Introduction

The Dawei Sea Port (DSP) is the centerpiece of a multi-billion dollar infrastructure and industrial development project in Myanmar. Major elements of the project include a new port and industrial zone located in southern Myanmar (near the town of Dawei) and highway and rail systems connecting the port to central Thailand, to provide access to transportation infrastructure to South China and other regions within Southeast Asia. The developer will be the Dawei Development Company Limited (DDC) and the general contractor will be the Italian-Thai Development Public Company Limited (ITD). The DDC was established by ITD after being awarded a 75-year concession by the Myanmar government to develop the Dawei Development Project, an ambitious project comprising an industrial estate covering nearly 204 square kilometers, oil and gas facilities, a deep sea port, power plants, steel mill, shipyard, a new township, and a transborder road/rail/power link with neighboring Thailand.

The port development will ultimately include 55 berths, including terminals for containers, general cargo, liquid cargo, LNG, coal and iron ore. In 2011 the Halcrow-Aurecon Design Consortium (HA) was awarded a contract by ITD for master planning, data acquisition, feasibility and optimization studies, and the detailed design of the port. This article provides a brief overview of the DSP project and a detailed discussion of the unique quay wall system that will be used, with concrete diaphragm walls (slurry walls).

Port layout

The layout of the port features a breakwater-protected Outer Harbor and an L-shaped Inner Harbor. The Outer Harbor will be used for berths with open pile supported structures, including the liquid and Dry Bulk terminals, the LNG terminal, and the tug base. The Inner Harbor will be used for the container and general cargo terminals, and will have closed quays constructed using diaphragm walls. The Inner Harbor will have a depth of 16 meters while the Outer Harbor will have a depth ranging from 14 meters to 20 meters.

The first phase of construction includes facilities for the Outer Harbor and the initial portion of the Inner Harbor, together with dredging, reclamation, and shore protection works, see figure 4.

The breakwater system has an overall length of approximately five kilometers and will be constructed with dynamically stable rock breakwaters (‘berm breakwaters’), using widely graded armor stone produced from a quarry located adjacent to the site. Extensive 3D physical model tests were performed in order to optimize the port layout and breakwater design, at the Canadian Hydraulics Centre (CHC) and the Council for Scientific and Industrial Research (CSIR) in South Africa. Comprehensive coastal numerical modeling studies were also performed in support of the design work and to assess environmental impacts. Modeling issues of special concern include the potential for deep scour holes near the tip of the breakwaters, and the potential for excessive wave agitation at the container terminal caused by the
penetration of long period (infra-gravity) waves, due to prolonged periods of high swells during the Southwest monsoon.

Diaphragm wall quays
Conceptual designs and comparative construction cost estimates were developed for a number of alternative quay wall design concepts, for both in-the-dry and in-the-wet scenarios for the basin excavation and quay wall installation. Anchored wall options included steel sheet pile walls with king piles, and diaphragm walls with single and multiple rows of tiebacks. Gravity wall options included steel sheet pile cells, concrete block walls, concrete caissons, and slip-formed concrete gravity walls. Platform quays were also considered, including various types of pile supported platforms with revetments.

The selected concept uses a concrete diaphragm wall with a single row of tie rods. This scheme was selected because it offers relatively low lifecycle costs, and provides important advantages from both design and construction standpoints. The diaphragm wall system consists of 1.5 meters thick wall panels with T-section panels at the locations of the fenders and bollards, which are spaced at 12.5 meters. The wall superstructure, above Low Astronomical Tide (LAT), features a precast concrete fascia wall system that is connected with cast-in-place elements. The tieback system consists of 110 millimeter diameter x 46 meter long tie rods, spaced at approximately 2.1 meters, connected to a precast concrete deadman. Bored concrete piles are used for the foundation of crane beams at the container quays.

Typical cross-sections of the quay wall are shown on Figures 5 and 6.

Geotechnical analysis and structural design
A large number of load combinations are considered in the design, and fall into three general categories: construction load scenarios (with full dewatering of the basin); service load scenarios (including backfill live loads and the fender and mooring loads); and the contingency level seismic event. Loads and deflections are determined by soil-structure interaction analysis using PLAXIS, (see Figure 7), taking into account each phase of the construction sequence. The wall is subject to extremely large concentrated loads at the bollards, which are transferred into the T-sections of the diaphragm wall using counterforts.

Extensive sensitivity analysis has been performed to optimize various elements of the design, including the depth of penetration of the diaphragm wall into bedrock, the elevation and diameter of the tie rods, and the setback distance for the deadman. Stringent criterion was adopted for allowable deflection at the top of the wall: 3 centimeters for service loads and 30 centimeters for the contingency level earthquake. These are relative deflections at the top of the wall following the initial deflections caused by the basin excavation.

Serviceability and durability design
The concrete structures are designed for a nominal service life of 100 years to the initiation of corrosion of reinforcing steel. An extremely long service life is required because of the long lease terms being offered to ITD, after which period the port facilities must be turned over to the Myanmar Government.

Conceptual designs and comparative cost estimates were developed for two general alternatives: 1) cathodic protection; and 2) high performance concrete (HPC). The selected approach is to use HPC but also include provisions for implementing a cathodic protection system at some point in the future.

Concrete mix designs to achieve the 100-year design life were assessed based on computer modeling studies of chloride migration. ‘Triple blend’ concrete mixes will be used consisting of type 1 Portland cement, fly ash, silica fume, and corrosion
inhibitor will also be used for elements with more severe exposure. Low water-cement ratios are needed (in the range of 0.37) and super-plasticizers and other admixtures will be required for workability. Based on the results of corrosion modeling prescriptive specifications have been developed for indicative concrete mixes, but performance testing will be required to confirm that the target chloride diffusion coefficients can be achieved for the selected mixtures and aggregates.

The outer reinforcement of the diaphragm wall is designed for a nominal cover of 100 millimeters and it is conservatively assumed that the placement tolerance of the reinforcing cage is +/- 50 millimeters. Accordingly, for the corrosion modeling a minimum cover of 50 millimeters is assumed, whereas for crack control checks a maximum cover of 150 millimeters is assumed.

The top of the diaphragm wall is set below LAT and will be permanently submerged. This was done in order to keep the tie rods at an optimum and relatively low elevation, and to avoid exposure of the diaphragm wall in areas where it would be visible at times and subject to highly corrosive conditions of the intertidal and splash zones. The precast concrete fascia is used to provide a clean and uniform appearance to the concrete, and provide the highest quality reinforced concrete in areas where the corrosion risks are highest.

Recommended solution
Diaphragm walls require land-based operations for all of the quay wall construction and for this reason are not commonly used for port development. However, the method is quite suitable for dry dock construction and for port development in cases where harbor basins are to be excavated from existing land or from reclaimed areas. One example where a rather similar diaphragm wall construction has been used is at the Shahid Rajaee Port (Bandar Abbas) in Iran.

At DSP the developer/contractor strongly preferred land-based quay wall construction operations and in-the-dry basin excavation techniques in order to maximize the use of local labor and subcontractors and to make optimum use of their available construction plant and in-house experience. Offshore reclamation options were deemed problematic due to unfavorable soil conditions. Diaphragm wall construction becomes attractive under these circumstances and offers other important design and construction advantages.

Overall, the diaphragm wall system is an optimum albeit somewhat unique solution for the quay wall construction at DSP.

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ABOUT THE COMPANY
Halcrow delivers planning, design and management services for developing infrastructure and buildings worldwide. With its roots as a ports practice over 140 years ago, Halcrow has remained at the forefront of maritime and coastal engineering. Halcrow has over 250 maritime specialists around the world, including project managers, port planners, coastal scientists, simulation and modeling experts, and engineer divers. Halcrow is a company of CH2M HILL, the global full-service consulting, design, construction, and operations firm. With almost 30,000 employees, the combined group is a world leader in water, environmental, transportation, and other infrastructure markets.

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