POST-STORM RECONSTRUCTION USING RESILIENT STRUCTURE IN COASTAL AREAS

FLORIDA SHORE AND BEACH PRESERVATION ASSOCIATION

TECH CONFERENCE, FEBRUARY 2018

Vanessa Benzecry, E.I., Antonio Nanni, Ph.D., P.E., Civil, Architectural and Environmental Engineering, University of Miami
Steven Nolan, P.E., Florida Department of Transportation
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

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

Coastal Population Growth between 1980 and 2003

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Coastal</th>
<th>Non-coastal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960 to 1970</td>
<td>19.5</td>
<td>11.1</td>
</tr>
<tr>
<td>1970 to 1980</td>
<td>12.1</td>
<td>11.2</td>
</tr>
<tr>
<td>1980 to 1990</td>
<td>14.9</td>
<td>7.8</td>
</tr>
<tr>
<td>1990 to 2000</td>
<td>12.4</td>
<td>13.5</td>
</tr>
<tr>
<td>2000 to 2008</td>
<td>6.5</td>
<td>8.7</td>
</tr>
</tbody>
</table>

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

VANESSA BENZECRY, E.I., UNIVERSITY OF MIAMI
# Hurricanes and their Damages

## Coastline Counties Most Frequently Hit By Hurricanes from 1960 to 2008

<table>
<thead>
<tr>
<th>Rank</th>
<th>County</th>
<th>State</th>
<th>Numbers of Hurricanes</th>
<th>Percent Change 1960 to 2008</th>
<th>Percent Change 2008 to 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Monroe County</td>
<td>FL</td>
<td>15</td>
<td>90.8</td>
<td>-9.2</td>
</tr>
<tr>
<td>2</td>
<td>Lafourche Parish</td>
<td>LA</td>
<td>14</td>
<td>67.2</td>
<td>-2.9</td>
</tr>
<tr>
<td>2</td>
<td>Carteret County</td>
<td>NC</td>
<td>14</td>
<td>104.3</td>
<td>8.4</td>
</tr>
<tr>
<td>4</td>
<td>Dare County</td>
<td>NC</td>
<td>13</td>
<td>465.9</td>
<td>12.1</td>
</tr>
<tr>
<td>4</td>
<td>Hyde County</td>
<td>NC</td>
<td>13</td>
<td>101.8</td>
<td>-11.1</td>
</tr>
<tr>
<td>6</td>
<td>Jefferson Parish</td>
<td>LA</td>
<td>12</td>
<td>103.9</td>
<td>-4.2</td>
</tr>
<tr>
<td>6</td>
<td>Palm Beach County</td>
<td>FL</td>
<td>12</td>
<td>464.7</td>
<td>11.9</td>
</tr>
<tr>
<td>8</td>
<td>Miami-Dade County</td>
<td>FL</td>
<td>11</td>
<td>166.5</td>
<td>5.4</td>
</tr>
<tr>
<td>8</td>
<td>St. Bernard Parish</td>
<td>LA</td>
<td>11</td>
<td>17.2</td>
<td>-43.8</td>
</tr>
<tr>
<td>8</td>
<td>Cameron Parish</td>
<td>LA</td>
<td>11</td>
<td>4.8</td>
<td>-27.6</td>
</tr>
<tr>
<td>8</td>
<td>Terrebonne Parish</td>
<td>LA</td>
<td>11</td>
<td>78.7</td>
<td>5.9</td>
</tr>
</tbody>
</table>

## National Damages from Hurricanes and Storms

Source: NHC NOAA

[Graph showing U.S. Tropical Storm and Hurricane Damages $BILLIONS Annually - Inflation Adjusted](#)
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

Source: I.A. Didenko. State Hydrolological Institute (St. Petersburg) and UNESCO (Paris) 1999

Saltwater 97.5% (1,365 million km²)
Freshwater 2.5% (35 million km²)

68.9% glaciers and permanent snow cover
30.8% groundwater, including soil moisture, swamp water and permafrost
0.3% lakes and rivers
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

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

Source: University of Miami
Design and Constructability

---

VANESSA BENZECRY, E.I., UNIVERSITY OF MIAMI
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
Other Applications

Any coastal structure:

• Seawalls
• Bulkhead caps
• Docks
• Marinas
• Breakwater
• Bridges

FDOT Bridge Substructure Rehabilitation
Source: FDOT

VANESSA BENZECRY, E.I., UNIVERSITY OF MIAMI
Projects with FRP Reinforcement

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

FDOT Bridge Rehabilitation project. GFRP and CFRP Used in Concrete Deck
Source: University of Miami
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!