BIOLOGICAL PERFORMANCE OF AN ECO-ENGINEERED ARMORING UNIT, THE COASTALOCK

Yaeli Rosenberg, ECOncrete, yaelir@econcretetech.com
Jorge Gutiérrez Martínez, ECOncrete, jorge@econcretetech.com
Andrew Rella, ECOncrete, andrew@econcrete.us
Philippe Leblanc, ECOncrete, phil@econcretetech.com

BACKGROUND

Increasingly, the permitting and construction of coastal and marine infrastructures (CMI) requires the integration of ecological measures to reduce potential impacts and create opportunities to enhance and restore marine biodiversity. Up until recently, the ecological principles were perceived as only appropriate for living shorelines or restoration of tidal wetlands and salt marshes (Gittman et al. 2014, Popkin 2015). However, over the past decade, with the evolution of ecological engineering, there has been significant research on the ecological enhancement of CMI while maintaining compliance with building codes and engineering standards. (Coombes 2011, Naylor et al. 2011, Naylor et al. 2012, Perkol-Finkel and Sella 2015, Evans et al. 2016, McManus et al. 2017). The Nature-Inclusive Design (NID) approach refers to the planning, design, and construction of CMI to create suitable habitat for native species (or communities) whose natural habitat has been degraded or reduced (Hermans et al. 2020). In this context, to facilitate the integration of innovative NID design principles in the marine construction industry, the first fully structural and ecologically engineered armor unit for coastal protection, the COASTALOCK^{TM} (CL), was designed. The CL is an interlocking, multidirectional, single-layer concrete armor unit with ordered regular placement, made with bio-enhancing concrete with proven abilities to enhance local ecosystems and habitat functionality of coastal defense schemes. This unit can be integrated into breakwaters, ripraps, and revetments as an alternative or to complement traditional armor protection, while offering diverse habitats for marine communities, such as water retaining features, overhangs, and cave-like shelters; mimicking natural intertidal habitats that are typically absent along armored waterfronts.

The CL armor unit was submitted to physical model tests to prove its hydrodynamic stability (Gutiérrez et al, 2023), and its biological performance has been investigated and results are presented hereby.

PILOT PROJECT

In March 2021, a three-year pilot project in the Port of San Diego to demonstrate an innovative developed design of the CL, was launched as part of the Port's Blue Economy Program.

The pilot was installed in two sections at Harbor Island, replacing the current waterfront armor protection which is a riprap rock mound, offering limited habitat value. This installation was the first CL installation in the world and includes 74 units, to provide environmentally sensitive edge protection. Installation was made in four rows, where the upper three rows were placed as water-retaining elements to mimic natural tidepools, and the lower row was rotated sideways to generate cave habitats.

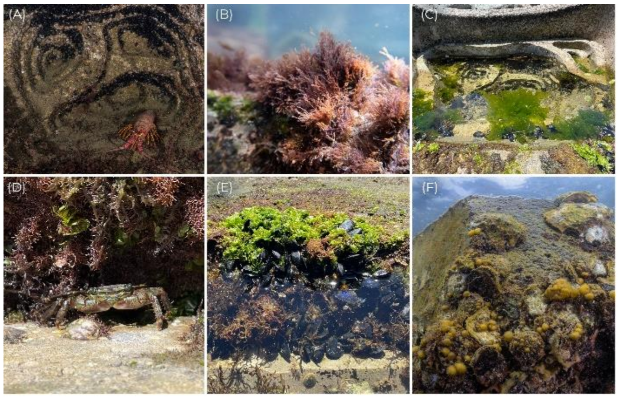

Figure 1 -. Biological growth on CL units over time (A) 6Months Post Deployment (MPD), (B) 8MPD, (C), (D) and (E) 14MPD, (F) 17MPD

MONITORING REGIME

The deployed infrastructure was monitored for two years aiming to evaluate the biological productivity and ecological value of the CL compared to the adjacent riprap rock at the two waterfront sites. The monitoring protocol provided data with respect to; 1) Differences in diversity indices, including biodiversity, species richness and species abundance; 2) Differences in successional stages and biogenic build-up; 3) Differences in water conditions between retained water within the units and nearby open water. Monitoring took place every six months for two years (with slight modifications due to travel restrictions during the COVID-19 pandemic) where each monitoring event included sampling the upper tidepool units during low tide when the pools are separated from the open water and sampling the lower cave units during high tide, sampling the entire exposed surface area of the CL units. Data was collected according to the protocol of Perkol-Finkel et al. (2008) which included percent of overall live cover, percent cover of encrusting species (sponges, tunicates, bryozoans, etc.), count of solitary organisms (oysters, tunicates, massive species of Polychaeta tube worms, etc.), and quantitative evaluation of taxonomic groups which cannot be quantified by the above methods (turf algae cover, coralline algae, Serpullidae, and Sabellidae worms, etc.). Species were identified to the lowest taxonomic level possible in the field and, if necessary, samples were taken for laboratory identification. All samples were photographed using an underwater camera to assist in the identification process. Species were classified by status as native, invasive, cryptogenic, motile, sessile, and or calcifying. During the final monitoring event, after 2 years, a sampling for biogenic buildup (accumulation of $CaCO_3$) and eDNA analysis was included.

RESULTS

The community structure of the CL units has shown increasing trends of species richness throughout the monitoring events compared to the adjacent control rocks, which have been in place for decades (the current rip rap protection was built in the 1950's). The monitoring results show that after two years, the species richness of CL units demonstrates a diverse community, including 15 algae species, 19 sessile invertebrates, and 11 mobile invertebrates, whereas, on the control rocks, there were 7 algae species, 14 sessile invertebrates, and 5 mobile invertebrates. In addition, significantly higher biomass accumulation was found on the CL units compared to the control rocks, both for organic and inorganic matter. The CL cavities constitute a newly introduced water-retaining habitat that was missing at the riprap rocks. This new habitat enables the recruitment of multiple species of algae and invertebrates, resulting in the establishment of a diverse marine community. This effect is amplified in the upper row, which acts as a separate pool during low tide. The water-retaining feature enables multiple species of marine organisms to thrive in this newly introduced habitat that could not inhabit riprap rocks of the same tidal height. Not only the cavities but the entire CL's texture, bioenhancing concrete and design enhance the settlement of different individual species such as Mollusks, Crustaceans, and others. It was observed mostly through the count-monitored species biodiversity that was higher for CL units in all three tidal heights than at the control rocks.

Figure 2 –. Biological development on the CL units two years post deployment

CONCLUSION

The integration of ecological enhancement measures such as ecologically designed armor unit in marine infrastructure can be an effective tool to maintain biological resources and their associated ecosystem values on site. Based on the results of this study, CL bioenhancing concrete and design features have increased the richness, abundance, and diversity of sessile assemblages compared to control rocks and supported a higher abundance of algae species. Nature Inclusive Design (NID) considerations should be integrated early in the design process of coastal and marine development projects as it promotes a more sustainable and adaptive approach to building climate resilient and nature positive CMI.

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