Open Cell™ Bulkhead: An economical port expansion solution

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Open Cell introduction

Port expansion necessitates ever-deeper water to meet the increasing vessel sizes dictated by economics. The industry has met this challenge by introducing new and better materials along with improved construction and fabrication methods.

Typically filled bulkheads have been desired over pile supported platform docks because they provide a lower initial construction cost and lower maintenance costs. These bulkheads have generally relied upon tied back z-sheets or combi-wall systems. Alternatively, in more expensive applications, the use of closed cell or diaphragm systems, with flat sheet piles have been used. However, the increase in water depths is approaching or surpassing the practical limit of these wall types.

The Open Cell structure provides an economical alternative to other dock types that can meet these challenges.

Port of Anchorage

The Port of Anchorage, Alaska is the state's largest port and serves its most populated region. All types of commercial cargo and petroleum products pass through this port and the military is an important user as well.

Space limitations on the 105-acre port site prompted investigation into ways to expand the acreage an additional 140 acres. By locating a new dock face seaward about 400 feet and expanding the deteriorating existing 2,000-foot long dock face to a new 10,000-foot dock face, a number of benefits can be realised (See Figures 1 and 2). Annual dredging would be reduced and the port could be deepened from the current El-35 to El -45-feet Mean Lower Low Water (MLLW). The longer dock face would be able to accommodate tour ships and barges as well as RO-RO and container ships of increasing size.

With geometric and use criteria established, this project has some of the world's toughest technical issues:

Tides:	El+35-feet to El-5-feet MLLW
Ice:	3-foot thickness
Seismic:	0.46g peak ground acceleration, 5 minutes duration
Phreatic Water:	El 19-feet
Dock Face Height:	80+ feet

Economics ruled out conventional pile-supported platform docks in favour of a new Open Cell Bulkhead. These structures can have configurations with narrow open cells and long tail walls, which will address even the most severe seismic, height and soft soil conditions. This Open Cell system will utilise about 30,000 tonnes of flat sheet piles along the 10,000-foot dock face.

In support of Open Cell technology there are about ten such structures totalling over one mile in length bordering Cook Inlet, and nearly 140 structures world wide. Port MacKenzie, with a face height of 60 feet and length of 500 feet, was built directly across Knik Arm from the Port of Anchorage in 1998. The bulkhead has weathered several earthquakes with no adverse affects. In addition, it is supporting increased use primarily for bulk cargos such as wood chips and gravel. This important structure is a prototype for the new Port of Anchorage.

Figure 1 (left). Port of Anchorage existing aerial oblique.
Figure 2 (right). Port of Anchorage proposed dock.

The Port of Anchorage Expansion will be implemented in phases over the next several years.

Open Cell system

The first Open Cell structure designed by PND was completed in 1981 for ARCO Alaska, Inc., to support and protect a bridge servicing the 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 sheet pile structure in which each cell's sheet piles are driven in the shape of a U when viewed from above. The system functions as a horizontally tied membrane

Figure 3. Open Cell model.

relying solely on the vertical flat sheet pile anchor wall to restrain a curved flat sheet pile arch face. The bulkhead becomes a series of U-shaped vertical member structures that does not need toe embedment for stability (Figure 3).

Open Cell technology provides low cost and high performance. The system has been used effectively in locations that are susceptible to severe ice, soft soils, deep water, scour, and seismic events. The Open Cell provides high load capacity and requires minimal sheetpile toe embedment. It is easily modified for increased loading or unforeseen conditions, and accommodates long-term settlement due to its flexible nature.

The Open Cell design provides cost savings for development in ordinary conditions, and provides savings that are particularly evident in difficult environments (deep water, soft soils, etc.). The minimal cost of the structure is a result of a straightforward design, a simplified construction process, and low maintenance costs.

Open Cell projects

Stockton Barge Slip

The Stockton Open Cell Sheet Pile Barge Slip was designed and constructed to support the construction of the new East Span of the Oakland Bay Bridge. Located in Stockton, California, at the Kiewit Pacific/FCI/Manson (KFM) precast concrete facility, the structure plays an essential role in transporting the world's largest precast concrete segments utilised at the new bridge construction site 40 miles away (Figure 4).

The Skyway is being constructed using the world's largest precast concrete bridge segments; each weighing up to 850 tonnes. To facilitate the construction of the concrete bridge segments, a barge load-out facility was needed at the precast yard. Initially a tied-back z-sheet pile wall was considered for the barge facility site. However, it was found that the z-wall would provide inadequate load capacity for the Straddle Carrier without a secondary load-carrying system or load-relieving structure, which would add substantial expense to the project. The Open Cell structure was developed as an alternate design, which provides more than adequate capacity and substantially reduced the cost of the barge facility.

Figure 4. Stockton Barge Slip.

The Stockton Barge Slip was designed to provide an opening 70 feet wide by 170 feet long with a wall height of about 30 feet. The soils found at the site were low-strength alluvial sandy clays and silts, typical of the area. The length and height of the sheet pile tail walls were designed to support the 1,345-tonne straddle carrier load in the relatively weak soils. Seismic loads were also considered, but did not control the design of the sheet pile tail walls.

North Star Island: Heavy loadout dock

This project involved a dock project for BP Exploration (Alaska), Inc.'s Northstar Island, an oil drilling and production island in the Beaufort Sea on Alaska's North Slope (Figure 5). This man-made gravel island, which is more than six miles offshore, was the first such production island in the United States. Dock design and construction at this arctic site presented a number of unusual challenges:

- Remote location
- Frozen soils

Figure 5. North Star Island.

- Seasonal thaw and settlement
- 24 hours of darkness in winter, combined with extreme cold (-50°F was common)
- Up to 6 feet of first-year sea ice; massive multi-year ice runs
- Unusually large load requirements

Open Cell technology offered necessary adaptability for these conditions, and was incorporated to build the 315- by 140-foot dock at the south end of the island. The dock had to be designed to withstand transport of modules weighing up to 5,000 tonnes.

PND recommended the Open Cell approach after other consultants were unable to offer a suitable solution. While tied-back or cantilever sheet pile walls often require deep toe embedment for lateral strength (removal of that embedment for any reason will result in failure), Open Cell structures do not require deep embedment for stability. This is because the Open Cell system utilises unconnected sheet pile tail walls that act as soil/friction anchors for curved sheet pile cell faces. By not connecting tail walls on the landward side, cost savings are realised including less sheet pile area, greater construction tolerance and adjustment capability, minimal pile penetration, and easier backfilling.

Ballyhoo dock

The City of Unalaska constructed a new deep water container crane port at Dutch Harbor, Alaska (Figure 6). The port is designed to take advantage of container trade between Japan, Russia, and the Pacific Rim, and also to serve the Bering Sea fishing industry.

Figure 6. Ballyhoo dock.

The design utilised the Open Cell sheet pile bulkhead concept. The dock was fitted with a 21-year-old Paceco A-frame container crane with a 30-long-tonne-capacity. The 550-tonne crane, standing over 150 feet tall and able to extend over 110 feet, is mounted on crane rails supported by driven piles. Uplift forces at tie-downs are provided by Spin-FinTM piles. High siesmic loading has occurred on a frequent basis in this ring of fire area.

ABOUT THE AUTHORS

Todd Nottingham, P.E. and **David Pierce**, P.E., S.E. currently live in Seattle, Washington. They have been designing waterfront structures since they joined PND Engineers Incorporated (PND) in the early 80's and are both current officers with that corporation. Their involvement has included structures such as bulkheads, retaining walls, wharves, piers, mooring and breasting dolphins, cargo facilities and cruise ship facilities. Having started their professional careers in Alaska, at the PND corporate office, their design challenges have included the extreme conditions of the Alaskan environment which at times have 150 degree (F) temperature swings and 50 feet of tide changes.

ABOUT THE COMPANY

PND Engineers, Incorporated is a full service civil engineering company established in 1979 in Anchorage, Alaska. PND has three offices located in Anchorage and Juneau, Alaska and Seattle, Washington. The firm focuses on transportation projects and has branched out to include other infrastructure support services to complete its services. Work is predominately located in the Pacific Northwest of the United States and the Pacific Rim, but also stretches worldwide. PND has received many awards over the past 26 years. Most notably PND's president received the NOVA award for his development of the Open Cell sheet pile bulkhead. PND has received a US patent on the Open Cell system.

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