CONCRETE SOLUTIONS FOR HIGH TEMPERATURES

Effects of elevated temperatures on concrete and cementitious materials

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Motivation

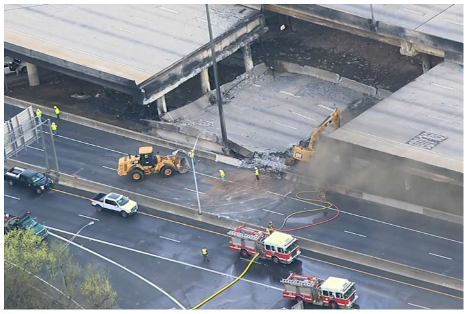
Concrete at high temperatures suffers loss in strength, which has led to catastrophic failures.

Objectives

- Improve understanding of effects of elevated temperatures on concrete materials
- Develop new construction materials to better withstand elevated temperatures

Research significance

Tunnels (Mont Blanc, 1999)



Bridges (I-85 near Atlanta, 2017)

Material development

Inspired by the thermal changes within concrete

'Mechanical' damage
Escaping steam
⬇
Microcracking
⬇
Solution: use polymer fibers!
melting = steam escape pathways

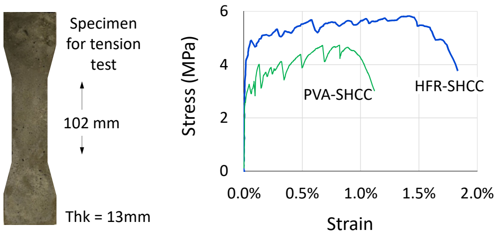
'Chemical' damage

➡ **PVA-SHCC** ... as a starting point

PVA-SHCC is a <u>ductile</u> fiber-reinforced concrete containing polyvinyl alcohol (PVA) fibers at volume fraction of 2%

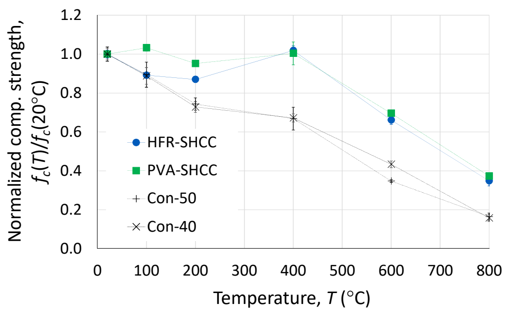
Material development *(continued)*

Main drawback in using polymer SHCCs
Fiber melting = loss in strain-hardening (ductility)
⬇
Solution: Use steel fibers
⬇
Multi-objective optimization of f_c' & tensile strain capacity
⬇
Hybrid fiber reinforced SHCC
HFR-SHCC
2% PVA fibers + 1% steel fibers
f_c' = 44 MPa
1.6% strain capacity in tension



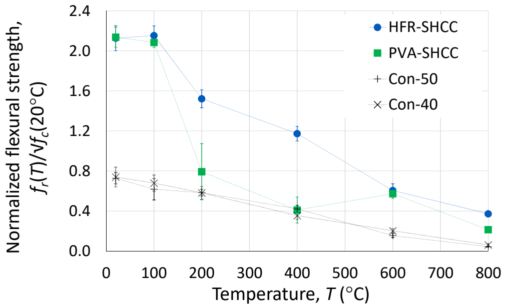
Results

Residual compression strength:



- 2% PVA fibers → strength retention up to 400°C
- Loss beyond 400°C similar in all concretes

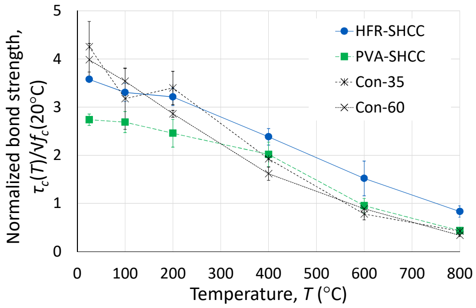
Residual flexural (tensile) strength:



- 2% PVA fibers only → similar to concrete after 200°C (melting of fibers)
- HFR-SHCC performs better up to 600°C than conventional concrete @ 20°C

Results *(continued)*

Residual anchorage bond strength:



- At 20°C, concrete bond strength larger than SHCC
- HFR-SHCC bond strength larger than PVA-SHCC
- HFR-SHCC - best retention of bond strength till 800°C
- Brittle response (splitting) of Con-60 and PVA-SHCC above 200°C (melting of PVA fibers)
- Ductile response (pullout) of HFR-SHCC at all temp.

Summary

Successful development HFR-ECC:

- Strain-hardening behavior at 20°C
- Compression strength retention till 400°C
- Superior tension strength till 600°C
- Improved bond performance over PVA-SHCC

References

Deshpande, A., Kumar, D., Mourougassamy, A. & Ranade, R. (2017). "Development of a Steel-PVA Hybrid Fiber SHCC." In Proc. of 4th SHCC Conference, 18-20 September, 2017, Dresden, Germany, pp. 195-202.

Sahmaran, M., Ozbay, E., Yucel, H.E., Lachemi, M., & 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.

Images:
https://www.tunneltalk.com/images/Mont-Blanc/The-aftermath-of-the-1999-fire.jpg
https://tribktla.files.wordpress.com/2017/03/s077272674-300.jpg?quality=85&strip=all&strip=all