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A breakwater is a structure protecting a harbor, anchorage or shoreline from waves. There are essentially three types: rubble-mound, vertical wall, and floating.

PND’s coastal engineers are experienced in designing all types of breakwaters and jetties, through all the phases of projects, from concept design through construction.

**DESIGN CHALLENGES**

Breakwater design is a challenging field in which designers must rely upon sound judgment and experience to efficiently solve problems associated with uncertainties in various environmental conditions. Relative to other engineering professions, design standards and codes often do not address the wide array of potential design conditions. Design demands the expertise and experience of those who specialize in coastal engineering.

PND is well-qualified to analyze wind, wave, tide and currents to determine wall heights, depths, and allowable wave transmission for any number of site conditions, including hindcast studies and wave reflection/refraction analysis. PND also has experience in specialized areas that can significantly affect project performance including boat wakes, scour, propwash and corrosion protection.

**BREAKWATER TYPES**

The choice of a breakwater type is largely dependent on wave height and period. The largest waves require rubble-mound structures that are able to absorb wave energy. Floating breakwaters can be used for smaller wave heights and periods, and allow for transient moorage space. Vertical structural wall types address the range falling between that of rubble-mound and floating breakwaters, as shown in the diagram on the right.
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TRADITIONAL BREAKWATER STRUCTURES

ST. GEORGE RUBBLE-MOUND BREAKWATER

In the Pribilof Islands in Alaska, this rubble-mound, berm-type breakwater was originally designed by PND in the early 1980’s. It provides moorage and safe refuge for a fishing fleet. Physical conditions at St. George are extremely harsh, with heavy icing and waves that reach up to 42 feet high.

After 22 years of extreme storms, a massive storm hit that caused non-critical breakwater damage. Due to the exceptional past performance, PND was asked to provide design repairs. Eight thousand cubic yards of quarry rock ranging from 56-2,500 pounds were required on the north shoreline, topped with 8,000 tons of armor rock. The south breakwater arm required 18,000 tons of armor rock.

CASCADE POINT MARINE FACILITY BREAKWATER

Cascade Point is the site of a rubble-mound breakwater that will protect floats and a dock for a gold mine near Juneau, Alaska. The site is constrained by relatively steep underwater slopes and the breakwater is designed to accommodate future expansion. The typical armor rock size is nominally four feet in diameter. A cross-section of the breakwater is shown below.

PORT ORCHARD WEST BREAKWATER

PND provided design for a floating breakwater at the Port Orchard Marina on Washington’s Puget Sound that protects the marina and serves as transient moorage. The marina has waves of up to four feet in height.

LA CONNER G-FLOAT

G-Float is a floating breakwater that provides protection for the La Conner Marina North Basin in Washington. The breakwater is an 800-foot x 9-foot modular concrete float on the marina’s outer perimeter and also provides transient moorage.
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PARTIAL PENETRATING WAVE BARRIER

The need to protect facilities from moderate-height waves has led PND to develop the partial penetrating wave barrier, a vertical barrier stopping short of the seafloor. In most situations, a partial penetrating wave barrier is the best breakwater choice, providing effective protection while minimizing the footprint of the structure.

RESEARCH & DEVELOPMENT

PND has been leading research including physical/numerical modeling on the partial penetrating wave barrier since it was first designed at a Coast Guard facility in Oregon in 1980 (pictured at top left). Extensive model testing helped to establish design methods and criteria published in 2001 that addressed incident and transmitted wave heights, wave period and length, run-up, and forces for various structural configurations. From these criteria, suitable structural solutions and use limitations can be developed for different soil conditions, water depths, and other factors. Model testing has been performed in wave tanks at B.C. Research, Inc., the U.S. Naval Academy, Oregon State University, and PND.

SYSTEM ADVANTAGES

- Reduces construction and maintenance costs
- Reduces construction time
- Minimal space required
- Allows natural basin flushing
- Minimizes impact on the marine environment
- Minimizes loading on submarine soils
- Reduces the breakwater’s susceptibility to seismic damage
- Does not require rock quarrying and related activities
- May be attached directly to existing docks
- May be used as a part of foundation system for future docks
- Can be removed readily for modification or expansion
- Allows construction in deep water

New partial penetrating wave barriers were installed at the primary harbor entrance for the Port of Bellingham at Blaine Harbor in Washington. The wave barriers replaced deteriorating timber pile barriers protecting the harbor’s entrance. The timber pier was rehabilitated and turned into a park. The new 580-foot wave barriers vary from 20 to 50 feet in height from mudline, and were designed to improve wave protection, decrease maintenance costs, and provide additional space for moorage just inside the entrance to the harbor.

The wave barriers used two different design styles chosen to best fit varying site conditions. In shallower water, a cantilever-type wave barrier was employed, which consists of large-diameter pipe piles with partial depth sheetpile barrier wings. The deeper water areas necessitated use of Spin Fin™ barrier clusters to handle the repetitive tension/compression loads from wave attack. The design surface waves have a significant height of 6.2 feet, with period of 4.6 seconds.

The photo on the right depicts the wave barrier in February of 2006, during the largest storm in conjunction with the highest storm surge in 40 years.
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The photo on the right depicts the wave barrier in February of 2006, during the largest storm in conjunction with the highest storm surge in 40 years.
A partial penetrating wave barrier in Astoria, Oregon provided expansion room for 22 additional 60-foot vessel slips by eliminating a filled bulkhead system. The alignment of the new breakwater allowed for the additional moorage.

The West Basin marina is located near the mouth of the Columbia River in Oregon where there are strong currents, high winds and ocean-going cargo vessels. The largest design loads are developed by 4.9-foot high significant waves with 4.3-second periods. A cantilever-style wall was selected that consists of large-diameter pipe piles with sheetpile barrier wings. This design provided the best wall alignment to protect the harbor without impeding access and creating wave-reflection issues. A typical section is shown to the right.

A realigned partial penetrating wave barrier structure with a concrete work dock was constructed at Shilshole Marina’s Pier A for the Port of Seattle in Washington. The new dock allows vehicle access for loading of large vessels.

Partial depth steel sheet pile barrier wings, welded onto the pipe pile, were driven and attached to a steel beam to handle wave loads. Spin Fin™ batter clusters were used to convert the wave forces into tension and compression to transfer forces into the soil. The batter pile clusters were also used to support the precast concrete promenade. Floats on the back side of the dock were included for 100-foot vessels.

The placement of the wave barrier on the inside face of the pier and the openings for fish passage have improved the flushing of water through the marina.

The top photo shows the West Basin prior to breakwater construction. The large photograph depicts the 22 additional moorage locations.

SHILSHOLE PIER A
WORK DOCK COMBINATION

WEST BASIN WAVE BARRIER
HARBOR PROTECTION & EXPANSION
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The placement of the wave barrier on the inside face of the pier and the openings for fish passage have improved the flushing of water through the marina.
PND provided services to the Washington State Parks Department for a partial penetrating wave barrier at Cape Disappointment State Park in Southern Washington State. The barrier protects a three-lane recreational boat launch facility, and was designed to replace an old timber barrier. The new cantilever wave barrier is approximately 250 feet in length and consists of galvanized pipe piles with sheet pile wings.

The partial penetrating design was selected because of its low environmental impact and small footprint. The barrier design also has a separation that allows for fish passage.

Bell Street Pier is a waterfront facility in downtown Seattle, Washington that provides public moorage, cruise ship operations, a maritime museum, a conference facility, and waterfront restaurants. The harbor is protected with a 900-foot partial penetrating wave barrier with lateral resistant battered Spin Fin™ piles.

The wave barrier was designed to resist storms producing 8-foot significant height waves with six-second periods. The wave barrier face extends into the water 32 feet at low tide. It is comprised of 48-inch diameter pipe piles placed 12 feet on-center acting as the vertical bending members. Bridging the gap between these piles are eight-inch-thick prestressed concrete panels. The height of the structure from mudline varies between 55 and 75 feet.

A three-dimensional wave model of the surrounding Elliot Bay (bottom right) was used to verify wave climate and barrier efficiency at B.C. Research Lab in Vancouver, Canada.
CAFE DISAPPOINTMENT  
BOAT LAUNCH PROTECTION

PND provided services to the Washington State Parks Department for a partial penetrating wave barrier at Cape Disappointment State Park in Southern Washington State. The barrier protects a three-lane recreational boat launch facility, and was designed to replace an old timber barrier. The new cantilever wave barrier is approximately 250 feet in length and consists of galvanized pipe piles with sheet pile wings.

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BELL STREET PIER  
CRUISE SHIP FACILITY

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For additional information please visit our website.
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