From Ruins to Dunes: The Benefits of Buried Revetments

Planted dune grass is an important component of the buried revetment system.

Introduction

BEACH and dune restoration is best done using the tools developed by Mother Nature. Natural qualities can be achieved in Lakeshore restoration even when a revetment is needed by placing the revetment in the right place and "burying" it, using beach nourishment if necessary. Even without beach nourishment, the shore of Sheboygan's Harbor Centre South Pier District Peninsula, where the Sheboygan River flows into Lake Michigan along the Wisconsin shoreline, was effectively transformed with the help of a buried revetment and dune grass. Beach nourishment will become important here as the level of Lake Michigan rises, and deserves more attention in the Great Lakes region to counter the effects of revetments being built to protect increasing development along the shore.

Historical Activities

The Harbor Centre South Pier District Peninsula had been a busy commercial port ever since European immigrants began pouring into the upper Midwest around 1850. Originally, the river had meandered around a narrow sand spit, which formed a barrier to an estuarine marsh just upstream of the mouth. Between 1852 and 1856, a straight channel was dredged across the spit, creating a port big enough for schooners plying the lakes at the time. The marsh was filled in behind timber bulkheads to make land.

Early exports of lumber, potash, and fish gave way primarily to the import of coal by the mid-1900's to fuel local industries. In the 1950's, concrete breakwaters were built more than a half mile

Concrete rubble placed in the 1960's to protect bulk oil tanks restricted Lake Michigan shore access or use.

out into the lake, providing all-weather refuge to modern ships, and bulk fuel oil delivery and storage was added. By the early 1970's, coal for the power plant began arriving by train instead of ship and Sheboygan's only oil refinery had shut down. The port then sat mostly idle, but for the arrival of an occasional load of fertilizer or road salt. Perceived environmental impairment and the need for major infrastructure reinvestment were insurmountable barriers to private redevelopment for the next three decades.

Present Day Activities

Surrounded by water on three sides, this 40-acre peninsula was a prime location to support growing tourism and recreation, and improve public access to both the river and lake. Growing tired of the land's blighted condition, the City of Sheboygan set up a Tax Incremental Financing District (TIF) as a mechanism to leverage future tax dollars generated by planned development on the peninsula, to finance current improvements. By using this method to fund cleanup and new infrastructure, the City of Sheboygan adeptly stepped into the lead role in redevelopment.

One of the first steps in the redevelopment process involved planning for the protection of approximately 1/2 mile of Lake Michigan shoreline and restoring the corresponding beachfront area. As design work for the project began in 2000, Miller Engineers & Scientists worked closely with the City of Sheboygan to develop a revetment for the peninsula that would protect inland development from the erosive effects of the lake and improve the aesthetics and func-

tionality of the site. In just a short time, what had long been an eyesore was transformed into a community gem, though not without meeting some challenges.

Any of the Great Lakes can briefly lie flat as a small inland pond, but water meets land with great force as storms drive deep-water waves onto shore. Open water waves twenty feet or more in height during storms are reduced in size by their own turbulence, breaking over successively shallower sand bars. In this way, it is the quite flat, near-shore bottom that causes waves to expend most of their energy before their final run up onto the beach. North of Sheboygan, steep eroding bluffs comprise the lakeshore. Southward, wide sand beaches and dunes stretch for miles and are backed up by woods and swamps. A natural example of this situation has been preserved as Kohler-Andrae State Park, located just a few miles south of the City.

The first step in construction of a buried revetment is excavation for its toe, with the sand placed outboard to later become a fore-dune.

Lakeshore Restoration

The ultimate goal of this project was to create a protective barrier for the inland development while incorporating as much of these natural aesthetics as possible. To re-create almost 1/2 mile of natural appearing shoreline for the Harbor Centre South Pier District, a version of the native beach and dune system had to be designed in a way that would adequately protect new private development within the peninsula from wave erosion. In order to leave enough land available for the generation of property

taxes to amortize the public investment funded through the TIF, the beach/dune system had to occupy less width than an entirely natural system. This protection had to be reliable throughout the six-foot range in water levels that occurs on Lake Michigan caused by long-term trends in precipitation.

Historically, unsightly piles of concrete rubble along the lakeshore had protected bulk oil tanks from wave attack. These were removed and the concrete was crushed and recycled for use as road base material on the interior of the peninsula. The resulting shoreline was then re-shaped and completely reconstructed in two sections: a conventional, exposed revetment to the north and a "buried" revetment to the south. Both of these systems were part of an integrated approach to transform the vacant land into a beautiful and environmentally sound recreational, residential, and commercial development.

The next step of a buried revetment is completely conventional. Fabric, bedding stone, then armor stone are placed in succession.

A "buried" revetment is generally placed further landward than a conventional exposed revetment, and is designed to be covered with sand and dune grass during all but the high water periods, when it must resist wave erosion. Optimum positioning of a "buried" revetment is determined by paying close attention to the historic erosion limits visible along the lakeshore and the nearshore bottom profiles surveyed one mile out into the lake. This, in combination with the measurements of sand grain size, allows for calibration of the simple equations for equilibrium of bottom profiles to local conditions. The equilibrium profile is a conservative boundary for design. The effective vertical and horizontal location for a revetment is between that and the historic erosion limit, being closer to the latter. The "barless" bottom profile, determined from the bottom survey at any location, defines the breaking wave height, which is used to determine the revetment proportions and materials.

A buried revetment is constructed in much the same way as a conventional exposed revetment. After excavating to the calculated "toe" elevation, successive layers of geotextile fabric, bedding sand, underlayer stones, and armor stone are placed to reach the designed revetment top elevation. As with a conventional revetment, the final revetment dimensions, material size, and configurations are dependent on the amount of energy provided by the open water system. However, unlike an exposed revetment, the buried revetment is positioned landward and covered with sand to create a natural appearing "fore-dune" as part of the restored beach environment. This allows the natural accumulation of sand to occur in front of the revetment, thus building the "dunes" during normal and low water conditions. This sand is then available to the lake system as a source of sediment, with the underlying revetment becoming exposed as the sand is washed out during periods of high water. As water levels drop, the sand in front of the revetment is exposed. This sand is then available to be redeposited (by wind) on the revetment, re-forming the dunes.

Although a number of native tree and bush species succeed amongst natural back dunes, it is grasses that have evolved to play the most critical role in sustaining natural beach dynamics. Storm waves during high water periods erode sand stored in the dunes, moving it out to form bars in shallow water. Without a reserve of sand available to build bars up as water levels rise, bigger waves reach the shore, causing more severe erosion. Conventional revetments eventually aggravate the situation by starving the system of this natural source of sediment. Normally, as water levels drop, the bare beach widens. Onshore winds blow the newly exposed sand until it's captured by the quickly spreading grass, re-forming the dunes that had eroded during the prior high water period. The new dunes then stand ready to be sacrificed during the next high water cycle.

The "buried revetment" system developed for the southern portion of the Harbor Centre South Pier District shoreline protects the private development from wave erosion during periods of high lake water level, while restoring the natural characteristics of beach and dunes. It features a combination of native trees and shrubs to re-create a natural-appearing dune system, while providing wave erosion protection to the new development just inland. The design takes into consideration the natural dynamics of the sandy shore throughout variations in lake level. Constructed fore-dunes cover the buried revetments, portions of which will be temporarily exposed to prevent erosion during periods of high water. In periods of lower water the dune grass, spread by its runners, will naturally capture sand, re-creating the dunes and covering the revetment.

The north end of the project consists

of a conventional limestone boulder revetment that creates a public use area to improve access to the federally owned South Pier (breakwater). This exposed revetment creates an energy-absorbing transition between the Pier and the beach restoration to the south, which comprises the majority of the shoreline work.

Beach Nourishment

Beach "nourishment" can offset the negative effects of exposed revetments by replacing the sediment that is removed from the littoral system as a result of their construction. Alternatively, buried revetments can provide protection where it is needed, with minimal impact on natural beach dynamics. The beach nourishment component of a buried revetment, or any revetment system, restores the natural shore through replacement of sand previously lost down drift or offshore. Properly positioned, smaller scale revetments combined with beach nourishment deliver the same or more protection than a conventional, exposed revetment. The immediate values of the system are construction cost savings and aesthetic improvement. Buried revetments provide the highest use to the beach-loving public, and they serve to restore the natural shore system.

Dune grass planted over the "buried" revetment (invisible but just to the right of the boardwalk) takes hold in just one year.

Sand sources for beach nourishment can come from land sources, offshore sources, or navigation channels. Grain size distribution should match the native

sand as closely as possible. Use of sand finer than the native material will require greater quantities to be placed and will result in flatter near-shore slopes than the native profile. Use of coarser material will result in a beach profile with steeper slopes, but will require less material.

The Benefits of Buried Revetments

While providing the community with a safer and more enjoyable waterfront recreational area in which to relax, exercise, and enjoy Lake Michigan, the buried revetment on the Harbor Centre South Pier District Peninsula re-establishes natural shore dynamics that are an important part of the coastal eco-system. Consultation with local park rangers and plant experts helped the design of the beach restoration, using native plants to mimic the surrounding beach landscape and predevelopment conditions. A paved path inland of the back dune and a boardwalk path amongst the fore-dunes complete the public pedestrian loop around the peninsula and nearby resorts and shops.

On a larger scale, the buried revetment configuration avoids the adverse impact that conventional revetments have on the character and sand dynamics of the natural shoreline. The beach and near-shore bottom sediments have an important role in absorbing wave energy. Conventional revetments don't allow the cross-section of the shore to respond to varying water levels and storm energy, resulting in progressive deepening of the near-shore bottom. This configuration allows larger waves to break in front of and on the revetment, aggravating a progressive process that ultimately results in the demise of the revetment. A large number of conventional revetments have been constructed along many reaches of the western shore of Lake Michigan. An adverse cumulative effect may already be taking place.

Ultimately, through their effectiveness in reducing short-term erosion, placement of exposed revetments results in starvation of sediment supply to the near-shore environment. Uninterrupted, the natural process of littoral drift moves sediment along a shoreline. Material that is moved down the shore is replaced by material that is transported from the upper sources. A continuing supply of material is ultimately provided through the natural erosion of the shoreline. Too many revetments along shorelines, particularly concentrated in urban areas, results in a dearth of sediment entering the system. In addition, "stabilizing" structures such as piers, jetties or groins along a shoreline disrupt the littoral flow and block the incoming migration of sediment along the shore. Buried revetments and beach nourishment provide a solution to this compounding problem. These alternatives maintain a source of sediment necessary to the lake system while providing the protection that is required by our increasing demands on the shoreline development. **L&W**

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