

POST-STORM RECONSTRUCTION USING RESILIENT STRUCTURE IN COASTAL AREAS

FLORIDA SHORE AND BEACH PRESERVATION ASSOCIATION

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71% of Earth's Surface is Water

- Urban development near the water is inevitable
- Water is an important factor in the development of communities
- Populations in coastal zones continue to increase



Population Increase

State	Total Change (Million Persons)	State	Percent Change
California	9.9	Florida	75
Florida	7.1	Alaska	63
Texas	2.5	Washington	54
Washington	1.7	Texas	52
Virginia	1.6	Virginia	48
New York	1.6	California	47
New Jersey	1.2	New Hampshire	46
Maryland	1.2	Delaware	38
Michigan	0.8	Georgia	35
Massachusetts	0.7	South Carolina	33

Coastal Population Growth between 1980 and 2003

Time Period	Coastal	Non-coastal
1960 to 1970	19.5	11.1
1970 to 1980	12.1	11.2
1980 to 1990	14.9	7.8
1990 to 2000	12.4	13.5
2000 to 2008	6.5	8.7

Percentage Increase in Coastal and Non-coastal Population by Time Period

Source: U.S. Census Bureau

Coastal Structures are Vulnerable

- Located in highly aggressive environment
- Exposed to hazards
- Non-resilient
- Low durability
- At risk



Downtown Miami during Hurricane Irma

Source: USA Today

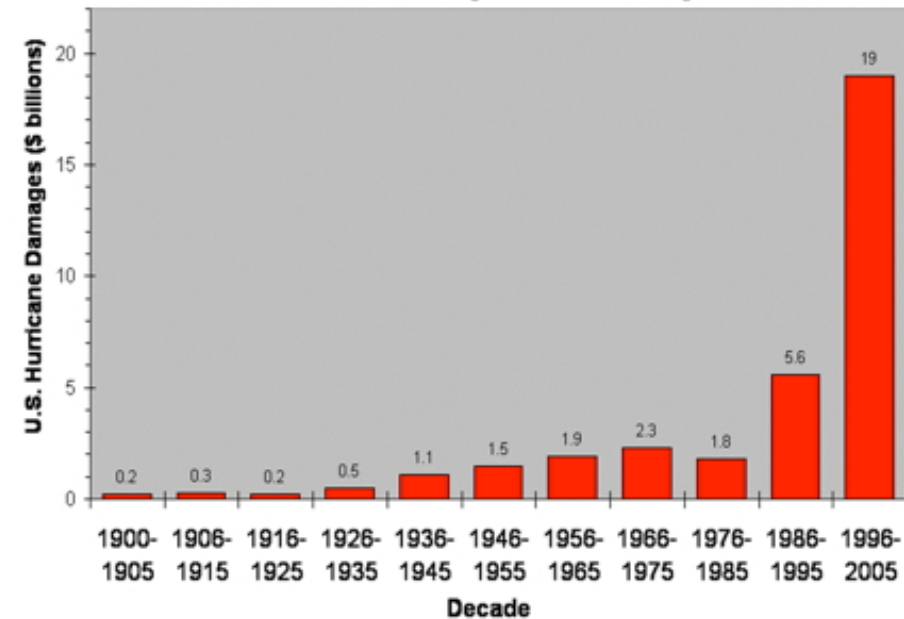
Hurricanes and their Damages

Rank	County	State	Numbers of Hurricanes	Percent Change 1960 to 2008	Percent Change 2000 to 2008
1	Monroe County	FL	15	50.8	-9.2
2	Lafourche Parish	LA	14	67.2	2.9
2	Carteret County	NC	14	104.3	6.4
4	Dare County	NC	13	465.9	12.1
4	Hyde County	NC	13	-10.1	-11.1
6	Jefferson Parish	LA	12	108.9	-4.2
6	Palm Beach County	FL	12	454.7	11.9
8	Miami-Dade County	FL	11	156.5	6.4
8	St. Bernard Parish	LA	11	17.2	-43.9
8	Cameron Parish	LA	11	4.8	-27.6
8	Terrebonne Parish	LA	11	78.7	3.9

Coastline Counties Most Frequently Hit By Hurricanes from 1960 to 2008

Source: U.S. Census Bureau

U.S. Tropical Storm and Hurricane Damages \$BILLIONS Annually - Inflation Adjusted



National Damages from Hurricanes and Storms

Source: NHC NOAA

Damages from Hurricane Irma



Dock Damaged by Hurricane Irma in Islamorada, FL.

Source Thestar.com



Collapsed Seawall due to Hurricane Irma in Punta Gorda, FL.

Source NBC2 News

Corrosion

- Failure mechanism for structures exposed to aggressive environments is often corrosion of steel reinforcement
- Chlorides from seawater penetrate concrete and reach steel
 - Through cracks
 - Through concrete porosity
- Corrosion is accelerated by carbonation of concrete that lowers the pH



Bridge Piling with Damage Caused by Reinforcement Corrosion.

Picture from NACE international

Corrosion



Miami Marine Stadium, beam with spall and corroded reinforcement.



Bulkhead cap with reinforcement corrosion.
Picture from Duoguard.

Current Mitigation Methods

Traditional corrosion mitigation efforts focus on keeping chlorides from getting to the reinforcing steel or simply delaying the time

- Admixtures
- Increase Concrete Cover
- Alter Concrete Mix
- Membranes & Overlays
- Epoxy coated or Stainless Steel
- Cathodic Protection



Stainless Steel Rebars

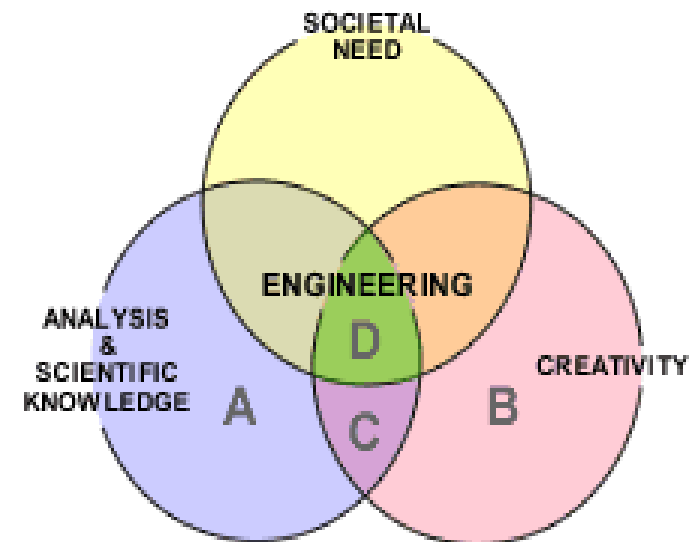


Cathodic Protection

Source: CLR Concrete Repairs Limited

Engineer's Responsibilities

- Problem solving
- Meet societal needs
- Safety and welfare of the public
- Minimize environmental impacts



Creating a Resilient Structure



Before Hurricane Irma

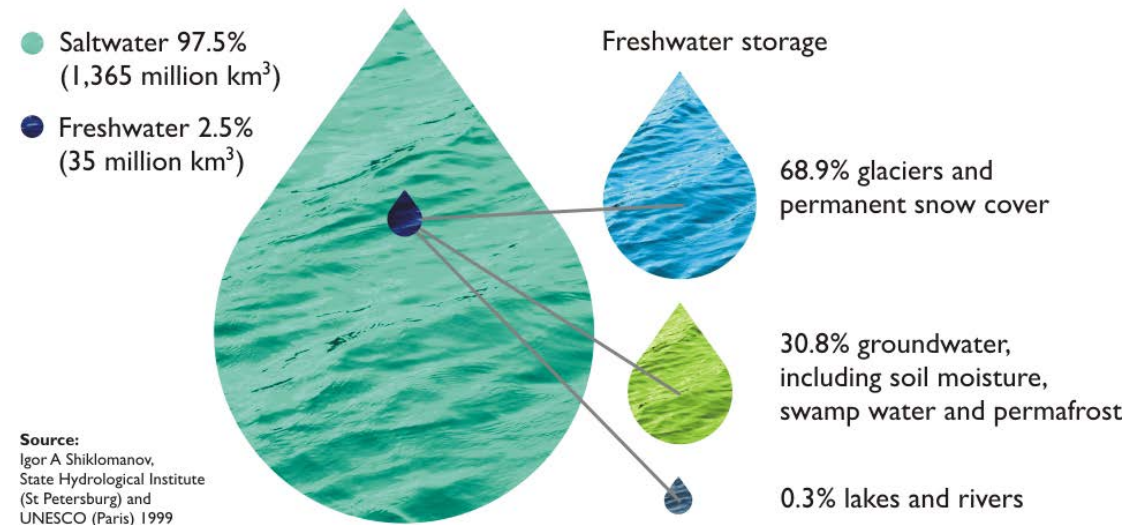


After Hurricane Irma – Current Conditions

I-Dock: A Resilient Coastal Structure

- A post-hurricane reconstruction project
- Designed to resist category 4 hurricanes
- Use of SEACRETE™ and SEABAR™

□ Seacrete™: Sustainable concrete using seawater, salt-contaminated aggregates, and non-corrosive reinforcement



Seabar™

- ❑ SEABAR™: non-corrosive reinforcement with superior performance in chloride-contaminated environments
- ❑ SEABAR™ includes Glass Fiber Reinforced Polymers (GFRP), Carbon Fiber Reinforced Polymers (CFRP) and Basalt Fiber Reinforced Polymers (BFRP) bars.



Seabar™ Advantages

- Non-corrosive
- High strength-to-weight ratio
- Ease of application & installation
- ¼ the weight of steel
- Transparent to magnetic fields and radar frequencies
- Electrically and thermally non-conductive



Construction Crew Lifting Reinforcement Cage.

Source: University of Miami

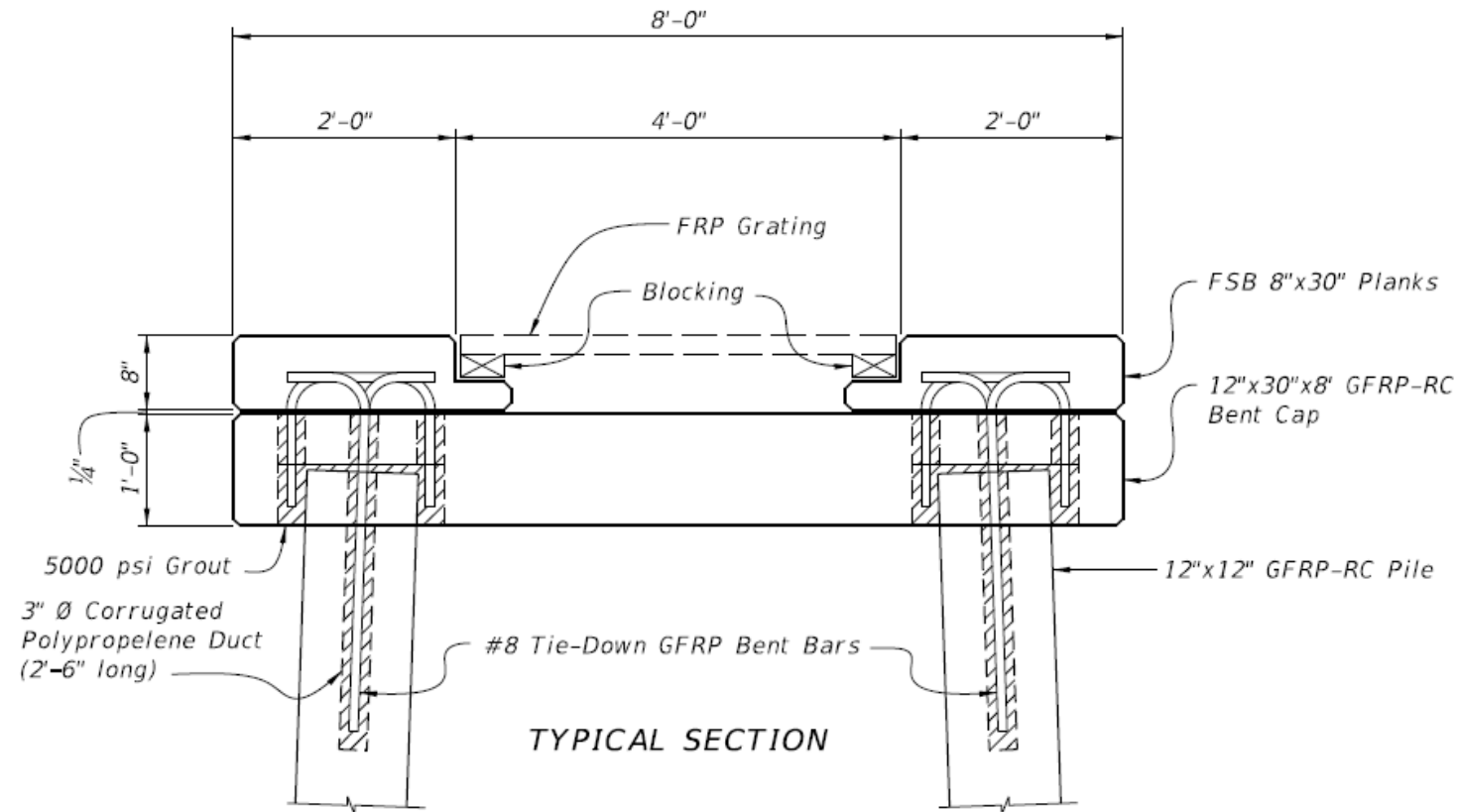
Seabar™ Disadvantages



Source: University of Miami

- No ductility
- Lower modulus than steel
- No ability to bend at site
- High CTE perpendicular to fibers
- Lack of familiarity among engineers and contractors

Design and Constructability



Final Product Look



Dinner Key Marina in Miami, FL
Source: GEF Innovative Solutions in Fiberglass



Panama City Beach Pier
Picture from Steven Nolan.



Miamarina, Miami FL

I-Dock Advantages

- Coastal structure that can withstand hurricane wind and wave forces
- Smart use of natural resources: seawater
- High durability: life expectancy 75+ years
- More tolerant habitat for marine life



Seacrete™ specimens

Other Applications

Any coastal structure:

- Seawalls
- Bulkhead caps
- Docks
- Marinas
- Breakwater
- Bridges



FDOT Bridge Substructure Rehabilitation

Source: FDOT

Projects with FRP Reinforcement



FDOT Bridge Rehabilitation project. GFRP and CFRP Used in Concrete Deck

Source: University of Miami



FDOT Bulkhead Rehabilitation Project. GFRP Used in Concrete Cap and Fascia Panels

Source: FDOT

Conclusion

- Eliminates the issue of corrosion in reinforced concrete
- Smart use of natural resources
- Light-weight reinforcement and smaller cross section: facilitate transportation and construction
- Resilient coastal structure
- Less harmful to the environment
- Cost-effective: long- term investment

Questions?



Thank you!

