Vol. 161 Oct 2005

US Army Corps
of Engineers
Detroit District

Great Lakes Update

Wave Absorbers at Federal Harbors on the Great Lakes

Attenuation or reduction of wave action in federal navigation channels has become a pressing issue throughout the Great Lakes region. Wave heights on the Great Lakes can reach well over 20 feet in deep water creating dangerous commercial and recreational boating conditions. Additionally large waves can accelerate erosion, putting both private and public property in jeopardy.

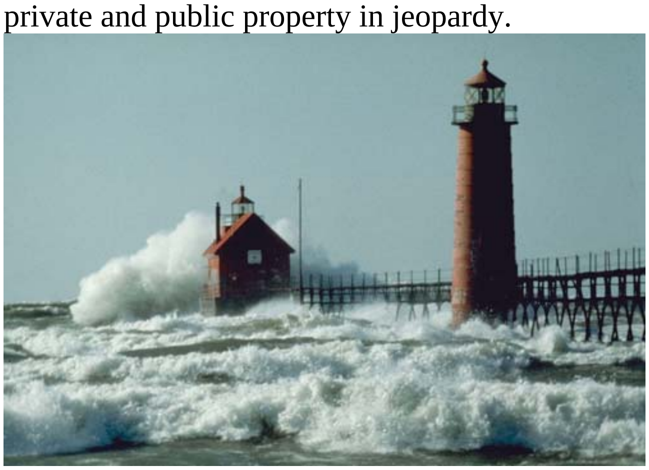

Figure 1: Wave action at Grand Haven Pier

Many inlets around the Great Lakes are stabilized by parallel jetty structures, also known as piers. Channel geometry and construction materials contribute a large portion to wave attenuation in federal harbors. The geometry and impermeable material used to construct these piers, allow them to shelter the inner-channel from a large portion of wave energy. These structures were originally built in the mid to late 1800's using stone filled timber cribs. Due to many years of physical, chemical and biological weathering, these structures deteriorated to the point where they became unstable. They were absorbing wave energy, but concurrent with every passing storm, being continually destroyed. The U.S. Army Corps of Engineers was tasked to rehabilitate these structures. The goal of the rehabilitation was to restore them so they would perform in a similar way as they did when the structures were originally installed.

The usual construction method has been to drive steel sheet pile on both sides of the deteriorating jetty and pour a concrete cap over the top. Steel sheet pile was chosen over timber to extend the structures useful lives. While this has proved to be a very durable alternative, it has made the wave climate between the jetties at some harbors more energetic when compared to the climate when the structures were deteriorated.

Because steel sheet pile is vertical and smooth, waves tend to reflect entirely off these structures with little to no energy being dissipated. With waves continually bouncing off the sides of these structures, resonance may occur, and on rare occasions may result in a large standing wave. A standing wave may hamper vessels' ability to gain safety inside a harbor.

To remedy this situation and provide for a safer environment, the Detroit District began installing wave absorber cells in some of their structures. A wave absorber is a pocket cut out of the existing steel sheet pile jetty, where large armor stone is placed. The armor stone size usually ranges from 2.5-10 tons and is normally placed on a slope. The uneven face of the stone configuration allows for much more effective wave absorption, while protecting the integrity of the structure. The armor stone configuration allows for a much more porous structure which absorbs wave energy much more effectively. Figure 1 shows the northern wave absorber at Pentwater Harbor. Figure 2 shows wave action on the lakeside of the wave absorber cell. Figure 3 shows wave action after interacting with the wave absorber cell.

Figure 2: Wave Absorber Cell
(Courtesy of Don Carpenter)

Figure 3: Wave action before the cell
(Courtesy of Don Carpenter)

Figure 4: Wave action after the cell
(Courtesy of Don Carpenter)

Depending on the configuration of the harbor, wave absorbers have been placed in both jetties or just one. The lengths of the absorber cells range from 200 feet to 600 feet, while the widths range from approximately 20 feet to 60 feet. In Figure 5, the 200-foot wave absorber structures on both the north and south jetties at Pentwater harbor are shown.

Figure 5: Pentwater Harbor

Currently, wave absorbers have been installed at seven harbors (Figure 6). Five of them are located on the east coast of Lake Michigan: Charlevoix, Portage Lake, Pentwater, White Lake and Saugatuck. Two Rivers is located on the west coast of Lake Michigan. The seventh is at Ontonagon, located on the southern shore of Lake

Superior. Grand Haven Harbor is scheduled to have one constructed within the next few years.

Figure 6: Wave absorber locations.

In order to examine the efficiency of these structures and possibly improve on them, the U.S. Army Corps of Engineers Coastal and Hydraulics Laboratory (CHL) and Detroit District have undertaken a study at Pentwater Harbor involving both detailed physical and computer modeling. This study is being done under the Monitoring Completed Navigation Projects (MCNP) Program. There were a number of purposes to this study, which are outlined below.

- Experiment with wave absorber length and placement to optimize future designs.
- Provide guidance to future wave absorber designers on how to conduct analyses to determine proper wave absorber size and placement.
- Determine efficiency of each wave absorber configuration and costs associated to achieve various levels of wave energy reduction within the navigation channel.

The bulk of the work effort on this project was on the physical modeling. The physical model was constructed at the CHL in Vicksburg, MS (Figure 7). Several wave conditions were modeled with 9 different wave absorber configurations. The configurations were as follows:

1. 200-foot wave absorber on north jetty, 200-foot wave absorber on south jetty (Existing condition at Pentwater)
2. 200-foot wave absorber on north jetty, no wave absorber on south jetty
3. No wave absorber on north jetty, 200-foot wave absorber on south jetty
4. 400-foot wave absorber on north jetty, 400-foot wave absorber on south jetty
5. 400-foot wave absorber on north jetty, no wave absorber on south jetty
6. No wave absorber on north jetty, 400-foot wave absorber on south jetty
7. 200-foot wave absorber on north jetty, 400-foot wave absorber on south jetty
8. 400-foot wave absorber on north jetty, 200-foot wave absorber on south jetty
9. No wave absorbers on either jetty

Figure 7: Physical Model

In addition to the physical model built at CHL, a detailed computer model was created using CGWAVE, a state-of-the-art computer program that is capable of predicting wave effects inside a harbor. The purpose of the dual modeling scenarios was to compare results of both the physical and computer models and make conclusions on whether the computer modeling is accurate enough to predict the same wave effects inside the harbor as that of the physical model.

Physical modeling is very costly when compared to computer modeling. If the computer model proves to be adequate in predicting harbor response then it can be recommended for future studies at a significantly reduced price. All of the configurations listed above were modeled using CGWAVE.

The graphic below shows a model run using an 8.2-ft wave. A wave of this height would most likely be the result of strong northwest winds. Note the intense wave action along the southern pier. The height of those waves along the pier is about 5 ft. After interacting with the wave absorber cells, the waves are drastically reduced.

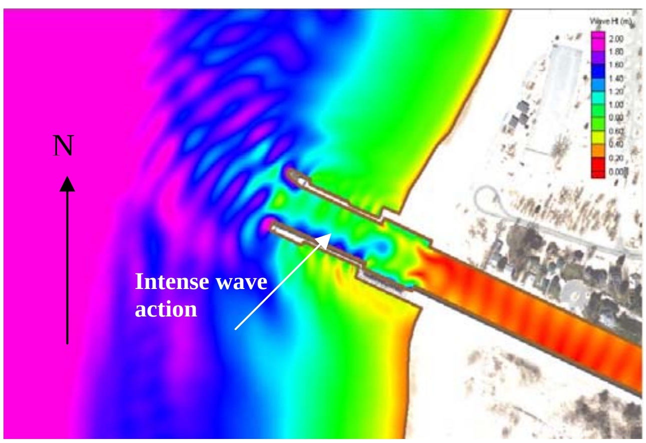

Figure 8: CGWAVE Output

Preliminary results are showing that a wave absorber on both sides of the channel is more effective than just having one. For example, when a 200-foot wave absorber was placed on the north and south side, it generally was more effective in reducing wave energy than just one 400-foot wave absorber on the north or south side. These preliminary results are very positive considering that Pentwater was built with two 200-foot wave absorbers.

The idea for the two-wave absorber configuration came from a field experiment in Charlevoix Harbor. In 1981, during reconstruction of the Charlevoix Harbor north jetty, field engineers attempted to mitigate for the increased wave reflection that was expected at completion of the project. They substituted a 400-ft section of large armor stone for the sheet piling along a portion of the rehabilitated structure, essentially creating a steel sheet pile-rubble mound hybrid structure. The rubble-mound portion was recessed into a pocket so that the toe of the rubble-mound would not encroach into the navigation channel, and these became know as pocket wave absorbers.

The local community found this to work very well in attenuating waves. When the southern jetty was being rehabilitated in 1989, a 200-foot section of rubble mound was placed. From that project forward, the application of a wave absorber at all new rehabilitation projects was examined. The length and placement of the wave absorbers varied from project to project as some harbors only called for small sections of the jetties to be reconstructed. Lengths of 200-foot and 400-foot were traditionally used since they were shown to work at the original harbor.

CHL and the Detroit District have completed all of the physical and computer modeling and are currently analyzing the data. A draft report was completed in September 2005 and the final report should be published sometime in 2006.

Based on the results from this study, the U.S. Army Corps of Engineers hopes to enhance performance of the federal structures and design cost effective improvements in the future. The ultimate goal is to provide safe navigation to all who want to work and play on the Great Lakes.