Ecologically Engineered Marine Infrastructure to Complement and Support the Offshore Wind Industry

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BACKGROUND & OBJECTIVE

Over the past decade, the scientific community has studied, experimented, and published a notable body of literature on the ecological enhancement of coastal and marine infrastructure (CMI). The Nature-Inclusive Design approach refers to methods and technologies that can be integrated into the design and construction of CMI to create a suitable habitat for native species (or communities) whose natural habitat has been degraded or reduced. To evaluate the structural and biological performance of new environmentally sensitive CMI technologies, a pilot project was deployed in April 2017 at Port Everglades, Florida.

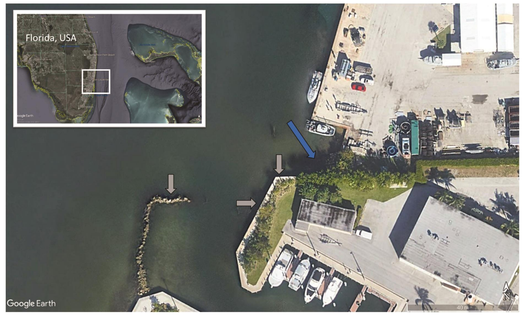
NATURE-INCLUSIVE DESIGN OF ARTICULATED CONCRETE BLOCK MATTRESSES (ACBMS)

What are ACBMs?

- Rectangular matrices made of concrete blocks joined together by ropes or cables into a unit with two-dimensional flexibility and a range of thicknesses to suit the required site conditions
- Used for anchorage and protection of underwater pipelines and cables and for scour protection of shorelines
- Designed to withstand intense hydrodynamic forces exerted upon CMI

ECOncrete created a Nature-Inclusive Design for ACBMs by incorporating **bio-enhancing, science based concrete additives, surface texture, and macro-designs** to create dry-cast Ecological Articulated Concrete Block Mattresses (ECO ACBMs)

Aerial view of the pilot location at Port Everglades, Florida, USA. The blue arrow denotes the location of the Articulated Concrete Block Mattress installation and the gray arrows denote the locations of adjacent artificial infrastructure that served as baseline. Image source: Google Earth



ECOLOGICAL ARTICULATED CONCRETE BLOCK MATTRESSES PILOT PROJECT

- Deployed on a degraded shoreline between the Port Navy Station and NOVA University, Halmos College of Natural Sciences and Oceanography in Port Everglades, Florida.
- Four 2.4x5.7m ACBMs
  - Half ECOncrete units, half traditional concrete units (i.e., no ecological admix or designs included)
  - Cast using a marine construction-grade concrete mix, including an ecological admix
  - Manufactured at the World Center for Concrete Technology (Alpena, MI) in a Besser production plant
- ECO ACBMs evaluated against controls of adjacent artificial structures and smooth-surface concrete blocks

Manufacture and installation procedures of the Articulated Concrete Block Mattress. (A) Lacing the blocks to form half-textured ECO blocks (treatment) and half featureless CEM-I-based blocks (control); (B) crane lifting; (C) lowering to the water; and (D) in place on the riprap with the tops aligned with the MHHW line.

ECO ACBM retaining water as the water level recedes, providing tide pool habitat

ECOLOGICAL AND STRUCTURAL MONITORING

Conducted a baseline survey of pre-existing adjacent artificial infrastructure

- Three locations sampled for intertidal and subtidal sessile communities: vertical seawall, concrete slab, riprap rocks

Monitored for two years at 3, 6, 9, 12, and 24 months

- Preselected blocks to avoid bias
- Four ECO intertidal, four ECO subtidal, four control intertidal, four control subtidal, no adjacent blocks, no blocks at the interface between the ECO and the control, and no blocks at the edges of the ACBM

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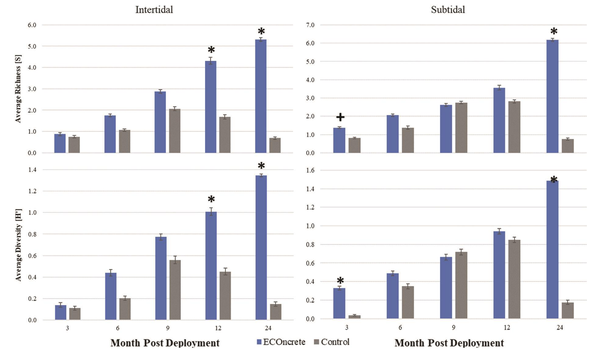
*Differences in univariate parameters between ECO and control blocks at 3, 6, 9, 12, and 24 months postdeployment for intertidal (left) and subtidal (right) areas. *Significant differences ($p < 0.05$); + Marginal differences. Error bars represent the standard error*



RESULTS

Ecological Results

- Community Structure
  - Increase of species richness and biodiversity
- Fish
  - More fish interaction with ECO blocks
- Biomass
  - Significantly more biomass accumulated subtidally on ECO blocks
  - Higher presence of calcifying organisms on ECO blocks

Structural Results

- Compressive Strength
  - Conducted using ASTM standard methods
  - ECO blocks endured higher loads per surface area after 12 months
  - ECO blocks endured overall higher loads after 24 months
- Freeze and Thaw
  - Average compressive strength after 75 freeze-thaw cycles complied with the minimum requirement in ASTM D6684
  - Average weight loss after 75 freeze-thaw cycles was lower than the commonly accepted threshold in ASTM C1262

A sample of one ECO block. (A) New and untested, (B) after 75 freeze–thaw cycles, (C) after six months of submersion

CONCLUSIONS

After two years of monitoring, significant ecological enhancement was noted on the ECO ACBMs in comparison to the control blocks. Communities recruited on the ECO blocks significantly differed from those recruited on the control blocks and the nearby artificial infrastructure, presenting higher values of species richness and diversity.This ecological improvement was achieved within the operational limitations of conventional manufacturing and installation technologies, complying with strict structural requirements for marine construction (such as compression forces, cracking, and resistance to freeze and thaw cycles), while considering biological factors. Based on the results of this study, altering the concrete composition, surface texture, and macro-design has increased the richness, abundance, and diversity of sessile assemblages compared to control blocks and supported higher abundance of mobile species.