123 Forum: Should 3D Printing be Codified?

ACI Convention Spring 2024

03-25-2024

Islam M. Mantawy

Assistant Professor

Civil and Environmental Engineering
Henry M. Rowan College of Engineering
Rowan University

Conventional Construction vs Hybrid Construction vs Additive Construction

Construction industry over the last decades

Comparison of construction techniques between 1950s (left) and 21st century (right).

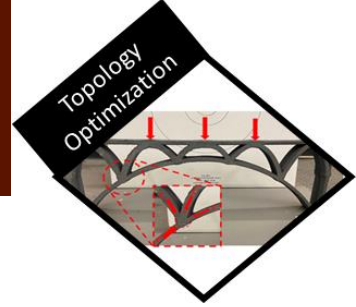
Conventional Construction vs Hybrid Construction vs Additive Construction

Conventional Construction
(forming, reinforcement placement & casting)

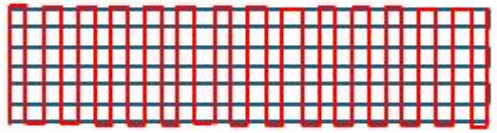
Additive Construction
with Topology Optimization

Hybrid Construction
(printing formwork, reinforcement placement & casting)

Topology Optimization

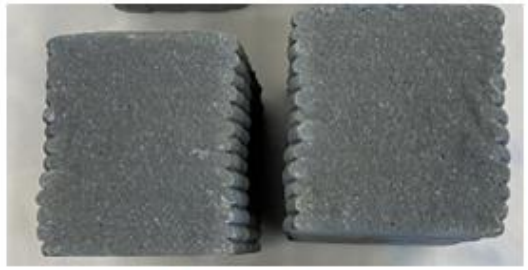


Printing Path (Plan)



Testing/ Failure Mode

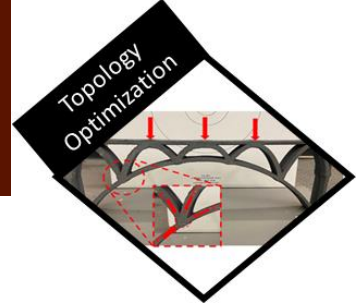
Interface



Beam 1 | Beam 2 | Beam 3

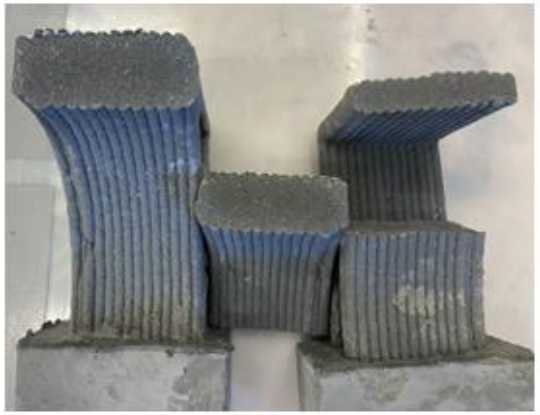
ID	Force		Span (L)		Depth (d)		Width (b)		Modulus of Rupture (R)	
	(kips)	kN	inch	mm	inch	mm	inch	mm	ksi	mpa
Beam 1	2.460	10.943	9.25	235.0	3.50	88.9	3.00	76.2	0.929	6.404
Beam 2	2.000	8.896	9.00	228.6	3.50	88.9	3.25	82.6	0.678	4.676
Beam 3	2.880	12.811	9.13	231.8	3.75	95.3	3.00	76.2	0.934	6.442

Topology Optimization



Equivalent Beam

Arch



	ID	Force		Span (L)		Depth (d)		Width (b)		Modulus of Rupture (R)	
		(kips)	kN	inch	mm	inch	mm	inch	mm	ksi	mpa
Calculated	Equivelant Beam	0.135	0.602	9.00	228.6	0.75	19.1	3.50	88.9	0.929	6.404
Tested	Arch	1.349	6.000								
	Ratio	10.0	10.0								

Low Embodied Carbon Concrete (Geo Polymers)

Low Embodied Carbon Mixes (Geopolymer Concrete)

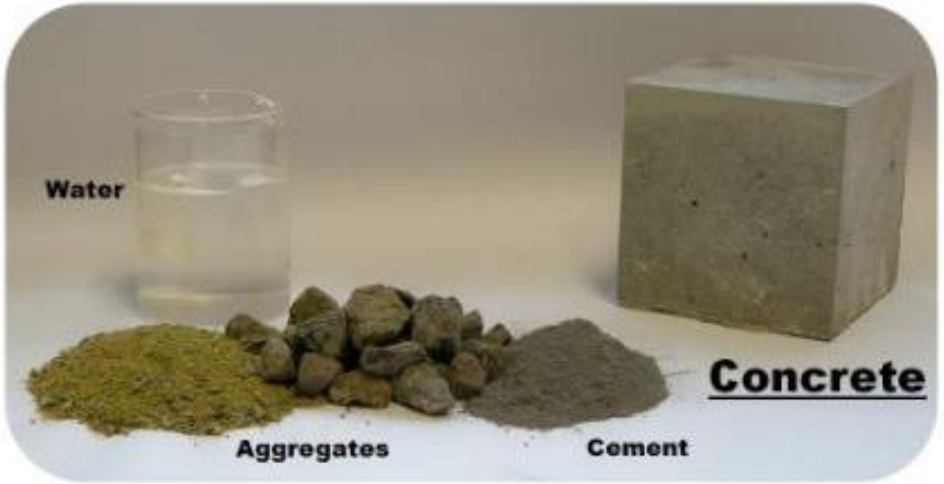
Concrete with Ordinary Portland Cement

The most consumed commodity in the world after water.

The most energy-intensive material.

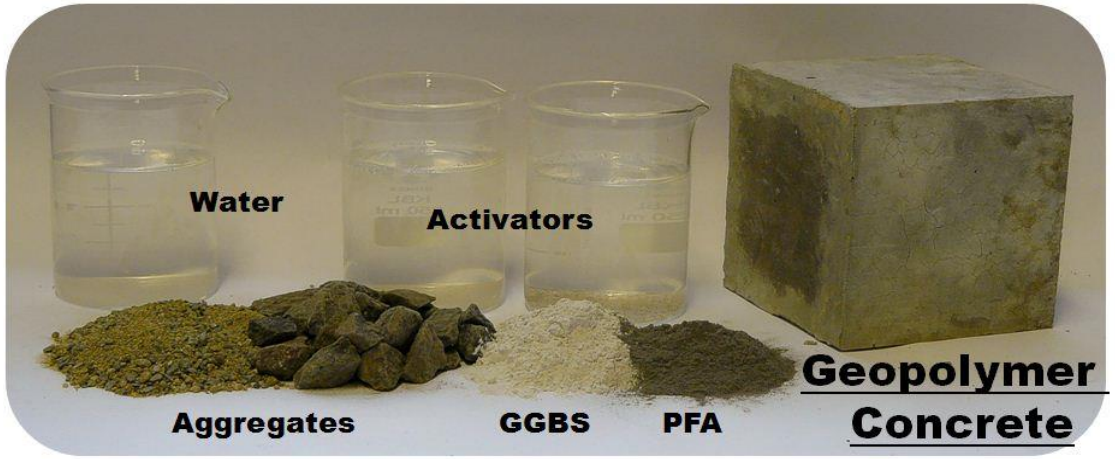
Cement production leads to high CO_2 emissions.

- 1 ton of CO_2 is produced for every 1 ton of cement.
- It's produced by the calcination of limestone and the burning of fossil fuels.



Geopolymer Concrete

- Viable low cost and greener substitute for conventional concrete.
- Utilize waste materials from industries such as Fly ash, Silica Fume, and GGBS.
- Reducing the need for landfills and associated costs.
- Conserving natural resources.
- (CO_2) emission avoidance.



Low Embodied Carbon Concrete (Geo Polymers)

Low Embodied Carbon Mixes (Geopolymer Concrete)




In-house printable Geopolymer Concrete developed at ARC lab, Rowan University.

Optimized Compression-Only (C-Only) Structures

Optimized Compression-Only (C-Only) Structures

Printing with Step Slopes (1K)

Printing with Step Slopes (2K)