HOW IS STONE BEING USED IN THE LIVING BREAKWATERS?

The breakwaters will be primarily constructed of stone. The stone will be hard, durable, and sourced from quarries within the region in order to minimize transportation distance and cost. There are a variety of stone sizes within the Living Breakwaters, with each stone size serving a different function:

**ARMOR STONE** is the large visible stone that clad the outside layer of the breakwaters. They function to dissipate wave energy as waves hit the exterior of the breakwaters and move through the gaps between the stones. The main breakwater segment will be covered in armor stone two layers thick. Most of the stones will be approximately 3.3 feet in diameter. In some locations in the breakwaters, the exterior armor stones will be replaced with bio enhancing concrete armor units (see sheet on bio-enhancing concrete units). Slightly larger armor stones (TOE ARMOR STONES) 4 feet in diameter will be used along the base of the wave side of the breakwaters to provide additional structural support.

**CORE STONE** is the smallest size stone used and forms the central core of the breakwater, establishes the side slopes for the breakwater segment, and provides the base for the armor stone to sit on. The approximate average diameter of the core stone is 1.33 feet. The core stone sits on top of a geotextile to prevent the stones from settling into the sandy bottom.

**RIP RAP** stone will be used primarily within the reef ridge of the breakwater and will consist of a bottom layer of stone with an average diameter of 2.5 feet (REEF RIDGE CORE STONE), as well as a top layer of stone with greater variation in stone size in order to create a wider range of crevices between the stones for fish and other marine life to inhabit (REEF RIDGE EXTERIOR STONE); these will have an average diameter of 2 feet. Smaller stone (1’ diameter or less) will also be found in the MARINE MATTRESS, stone-fill geogrid “bags” used at the base of the breakwaters (see cut-sheet on marine mattresses).
**WILL THE STONES MOVE AROUND ON THE BREAKWATERS?**

Stone sizes are specified by engineers based on an analysis of wave conditions to ensure that they will withstand the wave energy of daily waves and storm wave conditions. Stones are also placed in an fitted manner to ensure the stability and performance of the breakwaters. Some initial settling—slight (a few inches) movement and sinking—of the stones is typical immediately following construction.

**HOW WILL THE STONE BE BROUGHT TO THE SITE?**

It is anticipated that the stone will be shipped by barge to the project site either directly from the quarry or from an intermediate site where stone for the project is stockpiled and stored (a “staging area”). Once at the breakwater location within the project site, barges with a crane or large backhoe will lift and place stone materials in the water to construct the breakwaters.

**WHAT TYPE OF STONE IS USED AND WHERE ARE THEY FROM?**

At this time, it is assumed that granite is the preferred stone. The USACE Engineering Manual specifically identifies granite as the top ranked stone for this type of application, although there are several other types of stone that may be successfully used in marine construction. These include, but are not limited to, granite, diabase, basalt, gneiss, and limestone. Various quarries in the New York/New Jersey region have been identified as capable of providing stone for the Living Breakwaters project. The preferred method of stone transportation is by barge along the waterways connected to the project area.

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HOW ARE BIO-ENHANCING CONCRETE UNITS BEING USED IN THE LIVING BREAKWATERS?

Throughout the breakwaters, some of the armor stone units will be replaced with bio-enhancing concrete armor units. Using these units will maintain the structural stability of the breakwaters, while enhancing their ability to recruit marine organisms and promote diverse and vibrant aquatic ecosystems. Overall, approximately 1 out of every 47 armor units will be made of bio-enhancing concrete (based on volume); the remainder will be stone. There are two types of bio-enhancing concrete units that will be used in the breakwaters:

**BIO-ENHANCING CONCRETE ARMOR UNITS** are cubed-shaped armor units with chamfered edges and faces specifically contoured (textured) to create complex surfaces that attract biological organisms and allow them to settle and stay on the units.

**BIO-ENHANCING CONCRETE TIDE POOL UNITS** are designed to mimic the form of natural rock pools; they are basin-shaped and capable of holding water between tides. These units will be placed within the intertidal zone of the breakwater to provide additional habitat and will be flushed with the tidal fluctuations.
WHAT ARE BIO-ENHANCING CONCRETE ARMOR UNITS?

Bio-enhancing concrete armor units are engineered to function structurally the same way as armor stone. They are also designed to provide a substrate that promotes the recruitment of marine plants and animals through science based chemical composition and physical design.

ARE BIO-ENHANCING CONCRETE UNITS STRUCTURALLY SOUND?

All bio-enhancing concrete units fully comply with the requirements for marine construction, and are designed to engineered specifications. They have been previously used for different marine applications in case studies spanning over 5 years in harsh marine environments. For the Living Breakwaters project, scaled physical models of the breakwaters will incorporate these units to test and verify the structural stability of the design.

WHY ARE THE BIO-ENHANCING UNITS CONCRETE

The concrete used within the bio-enhanced units is specifically designed to enhance natural recruitment of the region's diverse marine life by eliminating and replacing certain negative elements within the concrete mix and providing complex micro-surfaces, without effecting the concrete's structural performance. In previous case studies and lab tests, the bio enhanced concrete was successful in supporting a range of marine life, increasing localized biodiversity and favoring key marine species such as oysters.

WHERE HAS IT BEEN USED BEFORE?

BROOKLYN BRIDGE PARK
BROOKLYN, NEW YORK
Bio-enhancing concrete (ECOncrete®) was used as a constructive solution for the deteriorating timber piles damaged by marine burrowers. Bio-enhancing concrete pile encapsulation jackets provided the necessary constructive support and required protection, while creating a new and productive habitat for marine plants and animals thus decreasing the ecological footprint of the structure. Bio-enhancing concrete tidepools were also used within the park’s rip-rap revetment to enhance the potential species recruitment and biodiversity in

HAIFA PORT
EAST MEDITERRANEAN SEA, ISRAEL
Bio-enhancing concrete (ECOncrete®) ecological cube-shaped armoring units called antifers, were used as a part of the construction of a new port breakwater. Three years of monitoring demonstrated their ability to create bio-diverse habitats. In comparison to standard concrete armoring units, bio-enhanced concrete armoring units yielded nearly double the number of invertebrate and fish species on the units.
HOW ARE MARINE MATTRESSES USED IN LIVING BREAKWATERS?

Marine mattresses will be placed underneath the breakwater to reinforce the sediment located on the sea floor and to provide a secure foundation for the placement of additional stone and bio-enhancing concrete units. This material is critical to the performance of the breakwater because it prevents ocean currents and waves from eroding the sediment at the base of the breakwaters (scour).
WHAT ARE MARINE MATTRESSES?
Marine mattresses are a commonly used material in marine construction. They are composed of high strength mesh enclosure filled with stone. The mesh will be composed of durable materials able to withstand marine conditions.

The marine mattress forms a stabilized base on which the breakwaters can be constructed and works to prevent scour around the structures. Marine mattresses are known in the field of coastal engineering for their ability to provide reinforcement as well as their durability in coastal conditions.

Stone is used as fill material in the marine mattress and is sized according to the desired thickness of the mattress.

HOW WILL MARINE MATTRESS BE PLACED IN THE PROJECT SITE?
In typical placement of marine mattress, lifting loops are constructed on each end of the mat and rigged to spreader beams, a lifting device used to help cranes pick up heavy loads and distribute weight of materials throughout the placement process. Once attached to the spreader beams, the marine mattress can be lifted to horizontally and place into the desired location as specified within the engineering drawings.

WHERE HAS IT BEEN USED BEFORE?

HOLLY BEACH BREAKWATER
GULF COAST, LOUISIANA
USACE
Marine mattresses were used in the construction of a breakwater system along the coast of Louisiana. Specifically, marine mattress served as the foundation layer before the placement of stone breakwater units in each segment.

LIGHTHOUSE SCOUR PROTECTION
BARNEGAT INLET, NEW JERSEY
USACE
A revetment, similar to an underwater retaining wall, was constructed of armor stones placed over a bedding layer of marine mattress. Instead of placing mattresses individually, up to six mattresses were tied together to form mats measuring 20 ft by 30 ft that were then deployed during ebb tide when currents are reduced.

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HOW ARE GEOTEXTILES USED IN THE LIVING BREAKWATERS?

Within the Living Breakwaters project, a geotextile will be placed under the breakwater before the stone is laid down to reinforce surficial soil at the sea floor and distribute loads of the breakwater to help ensure stability throughout the structure. Geotextiles may also be placed between adjacent layers of stone (e.g. core stone and armor stone) in order to prevent mixing and help minimize the overall volume of stone needed for construction. Geotextiles are commonly used materials within marine environments and serve as an important element to successfully install and secure breakwater materials.

WHAT OTHER TYPES OF STRUCTURES UTILIZE GEOTEXTILES?

Since geotextiles are widely used within marine construction, there are many applications for the material in coastal infrastructure. Groins, breakwaters, seawalls, and revetments are just a few of the many marine structures in which geotextiles are commonly used.
WHY ARE GEOTEXTILES USED IN MARINE CONSTRUCTION?

Geotextiles are used in marine construction as permeable protection layers, to secure other materials in place to reduce the potential for erosion, resuspension of sediment, or mixing of materials. Another key application is providing a foundation to prevent the erosion of base soils and ensure the structural stability of coastal structures such as breakwaters, groins, and jetties. In marine construction, it is important to specify a geotextile that serves the necessary purpose and can withstand the physical conditions such as waves and currents as well as chemical conditions such as salinity. The first documented uses of geotextile within the U.S. date back to the late 1950's, when waterfront property owners began looking for a more efficient way to provide a filter layer for protective structures, in place of the costlier graded granular layers that were normally used. In 1972, after 10 years of evaluating the new concept, the USACE issued their first comprehensive specification for filter fabrics, thus accepting geotextile layers as the superior construction technique.

WHERE HAS IT BEEN USED BEFORE?

PLUMB BEACH PROJECT
BROOKLYN, NEW YORK
USACE

This coastal management project consisted of constructing three stone structures: two stone groins and a permanent stone breakwater along with sand placement. During construction, geotextile fabric was layered between the structure base and the seafloor for both the breakwater and groins.

BREAKWATER PROJECT
FORT PIERCE, FL
USACE

The waterfront protection project included 12 island breakwaters and a peninsular structure designed to protect a marina from damaging storm waves. All of the structures use geotextile fabric in some capacity. Geotextile tubes were an integral component deployed in the construction of perimeter dikes, in the core of the groins in each island, as well as in constructing the living shoreline.

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