ACI International: iniziative e soluzioni per la sostenibilità delle strutture in c.a.

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Come l'ingegneria e la tecnologia possono garantire la sostenibilità delle strutture in calcestruzzo armato?

Università degli Studi di Napoli Federico II – CAMPUS SAN GIOVANNI

17 Novembre 2023

UNIVERSITY OF MIAMI

Center for Integration of Composites into Infrastructure

Part I - PREMISE ABOUT ACI

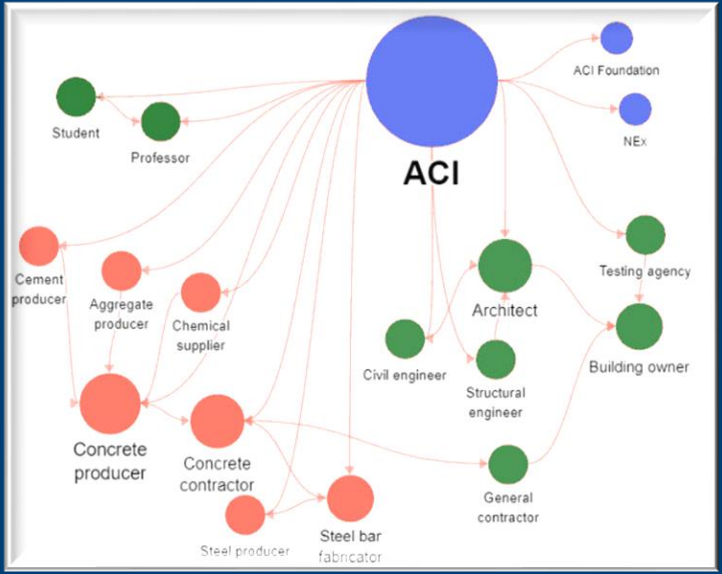
1) A few words about ACI: the organization
2) ACI Centers of Excellence: ahead of the curve
3) ACI Codes, Specifications and Guides

Essence & Connectivity of ACI…

- Founded in 1904, ACI is a professional society, not a trade association

Vision:

- ACI envisions a future where everyone has the knowledge needed to use concrete effectively to meet the demands of a changing world



Mission:

- ACI develops, disseminates, and advances the adoption of its consensus-based knowledge on concrete and its uses

ACI's Resources…

- 4000 Active Technical Volunteers
  - ✓ ~ $100+ MM Annual Effort
- Headquartered in Farmington Hills, MI with 150+ Staff
- International Office in UAE
- Regional Offices in CA, IL, and MD
- 140+ Technical & Educational Committees
- 1000+ Technical & Educational Documents
- Calibration with Industry Groups – PCA, CRSI, PTI, ACPA, etc.

ACI's Physical Locations…

World Headquarters - Farmington Hills, MI USA

Middle East Regional Office - Dubai, UAE

ACI's Physical Locations…

Resource Centers

Southern California
San Bernardino, CA

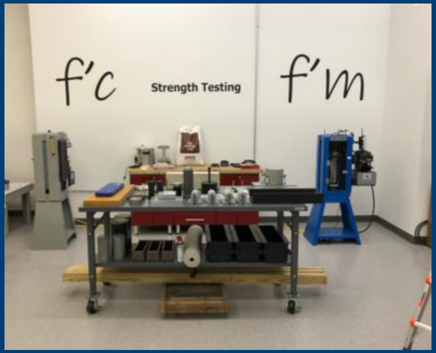
Chicago, IL

Columbia, MD

Resource Centers

Provide physical locations for:

- ✓ Training
- ✓ Certification
- ✓ Seminars
- ✓ Chapter meetings
- ✓ Industry events



ACI's Footprint…

- 33,000+ Members Worldwide
  - ✓ 15,000 Students
- 90+ Chapters
- 250+ Student Chapters
- 60+ International Partners
- Building Code used in over 60 countries
- Credentialed 700,000+ individuals in the concrete industry
- Select Documents available in 15+ languages

Advancements at ACI…

Centers of Excellence: PRO

PRO

An ACI Center of Excellence for Advancing Productivity

MISSION

Collaborate with designers, material suppliers, builders, and other industry stakeholders to improve design constructability and construction productivity for all concrete structures.

Centers of Excellence: NEU

neu

An ACI Center of Excellence for Carbon Neutral Concrete

Collaborate globally to drive education, awareness, and adoption of the use of carbon-neutral materials and technologies in the built environment.

Centers of Excellence: NEx

NEx™

An ACI Center of Excellence for Nonmetallic Building Materials

Collaborate globally on the use of nonmetallic building materials to drive research, education, awareness and adoption

ACI Codes, Specifications and Guides…

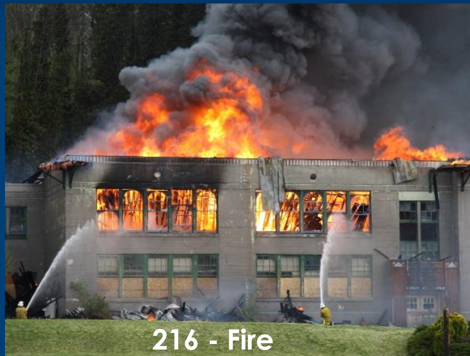
ACI Technical Committees

- *ACI Collection of Concrete Codes, Specifications, and Practices*
- 300+ Documents
  - Codes
  - Specifications
  - Reports
  - Guides
  - Technical Notes

ACI 318

(Main Concrete Code)

Other ACI Codes


216 - Fire


307 – Chimneys


313 - Silos


332 – Residential


349 – Nuclear Facilities


350 – Environmental


359 – Nuclear Contain.


369 – Seismic Retrofit


376 – RLG Containment


440 – Glass FRP Bar


437 – Strength Evaluation


562 - Repair

Part II – SUSTAINABILITY OF CONCRETE

1) Challenge and Market Response
2) ACI Response – Low Carbon Concrete Code

Current Challenges in the Cement and Concrete Industry

Carbon Emissions

Cement production is a major contributor to carbon emissions, accounting for approximately 8% of global greenhouse gas emissions

Environmental Impact

From extraction of raw materials to construction applications, concrete has significant environmental impact, including land degradation and water pollution

Roadmap for Net Zero Concrete

The industry needs a clear roadmap to transition to net zero concrete, reducing carbon emissions and minimizing environmental impact

Key Strategies for Achieving Net Zero Concrete

Low Carbon Cement Alternatives

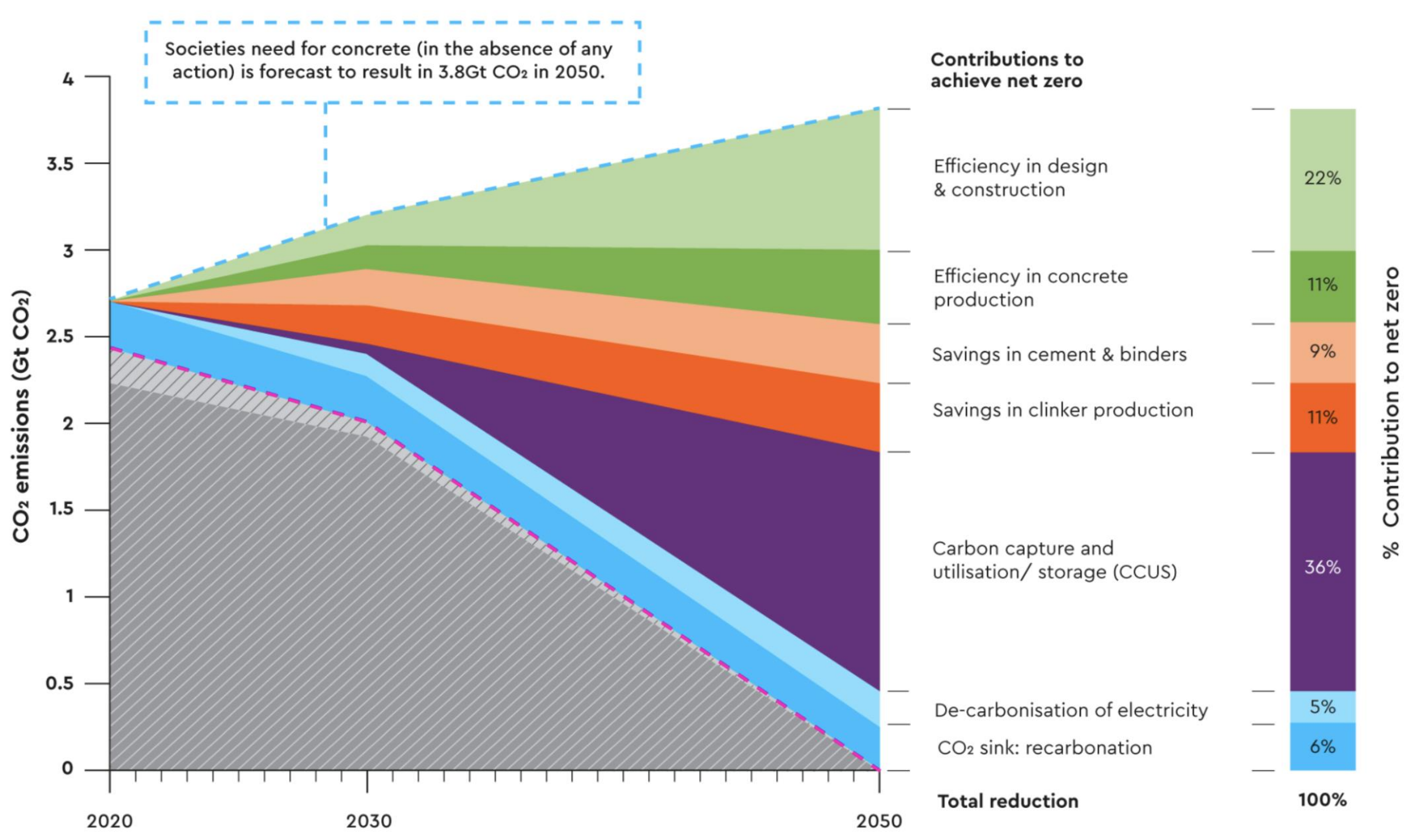
Developing and implementing innovative cement substitutes with lower carbon emissions, such as novel supplementary cementitious materials (SCMs) and alternative cements

Energy-Efficient Production Processes

Adopting energy-efficient technologies, such as alternative fuels, waste heat recovery, and advanced kiln designs, to reduce energy consumption during cement production

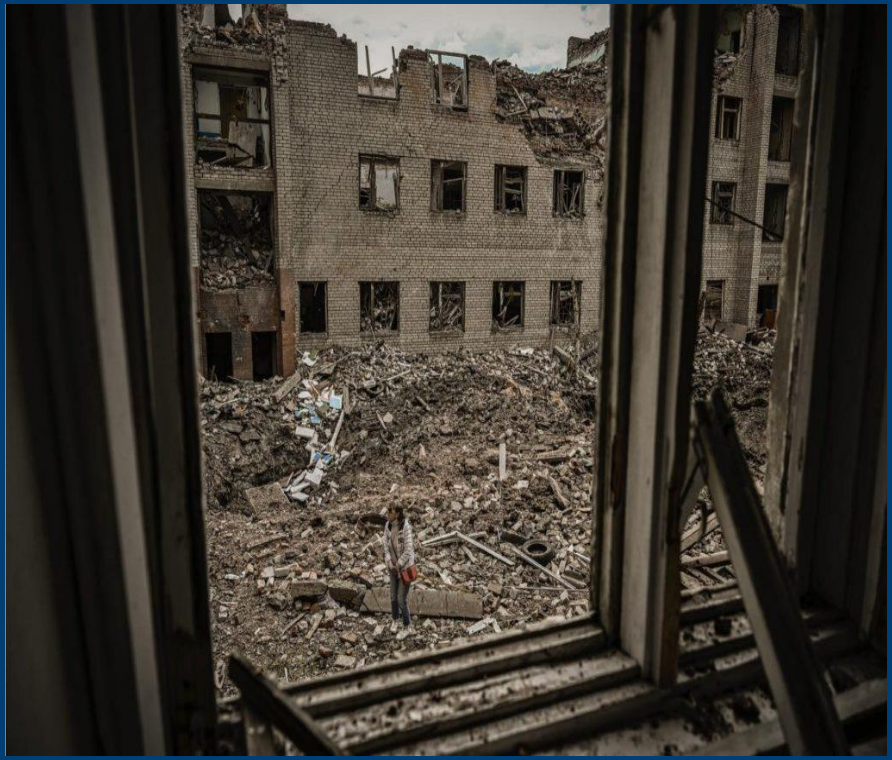
Enhanced Carbon Capture and Storage

Investing in research and development of carbon capture and storage (CCS) technologies to capture and store carbon dioxide emitted during cement production



Societies need for concrete (in the absence of any action) is forecast to result in 3.8Gt CO_2 in 2050.
CO_2 emissions (Gt CO_2)
4
3.5
3
2.5
2
1.5
1
0.5
0
2020
2030
2050
Contributions to achieve net zero
Efficiency in design & construction
Efficiency in concrete production
Savings in cement & binders
Savings in clinker production
Carbon capture and utilisation/ storage (CCUS)
De-carbonisation of electricity
CO_2 sink: recarbonation
Total reduction
22%
11%
9%
11%
36%
5%
6%
100%
% Contribution to net zero

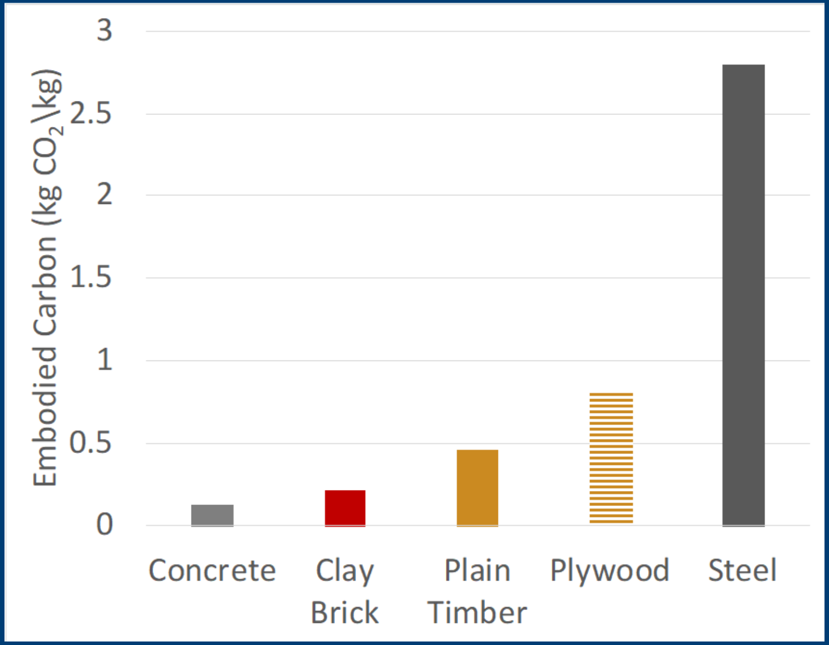
Globally, the military sector is estimated to generate around 6% of all CO_2 emission



Of the housing stock in conflict-affected areas of Syria, nearly ten percent is totally destroyed and nearly a quarter partially destroyed – estimates suggest the rebuild will emit around **22 Mt CO_2**

Source of Embodied Carbon

- Reinforced concrete has a low embodied carbon per unit volume
- Scale of production of concrete is the main cause of the high level of carbon emissions associated with concrete
- Over 400,000,000 yd^3 produced in U.S. each year, or ~ 615 Hoover Dams



Data from: Scrivener et al. 2014 and Hammond and Jones 2008

What is "Low Carbon Concrete"

Is there one concrete mixture to rule them all?

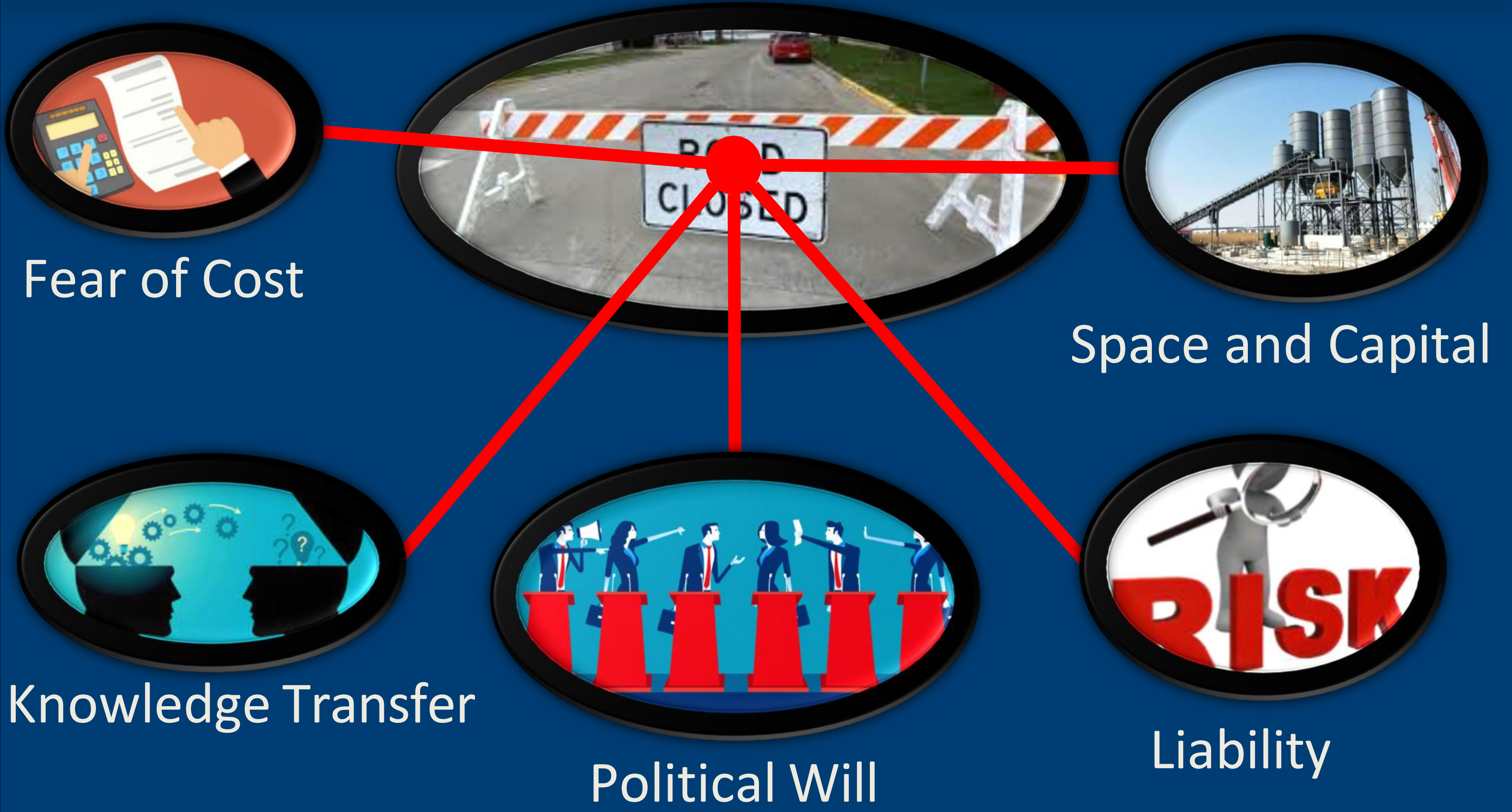
No current industry standard definition

What is "Low Carbon Concrete"?

- Low carbon concrete is a design goal
- Create concrete that has a lower amount of embodied carbon than the average concrete mixture
- Constantly changing target

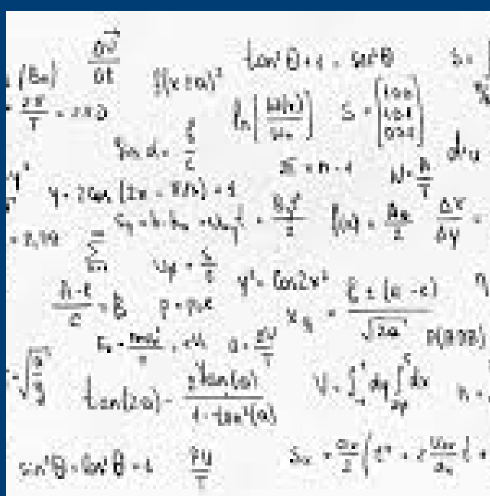
- Embodied carbon - expressed as **global warming potential (GWP)** – Quantifiable measurement of greenhouse gas emission's impact on warming

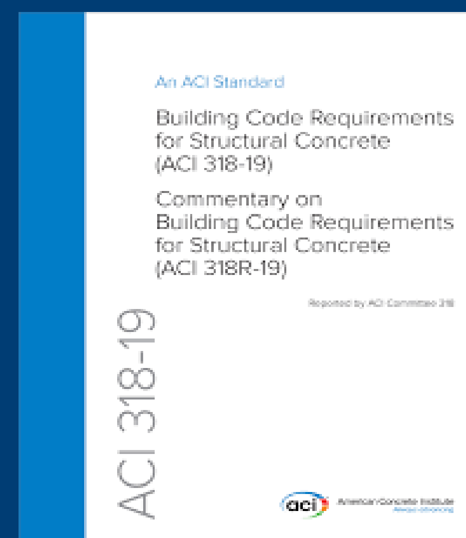
What’s Stopping Us?



What is needed?

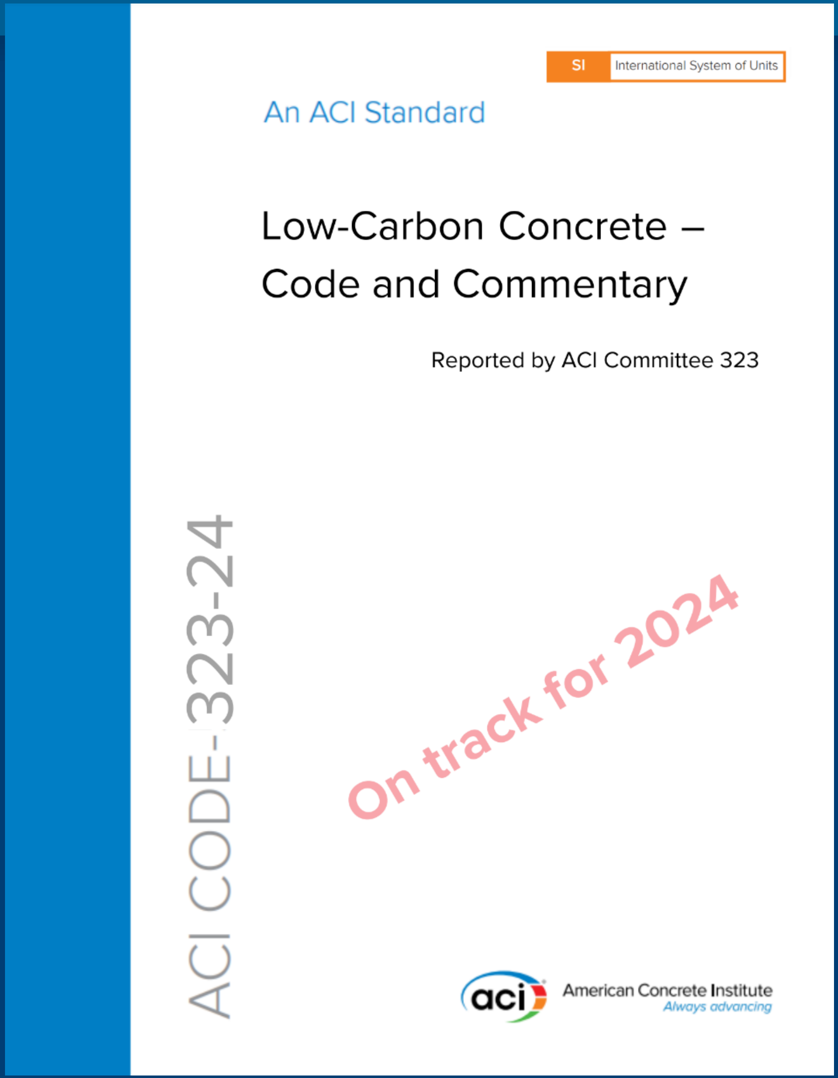
- How to determine the GWP?
- What limits to set?
- How do GWP limits interact with life-safety codes?





ACI Code Committee 323

- Here is first ACI answer:



ACI Participation at COP28

Part III – FRP-REINFORCED CONCRETE

1) ACI 440.11-22 Building Code & Commentary
2) Field Applications
3) Conclusions

Corrosion in Steel-RC

Protecting ferrous reinforcement from corrosion is the current state-of-practice (e.g., additional concrete cover, membranes, corrosion inhibiting admixtures, bar epoxy coating)

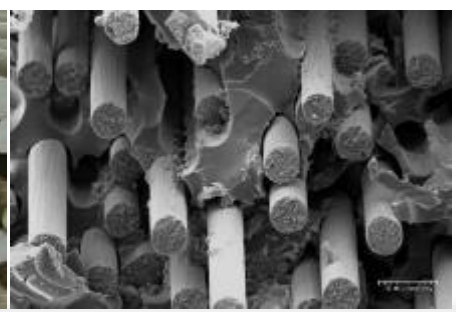
Reinforced concrete (RC) constructed with fiber reinforced polymer (FRP) rebars does not have durability and longevity issues present when using traditional carbon-steel

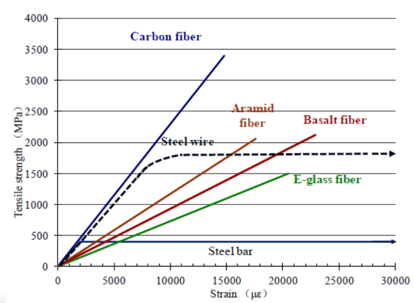
Fiber Reinforced Polymer (FRP) Bars

There are many fiber and resin types

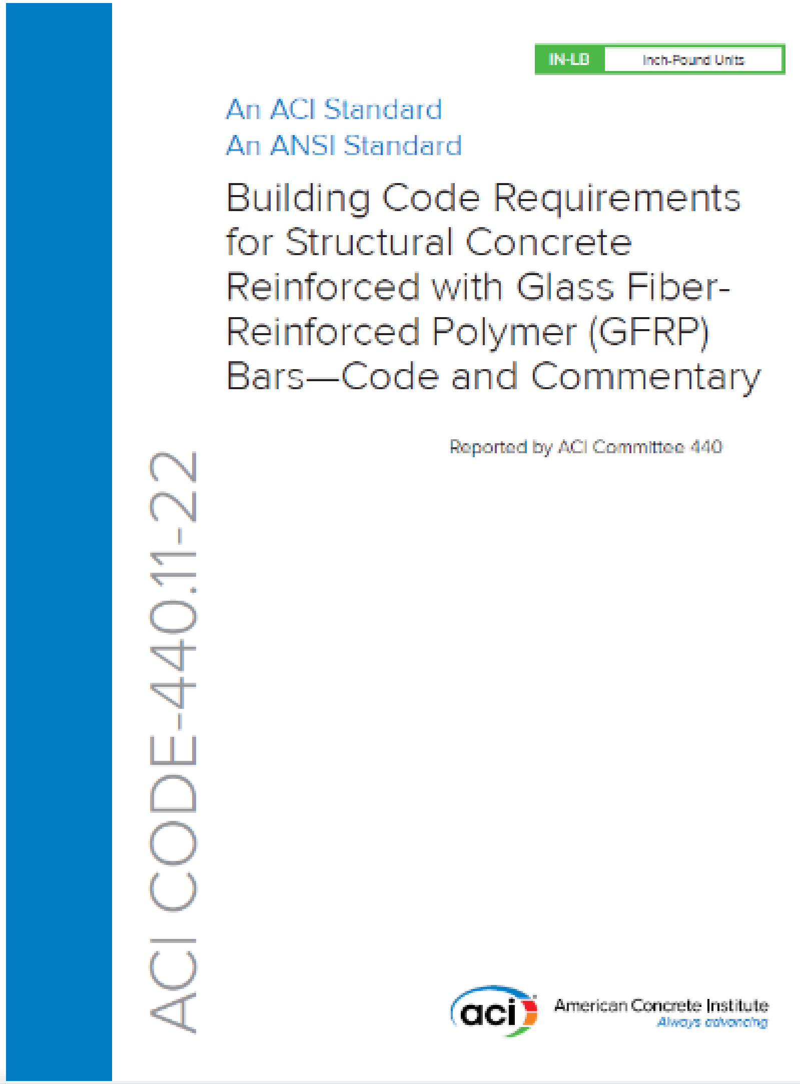
R&D of rebars with E-CR glass fibers in a vinyl ester resin has shown satisfactory performance

GFRP rebars must meet the requirements of ASTM D7957 that includes physical and mechanical properties based on ASTM test methods for strength of straight and bent bars





ACI 440.11-22 Building Code & Commentary


IN-LB Inch-Pound Units

An ACI Standard
An ANSI Standard

Building Code Requirements for Structural Concrete Reinforced with Glass Fiber-Reinforced Polymer (GFRP) Bars—Code and Commentary

Reported by ACI Committee 440

ACI CODE-440.11-22

American Concrete Institute
Always advancing

ACI 440.11-22: GFRP Building Code

"Building Code Requirements for Structural Concrete Reinforced with Glass Fiber-Reinforced Polymer (GFRP) Bars" ("Code") provides minimum requirements for the materials, design, and detailing of structural concrete buildings and, where applicable, nonbuilding structures reinforced with GFRP bars that conform to the requirements of ASTM D7957

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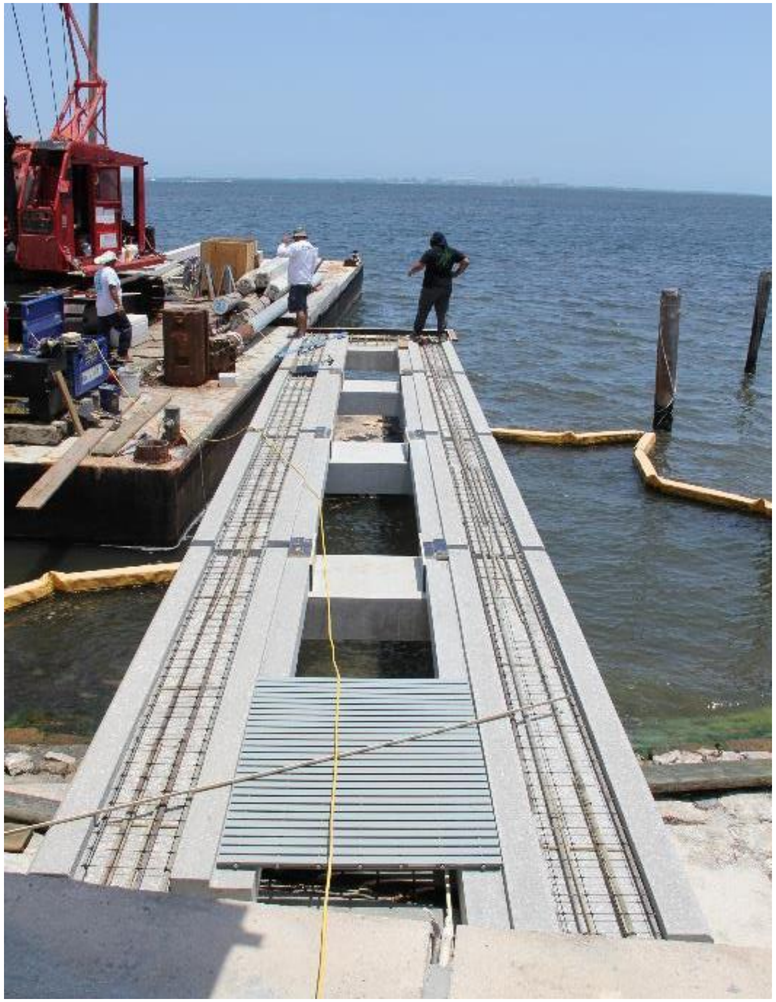
Field Applications

- iDock (Marine Dock) in Miami, FL
- SR-A1A Flagler Beach (Segment 3), FL
- SeaHive© at Miami Beach, FL

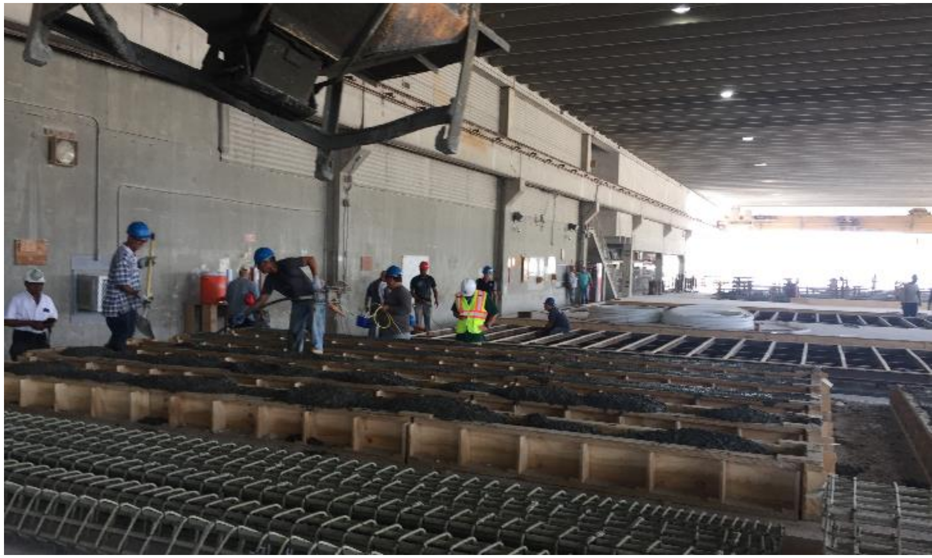
iDock Construction Intent - Miami, Florida

- Replacement of hurricane Irma-damaged dock with GFRP-RC precast concrete components, CIP BFRP-RC continuity pour and GFRP gratings
- Demo prototype for precast-concrete dock modular-system, that exhibits extended durability and resilience to extreme events



Benzecry, V., M. Rossini, C. Morales, S. Nolan and A. Nanni, "Design of Marine Dock Using Concrete Mixed with Seawater and FRP Bars," J. Compos. Constr., 2021, 25(1): 05020006, DOI: 10.1061/(ASCE)CC.1943-5614.0001100, 13 pp.

Precast Construction



Precast Construction

Traditional vs. Innovative Approach

- **Traditional:** precast steel-PC piles and cast in-place RC caps with timber decking
- **Innovative:** precast modular-units with rapid assembly time with GFRP & BFRP reinforcement to eliminate corrosion-related maintenance and provide higher resistance

iDock Precast Element Installation

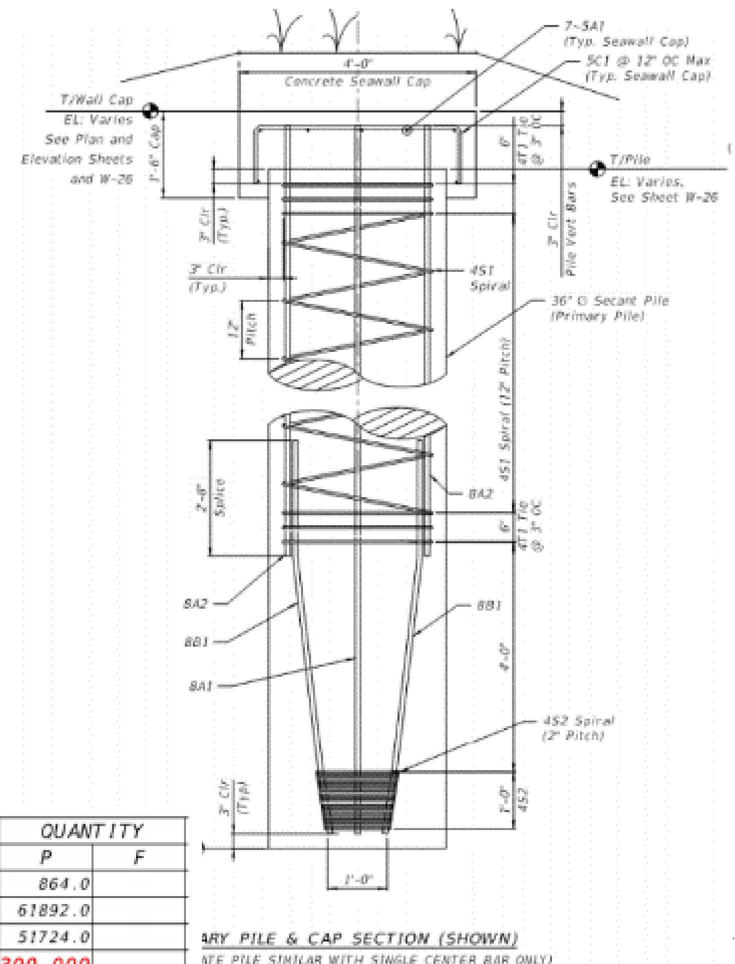
Field Applications

- iDock (Marine Dock) in Miami, FL
- SR-A1A Flagler Beach (Segment 3), FL
- SeaHive© at Miami Beach, FL

Flagler Beach, FL (SR-A1A) Damage & Recovery

GFRP Design for Secant-Pile Seawall

- 4920-ft. long secant pile seawall
- First FDOT project with about 1.5 million linear feet of GFRP bars
- Secant piles in high chloride content sand, high water table and periodically exposed to salt spray



WALL NO.	PAY ITEM NO.	PAY ITEM DESCRIPTION	LOCATION STA. TO STA.	SIDE	UNIT	QUANTITY P	QUANTITY F
W1 Thru W11	0400-4-11	Class IV Concrete (Retaining Wall Cap)		Rt	CY	864.0	
	415-10-5	Fiber Reinforced Polymor Bars, #5			LF	61892.0	
	455-112-6	Pile Auger Grouted, 36" Diameter			LF	51724.0	
		#5 GFRP Reinforcing Bars	approx.		FT	300,000	
		#8 GFRP Reinforcing Bars	approx.		FT	960,000	

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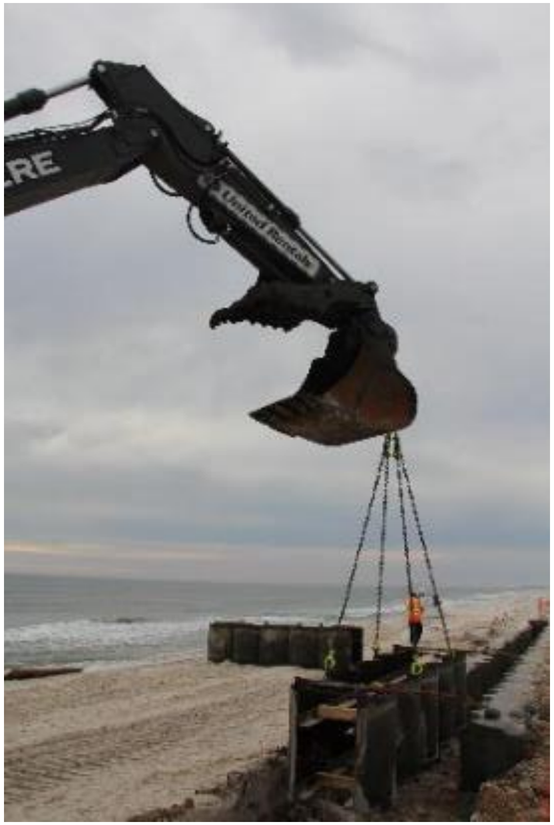
GFRP Bars - Cage Assembly

Guide Wall for GFRP Secant-Piles



Guide wall trench boxes installed to assure pile alignment

Secant-piles installed via guide wall form

Removal of steel formwork prior to drilling secant-piles

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Flagler Beach - GFRP Pile Cage Installation

GFRP cage installation

Auger-cast primary piles 36 in. in diameter and 36 ft. long
Secondary piles18 ft. long

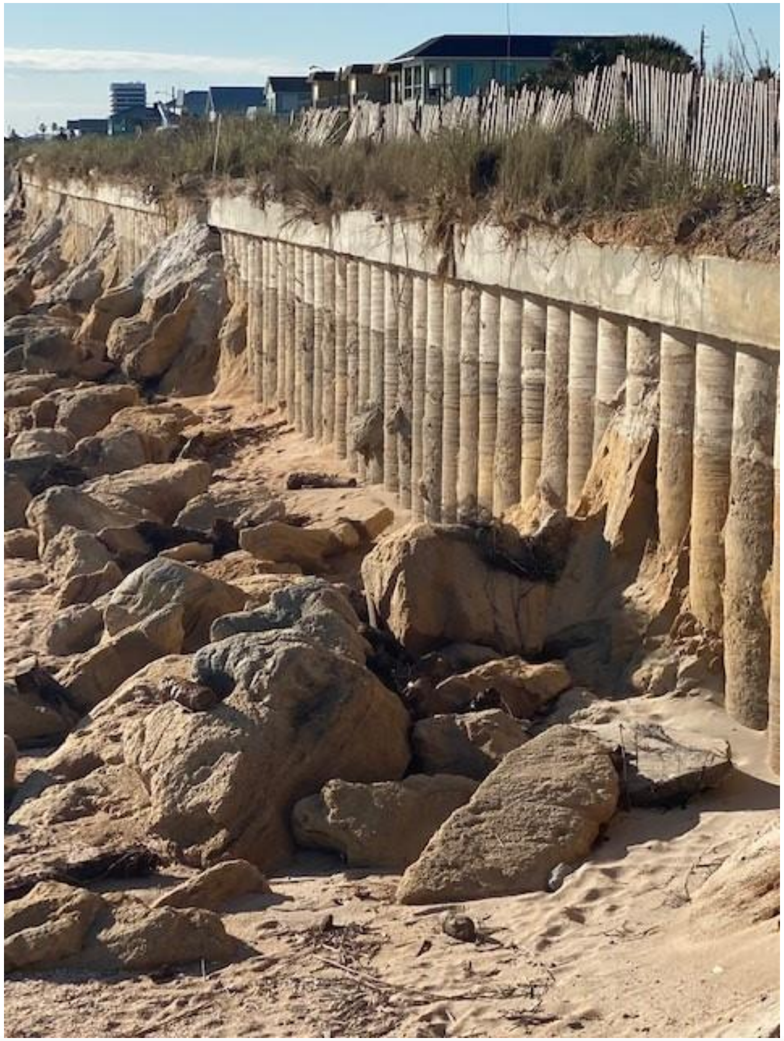
Continuous Pile-cap and Dune Restoration

Pile-cap placement and dune restoration/re-establishment

Project completed in 4½ months

Learning Outcomes from SR-A1A

- Fall of 2022 after Hurricane Ian



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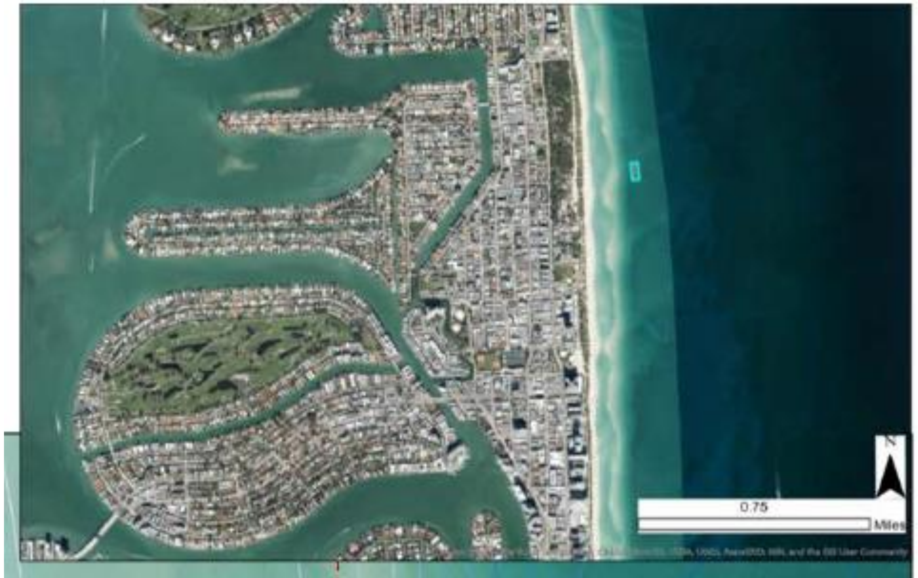
Part III – FRP-REINFORCED CONCRETE

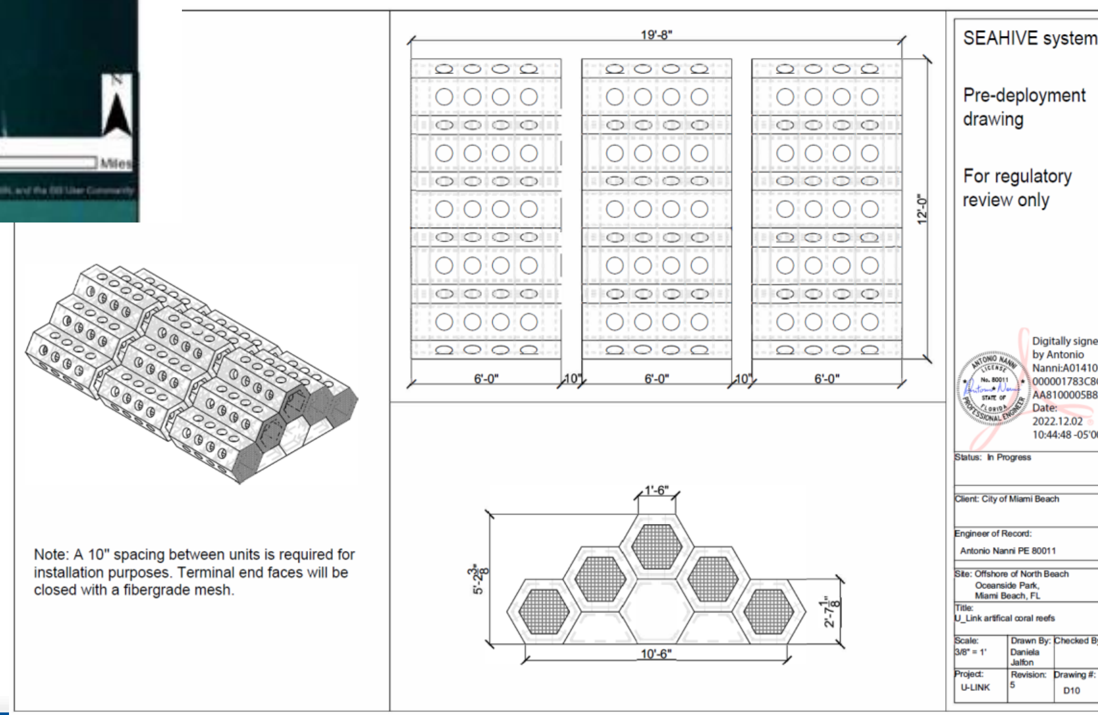
Field Applications

- iDock (Marine Dock) in Miami, FL
- SR-A1A Flagler Beach (Segment 3), FL
- SeaHive© at Miami Beach, FL

EcoReef, Miami Beach



EcoReef with SeaHive©



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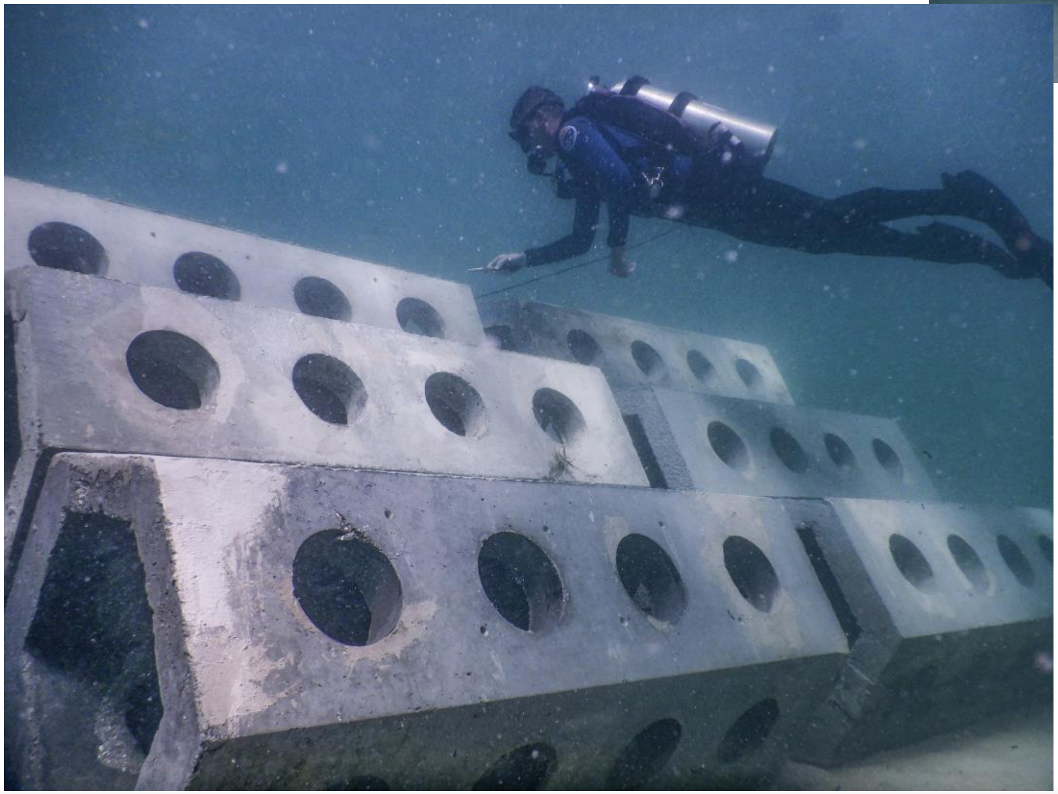
EcoReef, Miami Beach

EcoReef
Miami Beach, March 2023

EcoReef, Miami Beach

EcoReef
Miami Beach, March 2023



EcoReef, Miami Beach

EcoReef, Miami Beach, October 2023

an oasis in a sandy desert

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Part III – FRP-REINFORCED CONCRETE

1. ACI 440.11-22 Building Code & Commentary
   a. GFRP Bars as per ASTM D7957
   b. Mechanical Properties
   c. Specifics of the Code
2. Field Applications
3. Conclusions

CONCLUSIONS

Due to compelling sustainability and resilience reasons, FRP reinforcement could be a suitable replacement for conventional steel in RC structures exposed to aggressive environments

This technology would allow to:

- Save fresh water and other natural resources
- Eliminate corrosion and reduce maintenance costs
- Increase the service life of concrete structures
- Improve constructability by lowering transportation and installation costs

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