300	42.8	1600	6	230
Steel	500	25	7850	200	1700	20	1427

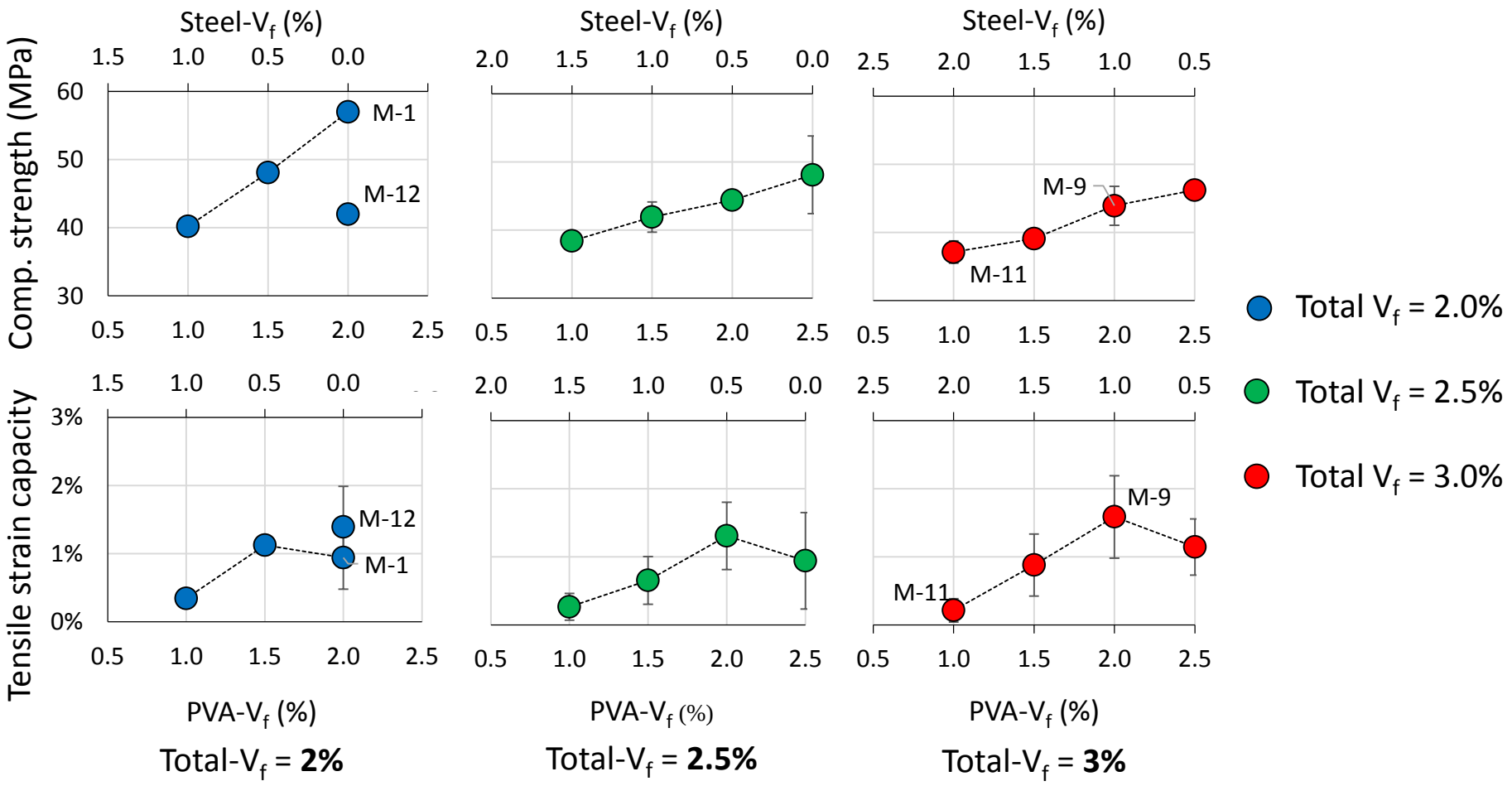




* Wang and Li (2007)

Image credit: http://www.helixsteel.com/technical

Results summary



Discussion – reaction of galvanizing

- Zn + wet cement → H_2 gas + …
- Expansion → set → shrinkage

… → **micro-cracking!**

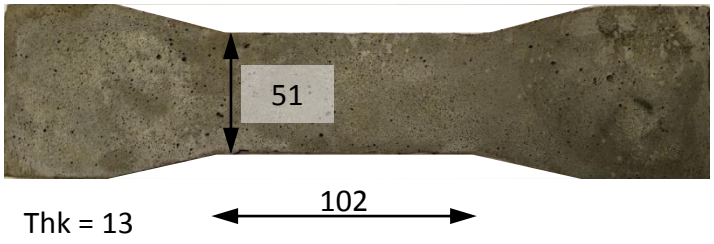
- Reduction in comp. strength

Only **PVA** fibers

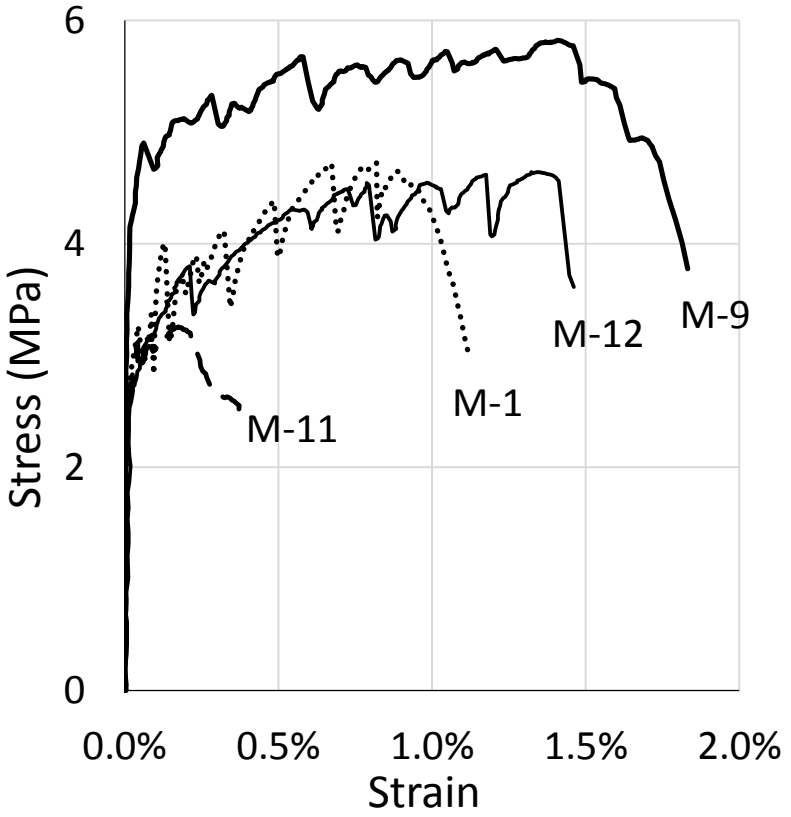
Only **Steel** fibers

Results – direct tension

- Representative curves
- Dogbone specimens



All dimensions in mm



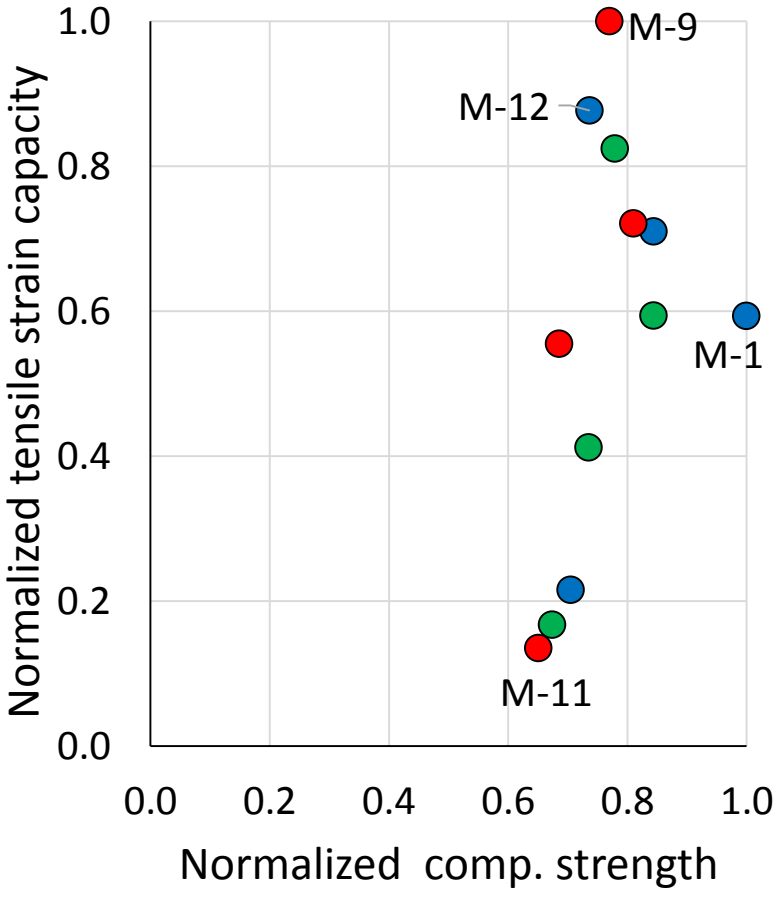
Optimization

- Multi-objective optimization (Ashby, 2000)

- Highest score: M-9

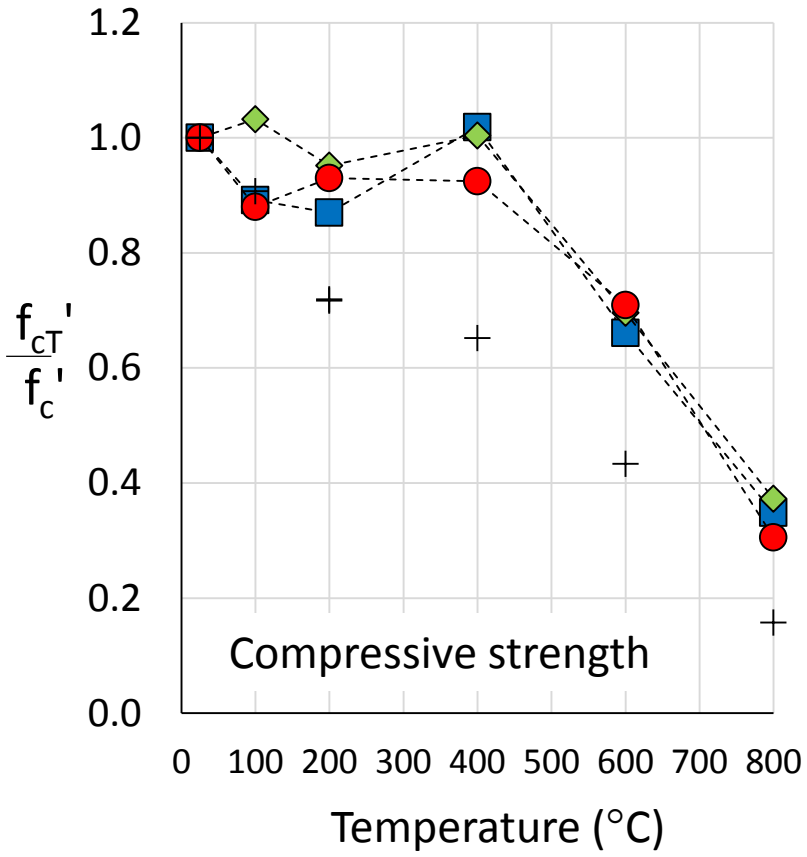
  (2%PVA+1%Steel)

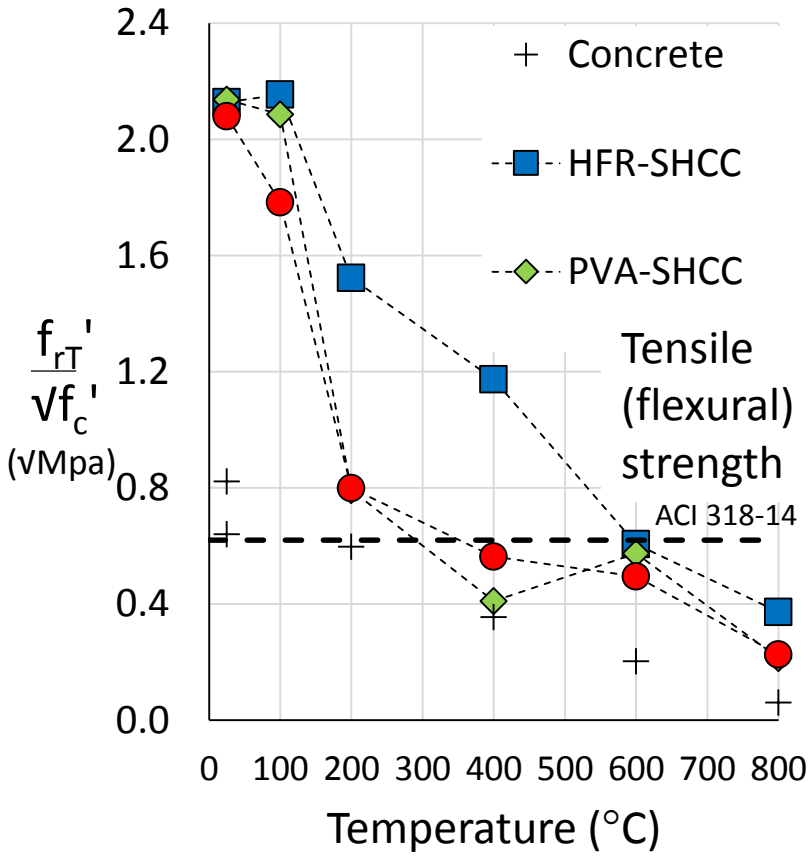
  44 MPa, 1.6%



… Additional work
Residual strength of HFR-SHCC

Results will be published in Deshpande et al., 2018





Acknowledgments

- Lafarge-Holcim
- WR Grace
- US Silica
- New Enterprise Stone and Lime (Buffalo Crushed Stone)
- Nycon

References

- Ashby, M. F. (2000). "Multi-objective optimization in material design and selection." *Acta materialia*, 48(1), 359-369.
- Chen, B., and Liu, J. (2004). "Residual strength of hybrid-fiber-reinforced high-strength concrete after exposure to high temperatures." *Cement and Concrete Research*, 34(6), 1065-1069.
- Kodur, V. (2000). "Spalling in high strength concrete exposed to fire: concerns, causes, critical parameters and cures." *Advanced Technology in Structural Engineering*, 1-9.
- Lau, A., and Anson, M. (2006). "Effect of high temperatures on high performance steel fibre reinforced concrete." *Cement and Concrete Research*, 36(9), 1698-1707.
- Li, V. C. (2003). "On engineered cementitious composites (ECC)." *Journal of Advanced Concrete Technology*, 1(3), 215-230.
- Naaman, A. E., and Najm, H. (1991). "Bond-slip mechanisms of steel fibers in concrete." *Materials Journal*, 88(2), 135-145.
- Peng, G.-F., Yang, W.-W., Zhao, J., Liu, Y.-F., Bian, S.-H., and Zhao, L.-H. (2006). "Explosive spalling and residual mechanical properties of fiber-toughened high-performance concrete subjected to high temperatures." *Cement and Concrete Research*, 36(4), 723-727.
- Pliya, P., Beaucour, A.-L., and Noumowé, A. (2011). "Contribution of cocktail of polypropylene and steel fibres in improving the behaviour of high strength concrete subjected to high temperature." *Construction and Building Materials*, 25(4), 1926-1934.
- Sahmaran, M., Lachemi, M., and Li, V. C. (2010). "Assessing mechanical properties and microstructure of fire-damaged engineered cementitious composites." *ACI Materials Journal*, 107(3), 297-304.
- Sahmaran, M., Ozbay, E., Yucel, H. E., Lachemi, M., and Li, V. C. (2011). "Effect of fly ash and PVA fiber on microstructural damage and residual properties of engineered cementitious composites exposed to high temperatures." *Journal of Materials in Civil Engineering*, 23(12), 1735-1745.
- Wang, S., and Li, V. C. (2007). "Engineered cementitious composites with high-volume fly ash." *ACI Materials Journal*, 104(3), 233-241.
- Yeomans, S. (2004). *Galvanized steel reinforcement in concrete*, Elsevier.
- Yu, J., Lin, J., Zhang, Z., and Li, V. C. (2015). "Mechanical performance of ECC with high-volume fly ash after sub-elevated temperatures." *Construction and Building Materials*, 99, 82-89.

Thank you!

Image credit: https://ubphoto.smugmug.com/Pages/Homepage-Curated-Collection/Here/i-S7r6329/A