

Sustainable Portland Limestone Cement-Based (Ultra) High-Performance Concrete



MIAMI

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Civil and Architectural Engineering

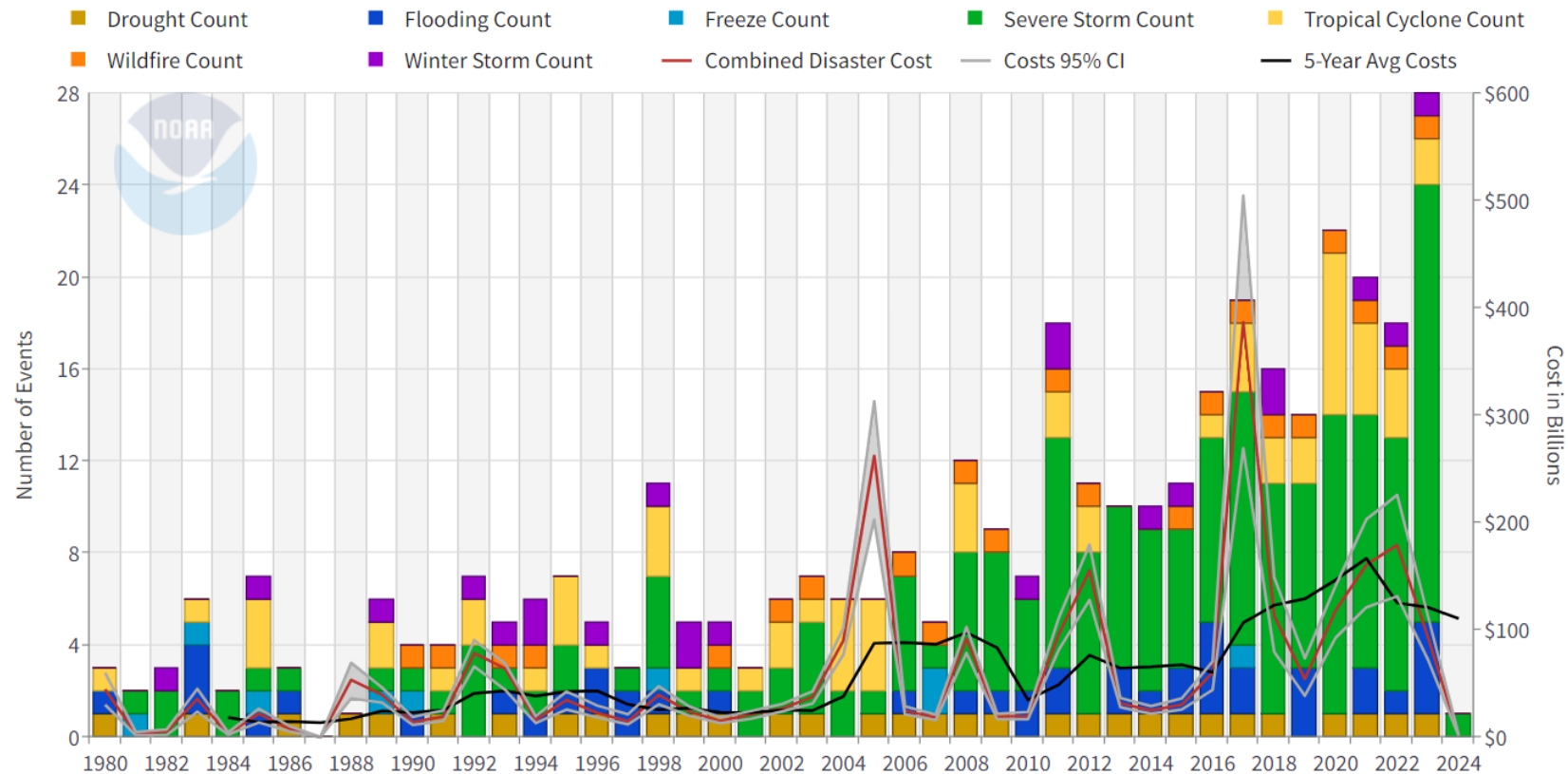
THE WORLD'S GATHERING PLACE FOR ADVANCING CONCRETE



3.2 billion people lives within 60 mi of the coast

Urban coastal areas exposed to climate change and sea level rise effects

United States Billion-Dollar Disaster Events 1980-2024 (CPI-Adjusted)



273 climate disasters
> \$ 1 B (since 1980)



THE WORLD'S GATHERING PLACE FOR ADVANCING CONCRETE

Nearly 14% of the U.S. shoreline (22,842 km)

“Hard” Structures

However...

...Often severely
damaged



Not designed with particular ecological role



SLR Adapted Sea Walls
+ Living Shoreline



Submerged
Breakwater



Enhanced Islands



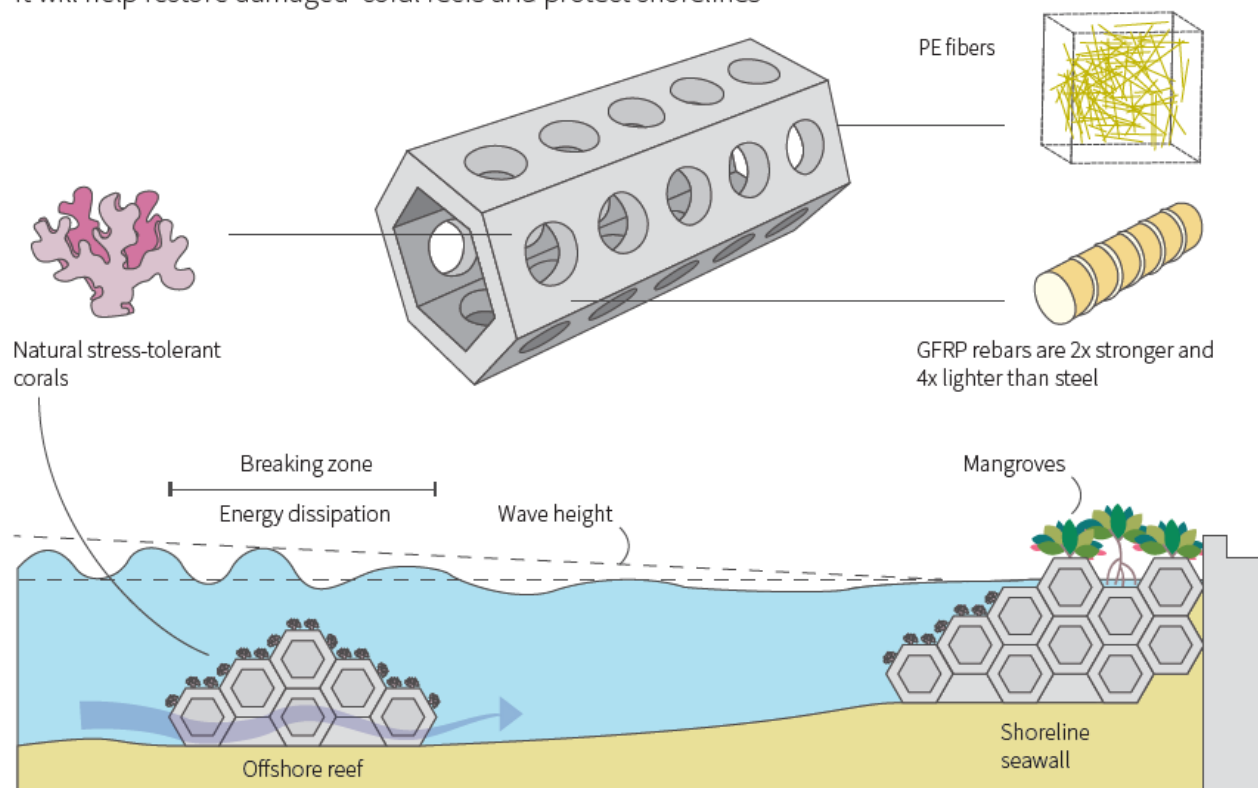
Mangroves



Reinforced Dune
System

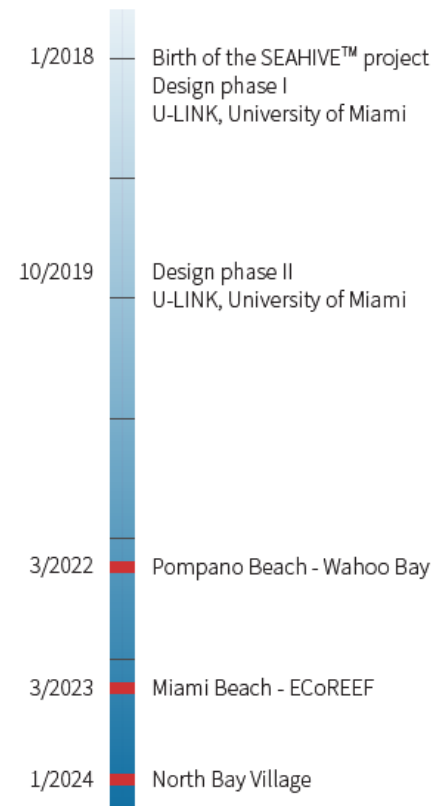
SEAHIVE™ hybrid reef system technology

The 18-foot-long honeycomb UHPC structure is the modular element of the system. It will help restore damaged coral reefs and protect shorelines.



From the cradle to reality

Timeline for the 3 pilot projects



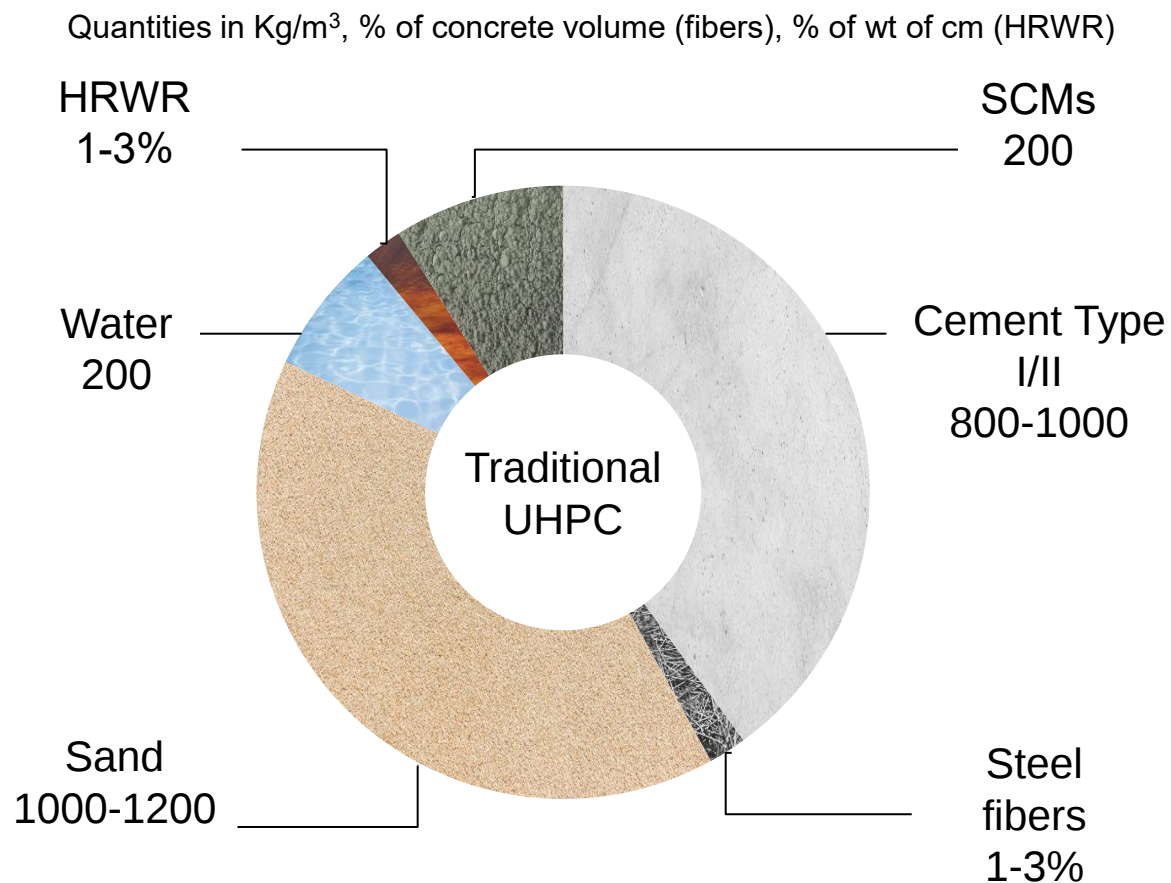
Materials:

- NSC
- UHPC
- 3DPC



<https://cae.coe.miami.edu/research/seahive/index.html>

Improve reinforced concrete coastal infrastructures' performance by developing new materials and designs

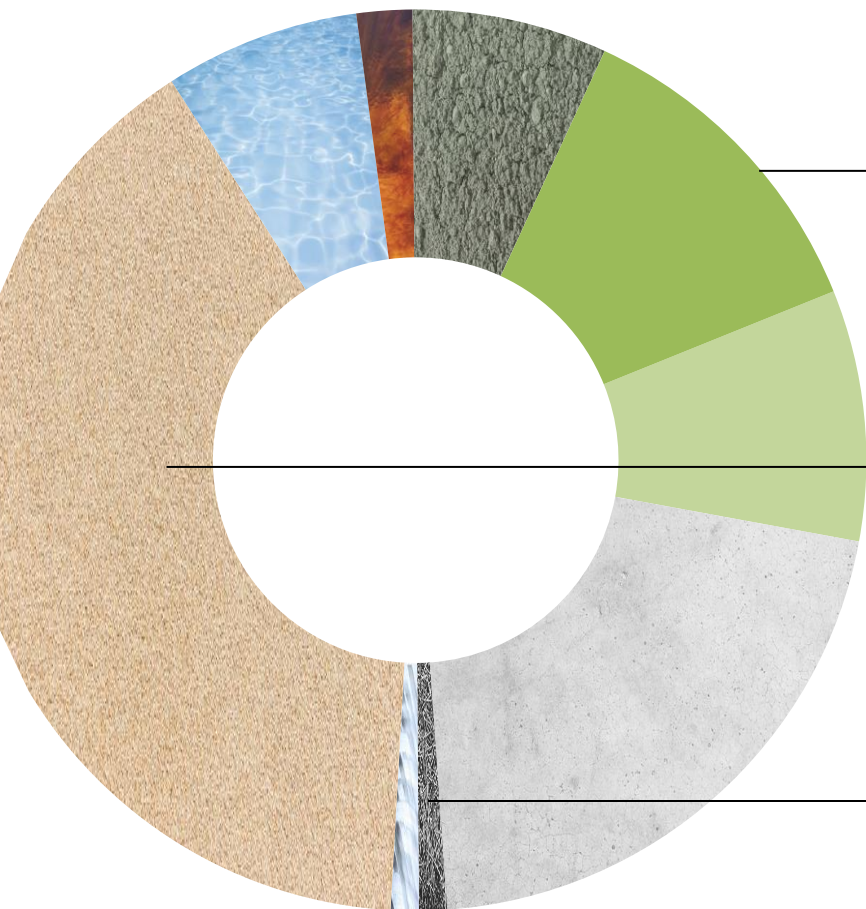


Great!!! ...but...

- Sustainability
- Materials cost

prevent its use on a large scale

Improve reinforced concrete coastal infrastructures' performance by developing new materials and designs



Up to 44% clinker substitution

- Replacing type I/II PC with PLC
- Adding SCMs (ultra-fine limestone, fly ash, slag)

Using coarser sand

Evaluating synthetic fibers to replace (at least partially) steel



BINDERS

PLC = Portland limestone cement
UL = 'Ultra fine' limestone
FA = Fly ash
SL = Slag
Sand

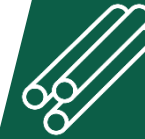


ADMIXTURES

HRWR = High range water reducer



WATER

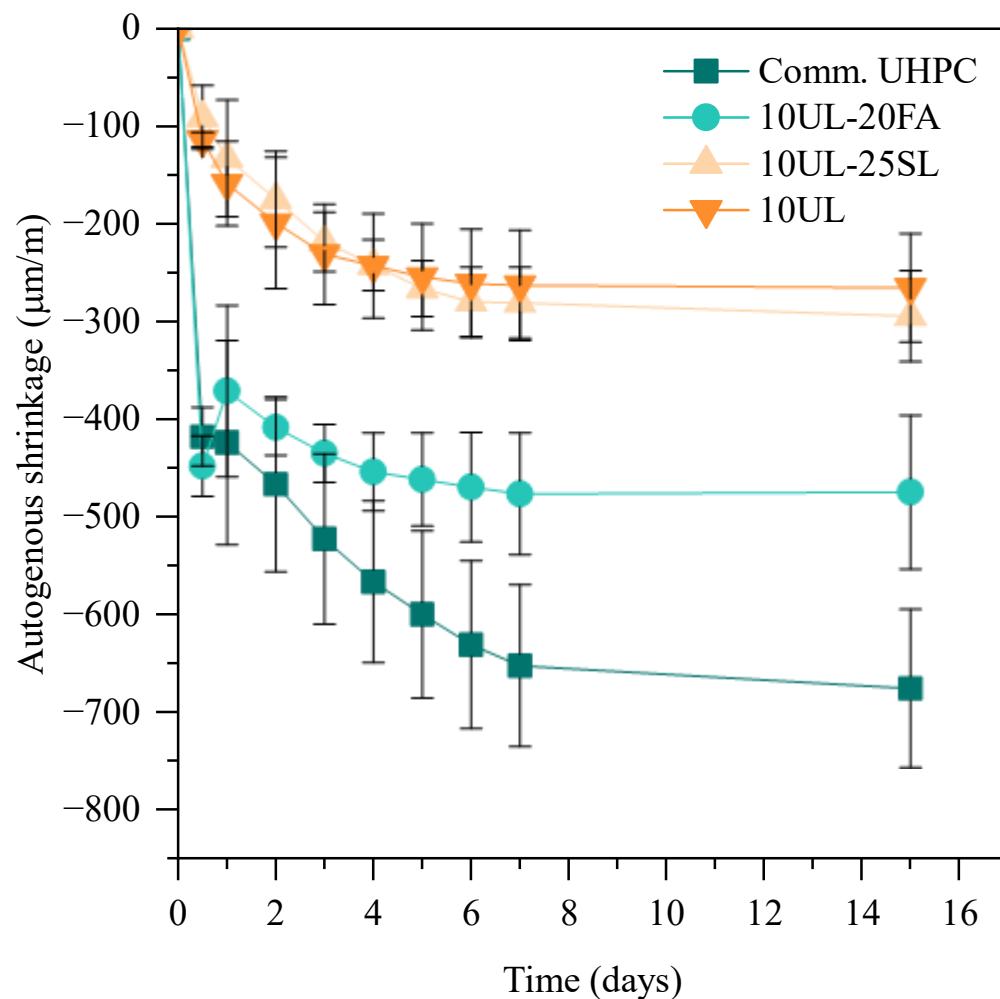


FIBERS

Sf = Steel fibers
Pf = Polyethylene fibers
SPf = Steel/polyethylene fibers

Quantities in kg/m³

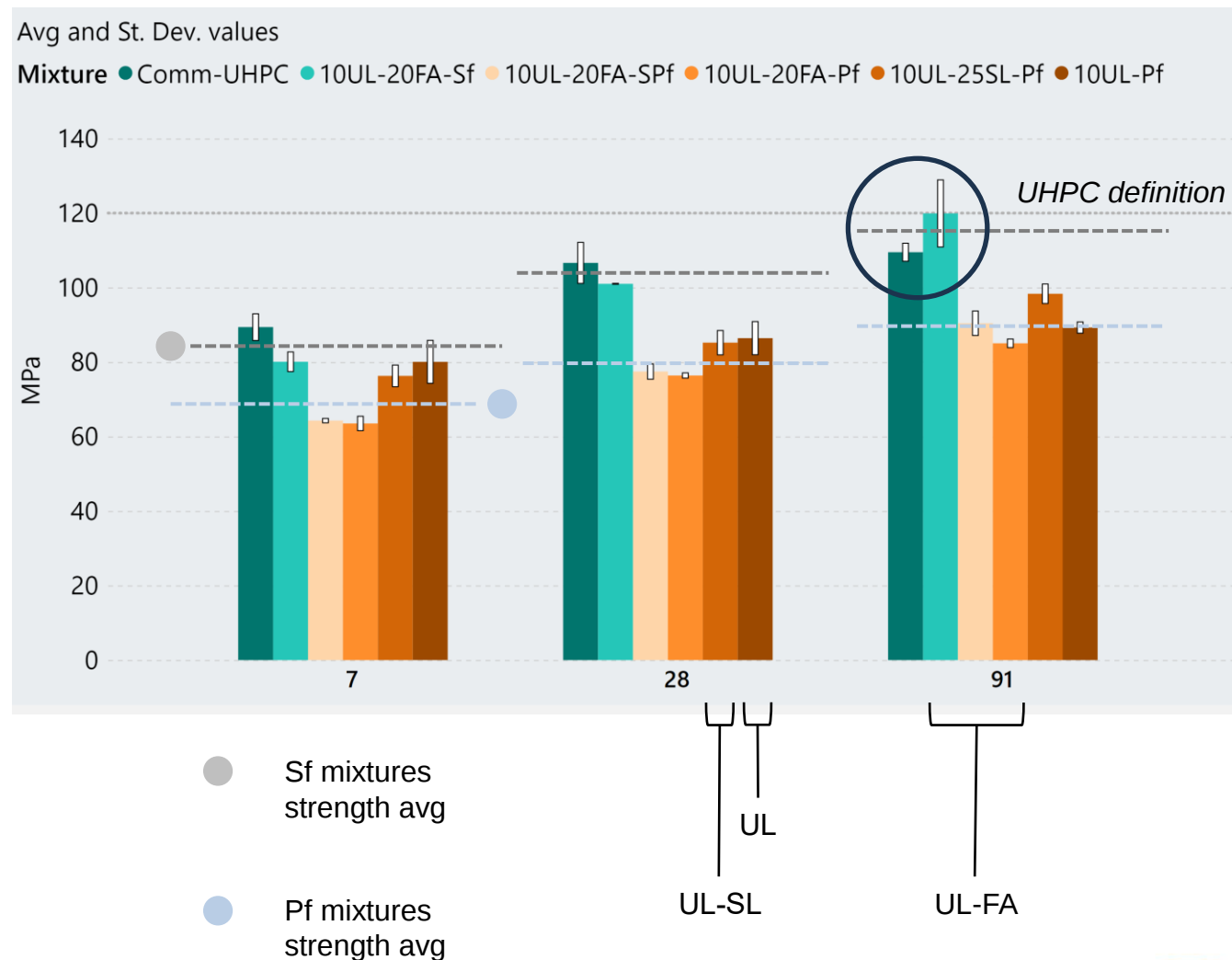
Mixture	Dry mix UHPC	PLC	UL	FA	SL	Sand	HRWR (2%)	Water (w/cm=0.2)	Sf (1-2%)	Pf (1-2%)
Comm-UHPC	2170	-	-	-	-	-	23	206	153	-
10UL-20FA-Sf	-	714	102	204	-	1022	20	204	157	-
10UL-20FA-SPf	-	714	102	204	-	1022	20	204	78	10
10UL-20FA-Pf	-	714	102	204	-	1022	20	204	-	20
10UL-25SL-Pf	-	664	102	-	255	1022	20	204	-	20
10UL-Pf	-	916	102	-	-	1022	20	204	-	20



- All the newly developed formulations perform better than Comm. UHPC.
- SCM's fineness and reaction help to decrease capillary pressure, better controlling shrinkage
- SL outperformed FA, possibly due to higher SL's SO_3 content leading to greater chemical expansion, mitigating autogenous shrinkage
(Tangtermsirikul,1998)

Fibers effects

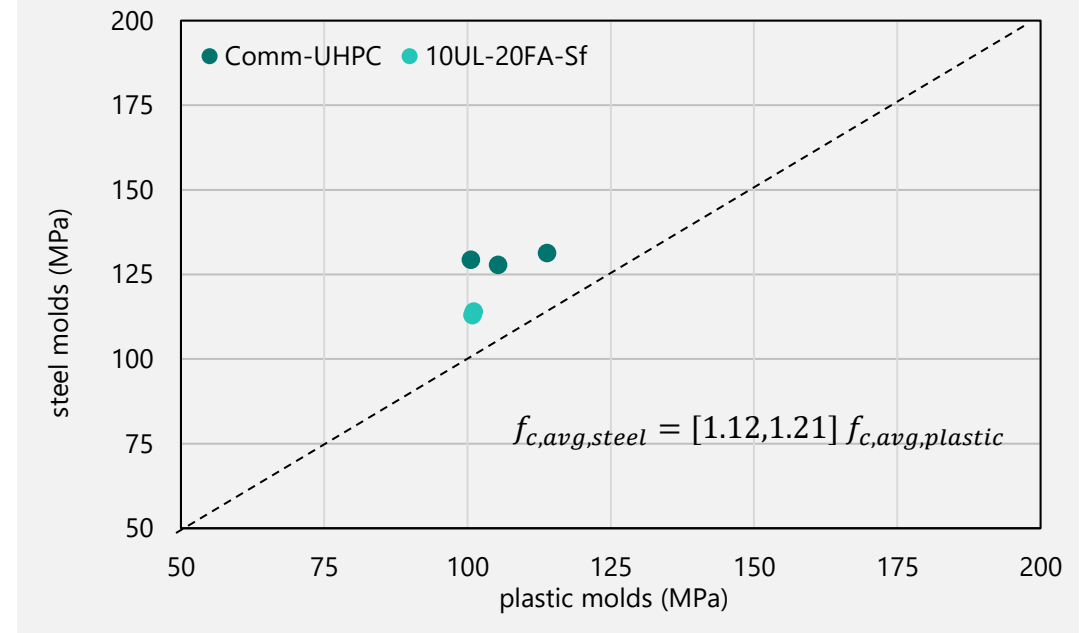
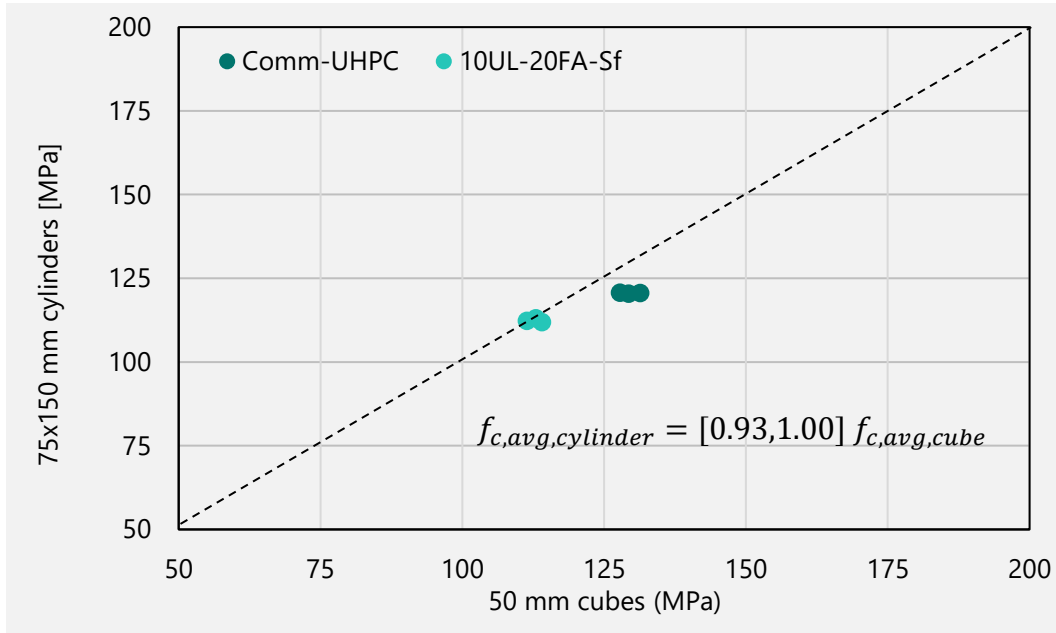
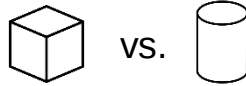
- Sf perform better than Pf
- 2% Sf content positively impact strength
(Le Hoang et al., 2010)
- Pf dispersion issues may have led to premature failure
(Meng et al., 2018)



Hydration effects

- UL contributes with filler effect
- SL latent hydraulic nature benefits strength more at early ages
- FA mixtures show continuous increase due to pozzolanic reaction

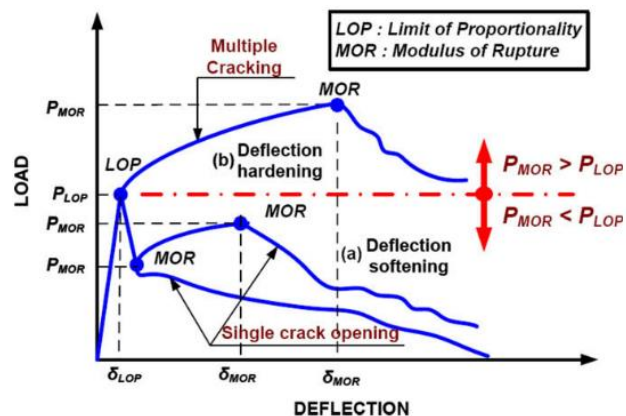
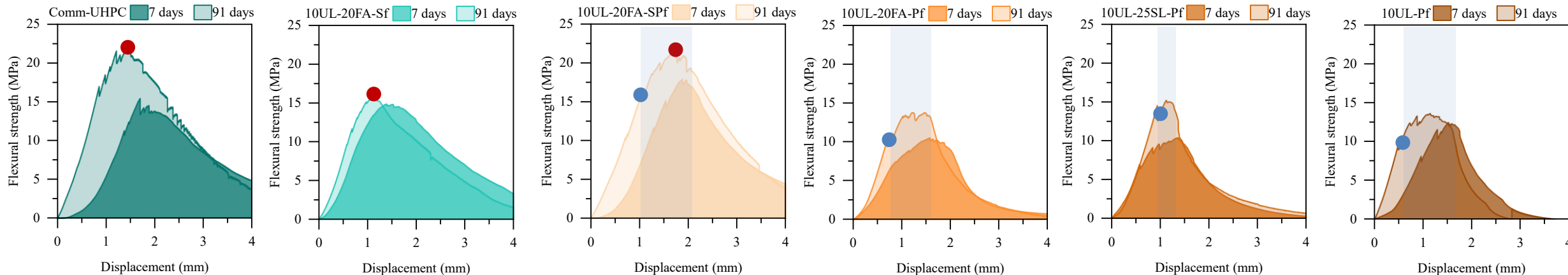




- Cubes are an acceptable alternative to cylinders to determine UHPC compressive strength

- UHPC cubes are sensitive to geometry imperfections and end preparations

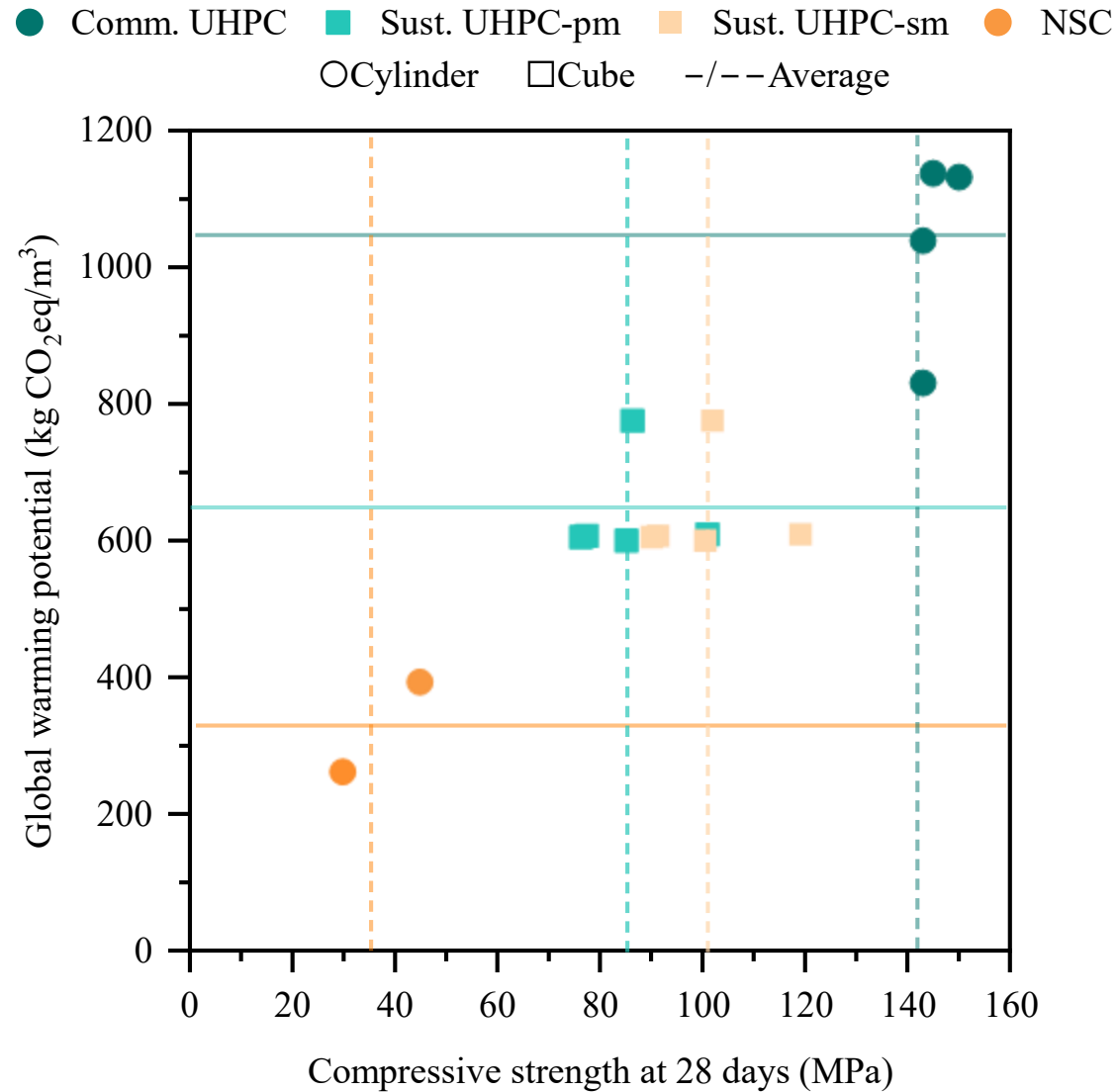
10UL-20FA-Sf exceed 120 MPa at 28 days, meeting UHPC's standard strength definition



Kim D. et al. (2008)

- Deflection hardening behavior achieved by every mixture
- Sf reinforced mixtures developed higher flexural peak strengths, while Pf fibers provide a better post-first peak strain capacity
- 10UL-20FA-SPf shows fiber synergistic effects, increasing strength and toughness





- All the newly developed formulations showed a significantly lower carbon footprint than the Comm. UHPC
- PLC based UHPCs performance are closer to NSC than Comm. UHPC, in terms of GWP

- Isothermal calorimetry showed similar reaction kinetics for all mixtures
- TGA showed that SL and FA containing mixtures exhibited higher calcium hydroxide consumption than the one containing UL only
- Sf reinforced mixtures showed a self-compacting behavior, while the workability of Pf reinforced ones was impacted by the properties of the fiber
- SCMs notably enhanced the electrical resistivity of UHPCs, particularly at later ages

More details @ [DOI: 10.13140/RG.2.2.24215.79529](https://doi.org/10.13140/RG.2.2.24215.79529)

Thank



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Let's
connect

Acknowledgments



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CONVENTION**