Open Cell™ bulkhead: materials development

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Open Cell introduction

Port expansion projects are often driven by the progressive increase in vessel size and corresponding deeper drafts. This has facilitated a need for new technology to provide cost-effective and structurally adaptable measures to accommodate port growth. Typically, filled bulkheads have been desired over pile-supported platform docks because they can provide a significantly lower initial construction cost, more rapid construction, lower maintenance costs, and higher load capacity than pile-supported docks. An alternative option is an Open Cell structure. This structure provides a feasible substitute to other bulkhead types and traditional pile-supported docks. The Open Cell system is advantageous because it can be constructed for wall heights of up to 80 feet. It provides low costs, rapid construction times, high surface loading capacities, and a structure that can be installed in soft or hard ground conditions.

PND Engineers, Inc., Chaparral Steel, and PilePro are a group of knowledgeable companies that work together at a technical level to advance the development of Open Cell structures. These companies continually work to develop a product line that is manufactured through a consistent supply chain and provides for optimal use in a variety of site conditions.

Open Cell history and development

The first Open Cell structure was designed by PND and completed in 1981 for ARCO Alaska, Inc. to support and protect a bridge servicing the North Slope oil fields. Since then, hundreds have been built for their unique performance and low costs.

The Open Cell bulkhead, used primarily on docks and similar structures, is a cellular flat sheetpile structure in which each cell's sheetpiles are driven in the shape of a U when viewed from above. The system functions as a horizontally tied membrane relying solely on the vertical flat sheetpile anchor wall to restrain a curved sheetpile arch face. This shape can be seen in the aerial photo of the American Construction bulkhead (Figure 1) as it is under construction.

Open Cell technology provides low cost and high performance. The system has been used effectively in locations that are prone to severe ice, soft soils, scour, and seismic events. The Open Cell structure provides high load capacity while requiring minimal

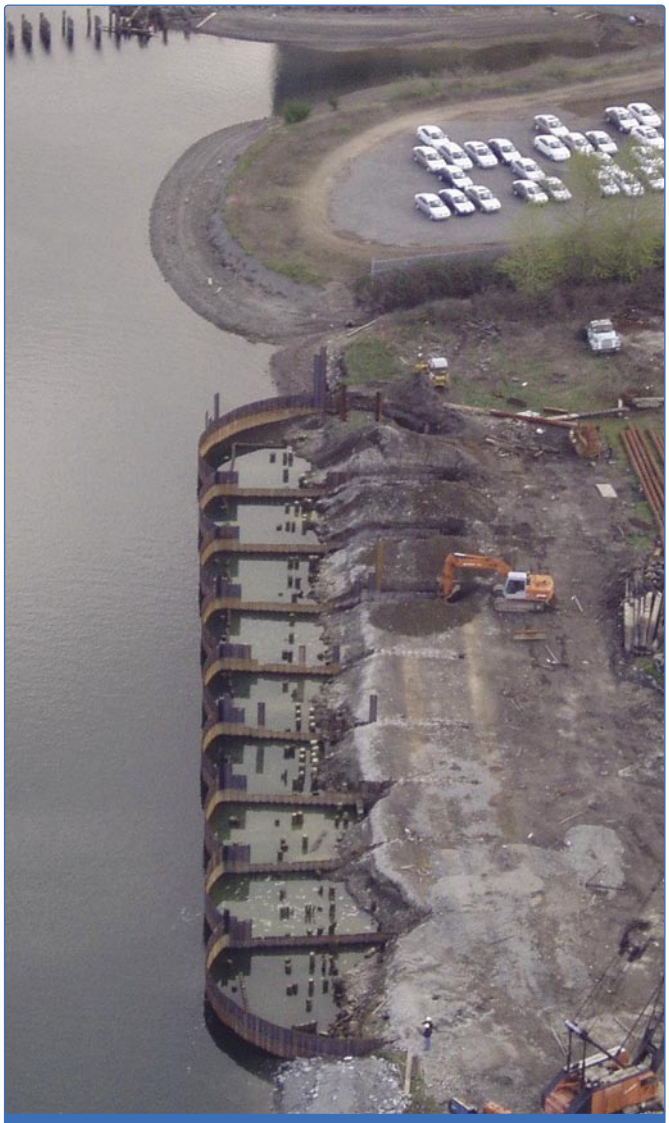

Figure 1. American Construction Bulkhead under Construction.

Figure 2. Pile Properties and Rolling Process for the PS 31 Flat Sheet Pile.

Figure 3. Pile Properties and Extrusion Process for the SWC 120 Pile.

sheetpile toe embedment. It is easily modified for increased loading or unforeseen conditions, and accommodates long-term settlement due to its flexible nature.

Material development

Flat sheet piles are the major component in development of Open Cell structures. Chaparral Steel has recognised the importance and applicability of the Open Cell system. Chaparral supplies PS 31 and PS 27.5 flat sheet piles produced in its mill in Midlothian, Texas, USA. Chaparral's engineers have continued to improve these flat sheet piles to work with the Open Cell system. This includes increasing interlock strength while maintaining necessary interlock swing, interlock clearance and driving, and engaged lay lengths. Figure 2 details the rolling process for the PS 31 flat sheet pile.

In addition, PND and Chaparral work with PilePro to develop extruded pile connectors suitable for use with the Open Cell system. In particular, the SWC 120 is proven to be effective and has replaced the previously used welded wye pile that was subject to dissimilar metal corrosion. This development has removed the need for welding at the heavily loaded face/tailwall connection and has provided a greater swing allowance with a single connection.

The SWC 120 is manufactured through a complex process that begins with heating billets in a revolving gas furnace to temperatures of 1,270° C. The heated billet is transported to an extrusion press that coats the surface with glass powder to minimise friction. The billet is then pushed through a die to form the desired profile. A glass pad acts as the main lubricant between the die and the billet while it is being struck by a ram. Annealing, followed by a straightening operation, is then performed. The dimensions, straightness and surface of every bar are inspected. A plus/minus gage is used to inspect the socket area of the undercut region. Figure 3 details the extrusion process and pile properties of this pile connector.

Chaparral Steel provides extensive testing of both flat sheetpile and connectors to ensure that the structural components meet necessary geometric and strength requirements. Testing takes place at the Physical Testing Lab at Chaparral under the direction of the General Manager of Quality Engineering. This process involves constructing a jig and doing 'pull tests' to replicate the forces within an Open Cell bulkhead (Figure 4). In addition, extensive chemical analyses have been done on the SWC 120 sample. The section has exceeded the expectations of the team, and performance matched the theoretical calculations.

Open Cell projects in development and recently completed

Sabine Pass LNG Terminal Bulkhead, Cameron Parish, Louisiana: Currently under construction is the 1,500 foot Open Cell bulkhead at the Sabine Pass LNG Terminal. The project, located in Cameron Parish, Louisiana, is being constructed for Cheniere Energy, LLC. The bulkhead has been designed to enable eventual dredging/scouring to an elevation of -45 feet, creating a total wall height of 55 feet. The Open Cell system was selected for this site to deal with local soft clays, clearance issues to an adjacent pipeline rack, and for a significantly lower cost than a conventional combi wall.

Broadway Dock Expansion, Skagway, Alaska (Figure 5): A new cruise ship dock was completed in time for the 2006 cruise ship season in Southeast Alaska. The Broadway Dock, originally developed for 800-foot cruise ships, was expanded shoreward to accommodate ships up to 1,000 feet in length. An Open Cell bulkhead at the head of the dock retains 64 feet of material required to allow the dredge basin to be increased. A fish passage structure for salmon penetrates the structure.

Tilcon Bulkhead, Jersey City, New Jersey (Figure 6): An Open Cell bulkhead was completed for Hugo Neu Schnitzer East in Jersey City, New Jersey. Located at a steel recycling facility on

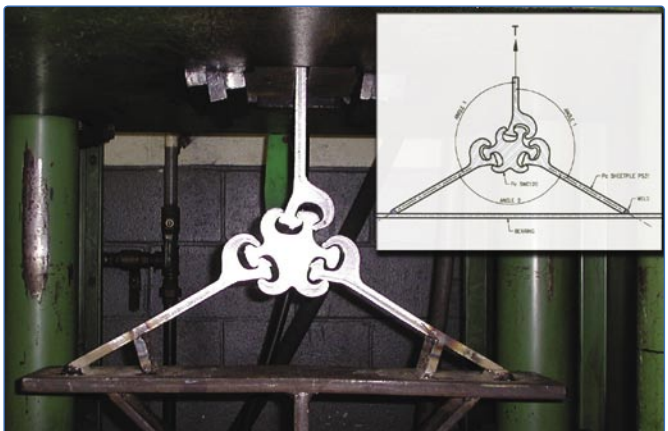

Figure 4. Testing of Interlock Capacity for the SWC 120.

Figure 5. Broadway Dock Expansion.

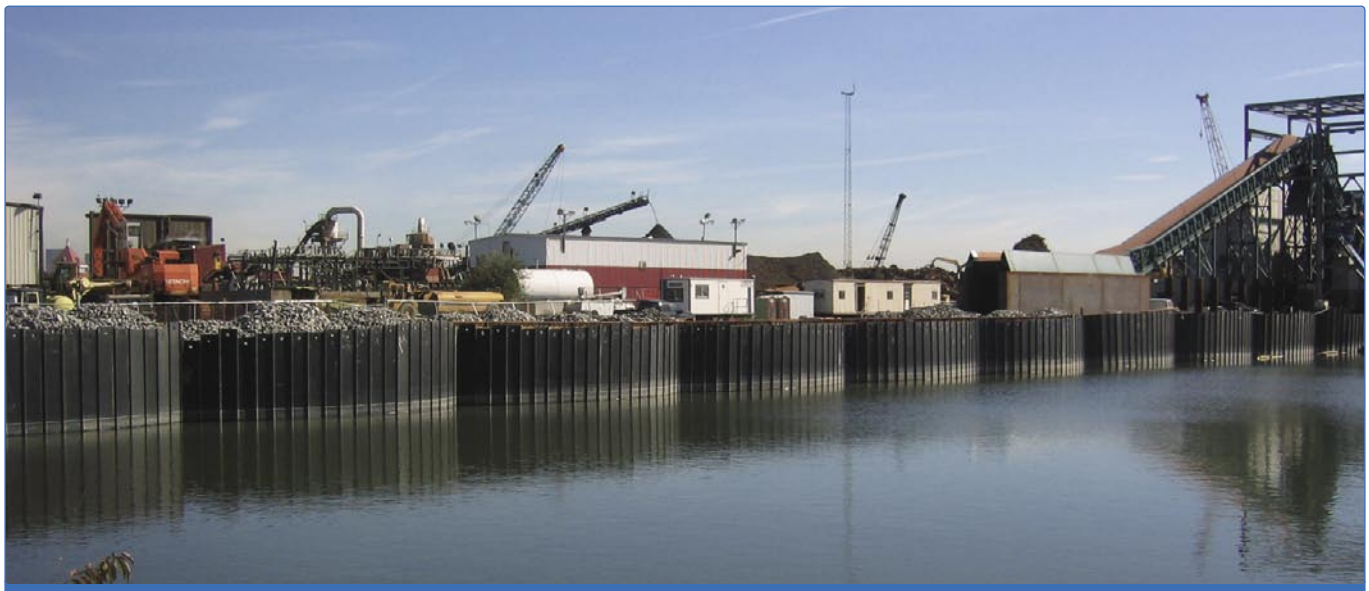

Figure 6. Tilcon Bulkhead.

the Hudson River, it is used for large scrap handling equipment requiring 1,000 pounds per square foot uniform load. The Open Cell structure was a highly competitive alternative to other bulkhead designs, and at completion the construction cost was well below original estimates. The Open Cell design was a practical solution to contend with large boulders at the site.

American Construction Bulkhead, Tacoma, Washington (Figure 1): The American Construction Company selected an Open Cell system for the construction of a work dock on the Hylebos Waterway in Tacoma, Washington. The Open Cell structure encapsulates the original failing bulkhead and contaminated soils at the site. Flexibility in the final layout allowed in-the-field adjustments to avoid obstructions while limiting impact to the existing bulkhead. The final dock, with its inherent high load capacity, allows use of high-capacity cranes along the face of the dock.

Open Cell projects in the future

Open Cell bulkheads are being planned for a variety of projects throughout the world with demands ranging from:

- Vertical wall heights over 80 feet
- Water level fluctuations over 40 feet
- Variety of soils, shallow bedrock to soft clays
- First year sea ice thickness in excess of 8-feet, and massive multi-year ice runs
- Seismic peak ground acceleration over 0.5g
- Live load demands over 10,000 pounds per square foot

The benefits provided by the Open Cell system will continually be explored with anticipated uses focusing in the areas of deep-water ports, dikes, erosion control and high load capacity structures.

ABOUT THE AUTHORS

Todd Nottingham, P.E. and **Bill Gunderson, P.E.** currently live in Seattle, Washington. They have been designing waterfront structures since they joined PND Engineers Inc. (PND) in the early 1980's, and both serve as company officers. Their involvement has included structures such as bulkheads, retaining walls, wharves, piers, mooring and breasting dolphins, cargo facilities and cruise ship facilities.

Stan Baucum resides in Midlothian, Texas and has been with Chaparral Steel for over 20 years. As Director of Sales – Engineered Products, his primary responsibilities are the Piling and Special Bar Product sales worldwide.

ABOUT THE COMPANY

PND Engineers, Inc. is a full service civil engineering company established in 1979 in Anchorage, Alaska. PND now has three offices, and focuses on transportation projects and other infrastructure support services. Work is predominately located in the United States Pacific Northwest and Pacific Rim, and also stretches worldwide. PND has received many awards, most notably a NOVA Award and a US Patent for development of the Open Cell system.

Chaparral Steel is the largest producer of sheetpiles, and the second largest producer of structural steel beams in North America. The company began in 1973 with the construction of a steel plant in Midlothian, Texas, and has since added a plant in Petersburg, Virginia. The combined annual production capacity of both mills exceeds 2.8 million tons. More information on the company can be found at www.chapusa.com and more details on sheet piling products at www.sheet-piling.com.

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