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LIGHTWEIGHT AGGREGATE PROVIDES DESIGN FLEXIBILITY FOR BREAKWATER

A 1,440 foot-long floating concrete breakwater was constructed in the state of Washington using lightweight aggregate produced at Boulder, Colorado. The \$8 million breakwater project was designed for the Port of Bremerton Marina to attenuate wind driven waves and ferry wakes. Additionally, it was designed to upgrade the marina's boat capacity, and enlarge the waterfront public space extending from an upland public park area.

Twelve individual floating bodies, with a maximum weight of 950 tons, are rigidly connected by post-tensioning to act as a single floating structure moored with 50 different mooring lines. Unlike fixed breakwaters, the floating structure is fish-friendly and allows marine life to pass underneath the structure. Concrete benches, light fixtures and future artistic sculptures were figured into the design to add counterweights and aesthetic elements consistent with the existing downtown waterfront park.

CONSTRUCTION

In fabricating the breakwater structure, the Bremerton Floating Breakwater is the first largesize floating concrete breakwater in Washington to use cast-in-place ready-mixed concrete with four different concrete mixtures.

Each concrete mixture design includes fine graded lightweight aggregate to optimize the final density of the structure. To enhance performance of the structure the engineer specified four different concrete mixtures to address design considerations depending on the desired density of the individual floating bodies.

The 12 concrete bodies ranged in weight from 131 pounds per cubic foot to 144 pounds per cubic foot. The final concept design required to meet the target strength, free board and stability was achieved by blending lightweight fine aggregate with normal fine aggregate.

Boulder facility crews assisted the engineering firms of Art Anderson Associates and Reid Middleton in the design of the concrete proportions to

economically meet the rigorous design criteria.

"Lightweight aggregate provided us the flexibility we needed to design individual concrete bodies to maintain stability even in the event of flood damage in one open cell of the breakwater. The lightweight aggregate also allowed us to accommodate add-on elements, such as benches and light poles, and still achieve the desired strength and stability," said Senior Engineer Willy Ahn of Reid Middleton.

Several experiments, using scaled model tests, were conducted to analyze different aggregate blends and concrete densities in the individual concrete sections. All four concrete mixes were batched at Glacier Northwest's ready-mix plant in Everett,



Washington, which is located near the casting site. The concrete was then cast-in-place by the pumping method.

“There seems to be a common misconception that lightweight concrete is extremely difficult to pump. However, we were very pleased with the consistency, ease of pump placement, and finishing characteristics of all four mixes,” said Dustin McClure, Project Manager at McClure & Sons.

The Bremerton Floating Breakwater project was completed with less than one percent change order costs, contributing to the overall timely installation of the breakwater.

INTERNAL CURING

The Bremerton Floating Breakwater was designed to last more than 50 years. Lightweight aggregate (LWA) concretes have generally exhibited excellent performance under severe

weathering conditions. One of the reasons cited for this is the high integrity of the interfacial transition zone formed between the LWA and the neighboring hydrating cement paste.

All four concrete mixtures will benefit from the highly absorptive microstructure of the lightweight fine aggregate. For internal curing to occur, the lightweight aggregate was pre-wetted prior to batching.

The water is absorbed into the lightweight aggregate and therefore does not increase the net water/cement ratio, and eliminates the initial absorption of batchwater. The absorbed water does not initially contribute to hydration. Only after initial set does this water migrate out of the lightweight aggregate particles and into the cement matrix, contributing towards continuous hydration and increased long-term durability. This process is known as internal curing.

Art Anderson Associates (AAA) was the Prime Consultant providing master planning and design services for the Bremerton Harbor Improvement Master Planning and Marina Expansion, and integration of the project into other waterfront redevelopment projects and funding sources.

The Harbor Master Plan includes the Bremerton Marina expansion, improved Passenger Ferry Terminal facilities, boundary adjustments to the Port's Harbor control area, and a comprehensive review and adjustment to the Bremerton outer harbor line.