Hybrid Design/Build Approach for Quaywall 729

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ABSTRACT

To support aircraft carrier maintenance at Puget Sound Naval Shipyard & Intermediate Maintenance Facility, the U.S. Navy retained BergerABAM to develop a request for proposal (RFP) for the replacement of Pier B and the retrofit of Quaywall 729. Due to a confined design and construction schedule for the design/build (D/B) team, the substructure design of Quaywall 729 was performed by BergerABAM and incorporated into the RFP document as a prescriptive design. This paper highlights the benefits and challenges associated with the combination of D/B with prescriptive requirements (design/bid/build) from the development of the RFP package through final design and construction by the D/B team.

BACKGROUND

Located in Bremerton, Washington, the Puget Sound Naval Shipyard and Intermediate Maintenance Facility (PSNS & IMF) at Naval Base Kitsap Bremerton is charged with overhauling, repairing, and maintaining the U.S. Navy's ship and submarine fleet. With the only dry dock (Drydock 6) on the West Coast capable of docking NIMITZ-class aircraft carriers, PSNS & IMF plays an important role in supporting carrier operations. When a carrier enters PSNS & IMF for maintenance, it spends about two-thirds of the time in dry dock, and the other third of the time waterside, berthed at Pier 3, which is located about 1,600 feet (490 meters) from Drydock 6. While there are other carrier berths within the shipyard, none are fully capable of supporting the requirements of waterside carrier maintenance. As a consequence, the carrier maintenance infrastructure and facilities must be relocated from Drydock 6 either when the vessel leaves dry dock or completely replicated at Pier 3 to avoid costly travel between facilities. Having a cold iron maintenance pier and associated support infrastructure and facilities adjacent to Drydock 6 would greatly enhance the effectiveness and efficiency of carrier maintenance operations. A pier at this location would create a carrier maintenance hub and eliminate the costly need to relocate or replicate the carrier maintenance infrastructure and facilities and personnel already at Drydock 6 to Pier 3 or another location.

The preferred location for a new carrier maintenance pier would be directly west of Drydock 6, where an existing Pier B was already located. While in the right location, the existing pier was not designed to support the requirements of modern aircraft carriers, and did not have the capacity to support rail-mounted portal cranes needed for waterside maintenance. In addition, the existing pier was not directly and continuously connected to Drydock 6, and was seismically deficient. Therefore, to develop a carrier maintenance hub, the Navy elected to replace Pier B with a pier that would satisfy the above requirements of carrier maintenance and meet modern seismic criteria. The replacement pier would occupy the footprint of the existing Pier B, but would extend directly to the West Mole of Drydock 6 to the east forming a contiguous deck surface. The pier was also lengthened approximately 100 feet (30 meters) to meet minimum berthing requirements of a carrier. Figure 1 shows a plan of the new Pier B and surrounding area. With the decision to replace Pier B, adjacent structures were evaluated for their ability to function within the new carrier maintenance hub. Similar to the existing Pier B, Quaywall 729 does not meet current seismic codes, so if Pier B were to be replaced then Quaywall 729 would potentially require retrofitting or replacement at the same time.

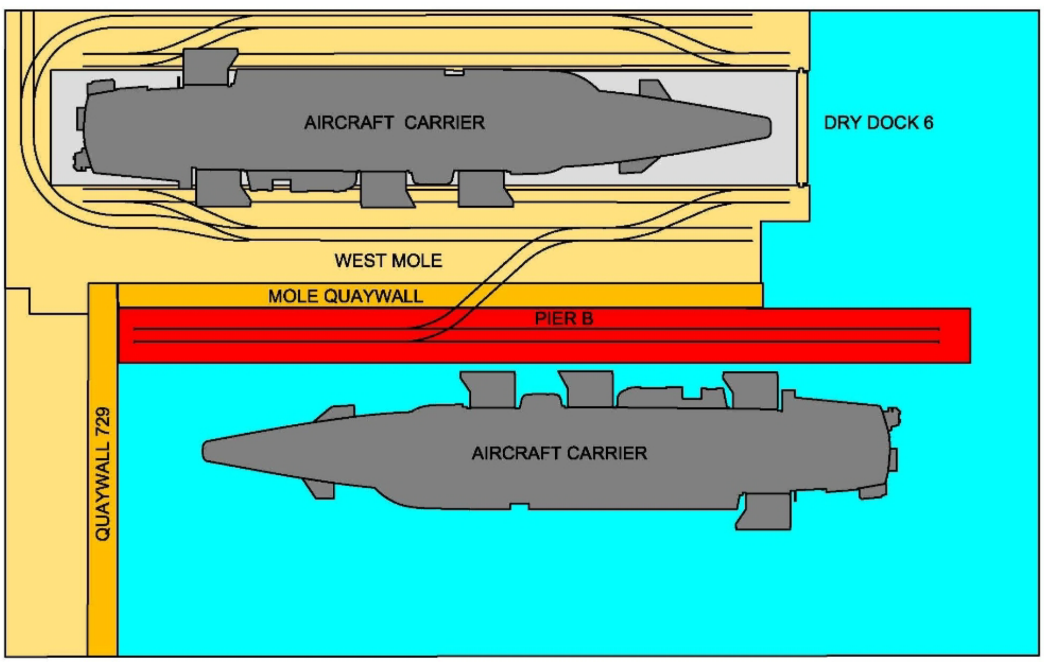

Figure 1. Site plan with new Pier B.

HYBRID DESIGN/BUILD

In September 2006, development of the RFP document began for the project with the understanding that all elements of the project would be fully designed and constructed under one D/B contract. Pier B would be replaced entirely with a wider pier; while a separate structure, the Mole Quaywall, would abut against the west side of the West Mole of Drydock 6 between the new Pier B and the existing West Mole; and Quaywall 729 would be replaced or retrofitted. To reduce environmental impacts to the marine environment, it was required that all modifications to Quaywall 729 would need to take place within the footprint of the existing structure. In addition, because of its location at the head of Pier B, the retrofitted/replaced Quaywall 729 would need to support substantial utilities, including a large electrical vault, mechanical vault, and potentially an oil-water separator for treatment of stormwater runoff from the entire Pier B project site.

One of the tasks for the RFP development team was assembling an accurate design and construction schedule for the project. Because Drydock 6 is unique on the West Coast and essential to carrier maintenance, the Navy maintains a schedule for the use of the dry dock many years in advance. For instance, at the time the RFP was being developed, a carrier had already been scheduled to be moored to the completed Pier B for completion of its maintenance after it left Drydock 6. Therefore, an accurate design and construction schedule was critical for the Pier B project.

The complexity of the three structures, the limited in-water construction periods available for pile and sheet pile installation due to endangered species, and the complex permitting process made it clear that the Navy would have to begin the permitting process prior to the D/B team beginning design. This posed the challenge of identifying the environmental impact of the structures necessary for the permits, before they were identified and designed by the D/B team. While Pier B was clearly defined to be a concrete pile-supported structure, the in-water structure of Quaywall 729 and the Mole Quaywall was less certain. If the permitting process didn't begin well in advance of awarding the D/B contact or was delayed during processing, and the construction start date was delayed, there was a high potential that the new Pier B would not be ready to support scheduled carrier maintenance operations.

To this end, the RFP development team investigated critical path items in the schedule to determine ways to reduce construction time, as well as methods to quickly start the permitting process. The RFP construction schedule was developed based on conceptual structural designs and the logical order of how the structures would be built. For this project, Quaywall 729 at the head of Pier B and the Mole Quaywall would need to be constructed prior to construction of Pier B because Pier B blocks waterside access to both quaywall structures. With the restrictions to the footprint of Quaywall 729, the conceptual design indicated that a limited depth, heavy steel sheet pile wall section would be necessary to encase the existing concrete sheet pile wall of the quaywall and provide vertical support for the new structure and vaults above. The quantity and size associated with typical sheet pile sections meeting these requirements typically have long lead times, which presented a significant schedule risk.

Because of this risk, the Navy and the RFP development team determined that a prescriptive design of the Quaywall 729 substructure and the Mole Quaywall would enable the D/B contractor to order long lead materials and begin shop drawing and work plan development immediately after award. By prescriptively designing the Quaywall 729 substructure, the D/B team would know the limiting loads of the substructure and have the capability of immediately designing the superstructure, including the large utility vaults and other utility supporting elements at contract award. Also, with the final design of these two structures provided in the RFP package as prescriptive elements, in conjunction with the typical performance elements, the permitting schedule would be shortened and chances of delays in permitting reduced.

Once the substructure design of Quaywall 729 had been identified as a potential candidate for removal from the D/B contract, other benefits of removal began to materialize. The RFP development team had been concerned with the complexity of interfacing with the existing quaywall and the potential for discovering unknown conditions during construction. In particular, the large number of timber piles that would need to remain in place and functional while constructing the new Quaywall 729 structure. This added risk for all parties. To be awarded the contract, the D/B team would have to have the winning bid based on their preliminary concepts for the structures and assigned prices. Developing and pricing a concept for Quaywall 729 would be particularly challenging because the new design would depend on the condition of the existing structure. Ideally, in a D/B project the RFP should identify the existing condition or state that the condition of a given element is unknown. If the RFP stated a known condition, then the Navy might be liable if the condition differed. Alternatively, if the RFP said that the condition was unknown, then the D/B team would have to either (1) develop a very conservative design with a high cost and risk not winning the project, or (2) assume the quaywall was is in good condition, bid the job, and risk being incorrect

The Navy would choose the D/B team based largely on cost and, therefore, probably select a team that assumed the condition of the quaywall was good. If so, the project would progress smoothly for the Navy and the D/B team. If not, the project could be exposed to delay and the Navy to costly project changes or requests for equitable adjustments. However, if the design of the Quaywall 729 substructure were removed from the design portion of the D/B project, then some risk could be reduced or eliminated. The D/B team would no longer have to try to ascertain the condition of Quaywall 729 during the bidding process, and the risk to the Navy would be reduced because the designers (RFP development team) would have more time to investigate the existing conditions and develop an appropriate replacement structure. In addition, permitting risk to the Navy would be reduced because designers from the RFP development team working for the Navy could present a definitive nearshore structure replacement to the permitting agencies and stakeholders.

QUAYWALL 729 HISTORY

Built in 1922, Quaywall 729 serves as a deep-water bulkhead for 580 feet (177 meters) of shoreline. Originally constructed offshore, the quay structure acts as an abutment to retain the fill placed between the quay and the existing shore, allowing the Shipyard to expand out to the deep water necessary for berthing large ships. The average mud line depth is 36 feet (11 meters) below the top of the quay deck. In construction of the quay, closely spaced plumb and batter timber piles were driven into the native beach and timber pile caps were used to interlock the tops of all the piles. The timber pile caps were unique because they were not directly on top of the piles, but rather bolted to the side of piles and only functioned during the construction of the quay. The tops of the timber piles and the pile caps were roughly 16 feet (5 meters) below the final quay deck. With the timber piles framed together with the pile caps, concrete sheet piles were jetted into the native soil along the outboard face of the quay and bolted back at the top to the timber pile caps, relying on the timber batter piles for lateral restraint. A photo of the timber substructure of the original Quaywall 729 in construction is shown in Figure 2.

Figure 2. Original quaywall in construction, 1922.

With the concrete sheet pile wall restrained at the top, fill material was placed behind the sheet piles until it was level with the top of the timber pile caps. Then, using this fill as a working surface, a two-bay concrete portal frame, 26 feet wide by 16 feet tall (8 by 5 meters), was constructed with bents at 10 feet (3 meters) on-center, matching the timber pile caps. Over the closely spaced batter piles, a continuous concrete counterfort wall was constructed, and a deck was cast atop the portal frame. As noted previously, the timber piles extended through the timber pile caps, allowing the piles to be cast directly into the concrete pile caps and the base of the counterfort wall. In addition, the top of the concrete sheet piles were encased in a continuous concrete pile cap. A photo of the concrete portal frame, counterfort wall, and deck is shown in Figure 3. Once the counterfort wall was finished, more fill material was placed behind it to bring the ground level with the deck of the portal frame.

Shortly after construction of the concrete portal frame and counterfort wall, the fill material that brought the surface up to the top of the timber piles had settled, exposing the top of the timber piles. To correct this, additional fill material was sluiced in from the open waterside of the portal frame to bury the timber piles and the lower portions of the concrete pile caps. Keeping the timbers buried was critical to maintain the life of the structure because the timber piles, which were untreated, support the quaywall structure, both vertically and laterally. Exposure to the marine environment would allow aerobic conditions to develop and result in conditions conducive to the quick deterioration of the timbers. (Similar quay structures, such as the Alaskan Way Seawall in Seattle, Washington, have suffered deterioration due to aerobic conditions surrounding the structures' timber support, resulting in reduced capacity to resist seismic forces.) After placing the fill, many of the timber piles were still only about 1 foot (300 millimeters) below the ground surface, a questionable amount for avoiding aerobic conditions. When the RFP development team began considering how to replace Quaywall 729, the condition of the timber piles was unknown.

Figure 3. Original quaywall in construction, 1922.

QUAYWALL 729 SUBSTRUCTURE DESIGN

While there were concerns about the existing condition of the quaywall structure timber support piles, another existing problem was that the quaywall was not designed to modern seismic design criteria. Although the structure may not represent an extreme life-safety risk, primary utilities critical for shipyard functions are located directly behind the existing quaywall.

As the RFP package was developed, it became evident that replacing the quaywall would face some difficulties. First, because it retains soils with potential contaminants and primary base utilities as well as footings of adjacent buildings, the quaywall could not be removed before the new quaywall was built. Second, as mentioned previously, environment permits dictated that the new footprint could only extend at most a few feet past the existing footprint, within the shadow of an existing walkway cantilevered over the edge of the quaywall. It would also need to be constructed while the existing quaywall was still functional with respect to lateral support. As a result of these reasons, the RFP development team had to design a new quaywall substructure that could be constructed around and within the existing structure, taking into account known and assumed deficiencies with its integrity while not compromising its structural integrity during construction.

The new quaywall substructure framing is similar in layout to the existing quaywall, with an exterior steel sheet pile face, laterally restrained at the top by batter piles (steel pipe piles at 5 feet on-center). However, in the new structure, the batter piles act in tension, with the exterior sheet pile wall in compression. To provide the rotational restraint to the sheet pile cap, transverse pile caps at 10 feet (3 meters) on-center were extended back to the existing counterfort wall, where they are supported by plumb steel H-piles. The transverse pile caps stiffen the structure by counteracting the moments that develop between the batter piles and sheet piles and provide for a more balanced lateral load distribution between the batter piles and sheet piles. Once the pile caps are cast, the quaywall substructure is vertically and laterally stable. The concrete pile caps also provide the working surface for the D/B performance design. Figure 4 shows the new quaywall integrated with the existing quaywall.

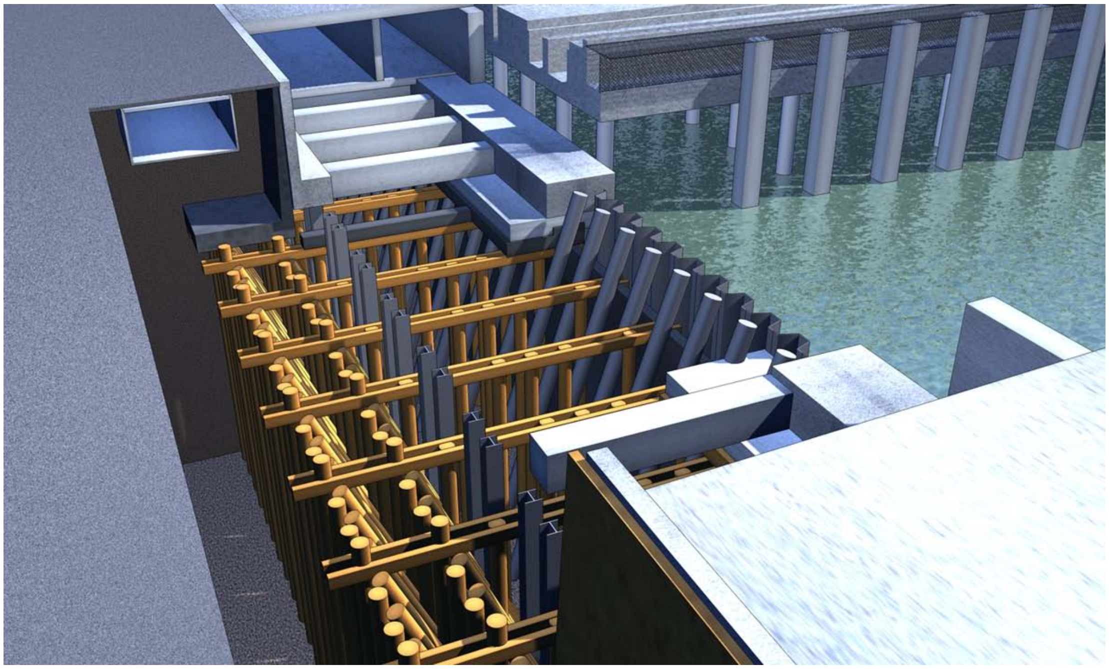

Figure 4. Quaywall 729.

To avoid the existing timber batter piles below the counterfort wall, which extend toward the water as they progress deeper, the new steel batter piles were driven within 4 feet (1,200 millimeters) of the new sheet piles. This meant that the new batter piles would need to be driven through the existing concrete pile cap. Fully demolishing the existing pile cap could have compromised the lateral restraint support of the existing concrete sheet piles — an undesirable situation, given that the steel pipe piles would be driven directly behind the compromised existing concrete sheet piles. Therefore, to maintain lateral restraint of the concrete sheet piles, two support systems were used to shore the existing pile cap before the cap was partially demolished and the new piles driven through. First, the new steel sheet pile was installed; then, the space between the new sheet and existing sheet piles was back-filled with gravel to provide a load path from the existing sheet piles into the new sheet piles. Second, a first stage pile cap was cast around and over the existing pile cap. This new pile cap contained block-outs for the new batter piles and reinforced the existing pile cap with respect to the lateral loads that the cap would transmit from the concrete sheet piles into the existing transverse concrete pile caps.

CONSTRUCTION

Construction began in the spring of 2009. As expected, the D/B team refined the layout of the utility vaults in the quaywall. These changes resulted in point loads from columns on the Quaywall 729 substructure where only uniform loads had been anticipated. However, conservative member sizes in the prescriptive structure accommodated the additional reinforcing steel necessary to carry the column loads without increasing the overall dimensions of the member.

While the prescriptive and performance designs came together without major difficulties, the prescriptive reinforcing shop drawings in the locations between the designs submitted during construction within the fast-track process provided additional challenges. The first prescriptive stage of the quaywall substructure construction progressed as planned, but when construction of the performance-based portion of the structure was approaching, it was discovered that the shop drawings did not reflect the both the prescriptive and performance aspects of the submittal. In addition, the typical project changes and RFIs combined to make numerous avenues for change to the project. To combat the potential for confusion, review meetings were held well prior to major concrete pours between the Navy, the prescriptive designer (the RFP development team), and the D/B contractor. At these meetings, all parties reviewed known modifications to the base prescriptive design to ensure seamless integration between the prescriptive and performance designs. Figures 5 and 6 show Quaywall 729 under construction.

CONCLUSION

The U.S. Navy and the RFP development team successfully used a combination of both design/build and design/bid/build methods to significantly reduce overall project schedule, cost, and risk for the construction of the new aircraft carrier maintenance pier and associated structures at Puget Sound Naval Shipyard. Prescriptive design of the quaywalls ensured success during the permitting process, satisfying legacy design bid build permitting requirements, and allowed the constructor to fast-track critical in-water work elements to meet the project design build construction goals.

Figure 5. Quaywall 729 driving sheet piles, 2009.

Figure 6. Quaywall 729 stage I pile cap with pipe pile block outs, 2009.