Philadelphia Shipyard is State-of-the-Art

by Jared Loos P.E. and Pradeep Patel P.E.

After almost 200 years of operation, the Philadelphia Naval Shipyard in Pennsylvania was closed in 1996. In an effort to revitalize the site, the city and state struck a deal with Norwegian based Kvaerner ASA to construct a new, "state of the art" shipbuilding facility centered around two of the existing dry docks. When Kvaerner solicited proposals in early 1998 for the design of their first US based facility, it became clear that the schedule and magnitude of the task would require the resources of more than one firm. The firms of Ewing Cole Cherry Brott, Urban Engineers and STV Inc. joined forces to respond to the challenge and created the joint venture, Pennsylvania Shipyard Engineering & Architecture LLP (PSE&A).

Pradeep Patel, senior V.P. of Ewing Cole Cherry Brott and project director for PSE&A, managed the 100 plus person, multi-discipline and multi-firm design team that was assembled to tackle this $450 million dollar project. PSE&A was awarded the project in May of 1998 and faced the challenge of accelerating the design in order to begin construction in the fall of 1998. The goal of an operational shipbuilding facility by early 2000 was set by Kvaerner and the city of Philadelphia during their early negotiations. Due to the compressed schedule, a conventional design/bid/build process was not possible. A preliminary design and material take-off indicated that approximately 18,000 tons of structural steel would be required to construct the five building, 700,000 sq. ft. facility. Through the cooperation of Kvaerner Construction and PSE&A, steel bid documents were released in July of 1998—only two months after award of design.

The steel bid documents consisted of a matrix of steel quantities based on classifications that would allow steel fabricators to reserve and block out steel quantities for mill order. As with the design, the fabrication of 18,000 tons of structural steel in less than a year required the forces of more than one fabricator. The contract was ultimately awarded to a joint venture of Havens Steel and SMI Owen. Shawver-Price coordinated the production and review of over 14,000 structural steel shop drawings between the joint ventures.

The shipyard facility includes: five major buildings, a fabrication shop, panel shop, grand block shop, paint shop and dock shop and each building had it's own specific design challenges. The structural bay sizes and roof heights of each building were tailored to the specific function of the shipbuilding process. Column spacings were optimized to reduce the need for top and bottom flange crane girder bracing whenever possible. Jumbo steel sections were also avoided due to the tight schedule and availability of material. When readily available sections were not adequate to handle the loads, built-up sections or plate girders were used.

X-bracing and laced columns were used to provide lateral stability against wind loads and horizontal crane forces. Slip critical connections were used for X-bracing and crane bracing connections due to repetitive and cyclic loading produced by the cranes. Three dimensional Staad III models were created through a three-bay slice of each building to optimize the design. This allowed adjacent column bays to share the horizontal crane loads and produce a much more efficient design. Horizontal plan X-bracing was introduced at the bottom chord of the trusses to assist in the transfer of forces and create a stable diaphragm. Numerous load combinations were required, especially in bays where multiple cranes at various elevations were supported by common columns.

Over 8000 steel pipe piles and HP piles were used for the foundations of the five buildings and site cranes. Pile caps and pile groups were also designed for multiple load combinations including uplift due to large building heights and low dead weights. The columns and base plates were set in pockets created in the concrete slab above the pile caps to assist in the transfer of shear forces into the foundation system. Concrete slab thicknesses ranged from 17 to 21 in. to support the required 1000 psf floor loads.

W14 column sections were typically used for the laced columns. As with the roof trusses, sections that were less than 14 ft. deep were shop welded together. Due to standard shipping widths, the sections larger than 14 ft. deep received field bolted connections to reduce the amount of field welding. In some cases alternate connections were provided on the contract drawings to give the fabricator the option to bolt or weld a joint. In other cases, forces were provided and the fabricator was responsible for the final connection design within the context of some standardized details.

Thirty-two overhead bridge cranes required coordination of column spacing, crane girder spans and roof clearances. Crane girder sizes varied from W21s to 60 in. deep plate girders and trusses. The grand block

Larger spans utilized W14 chord and web members with field bolted connections to speed erection.

Site view: Panel and Fabrication shops to the far left, Grand Block shop in the center, and Paint Shop to the right. Goliath crane is also to the right, and the existing dry dock is in the foreground.

View inside Panel shop showing fabric doors, overhead trusses and bracing.

required a truss to span 120 ft. as well as supporting a 220 ton crane on its top chord and a 40 ton crane on its bottom chord. This truss became a box truss due to the horizontal bracing required to resist the lateral crane forces, and weighed in excess of 1 ton per linear foot. Compatible deflections were also a challenge where long span trusses supported cranes on one side with typical span girders on the opposite side.

The crane manufacturers required deflection criteria below L/1000 for many crane spans. Flatness and alignment criteria was also kept within 2 millimeters for certain crane runways and support brackets due to the precision required for the welding and cutting equipment. Short slotted holes and shims were utilized whenever possible to allow for adjustment in the field to achieve the desired tolerances. Cornell Inc., a NJ based steel erector, provided the erection for the main building steel as well as the "Goliath" crane, which towers over 200 ft. above the existing dry dock and has a 660 ton lifting capacity. The girders of this crane are constructed of 2 in. thick plate steel and span over 400 ft. across the dry dock and production areas.

Roof trusses spanned from 100 to over 200 ft. in the larger production bays and ranged up to 20 ft. deep at midspan. Designers used repetition in details and design where ever possible to make the design, detailing and shop drawing process more efficient. Trusses were typically constructed of WT top and bottom chords and double angle web members. The larger spans, however, utilized W14 chord and web members with field bolted connections to speed erection.

Large operable doors were provided in most of the buildings to accommodate the movement of large ship sections in and out of the structures. The largest door is over 100 ft. wide and 100 ft. high. These large openings required the roof and metal siding to be designed for internal pressures and uplift that in some cases required bracing at the bottom flanges of roof beams. The columns on each side of the large doors act as both a support member and a guide for the wheels. These largest of these columns is a 40 in. deep built-up member that required a tolerance of L/1700 in vertical plumbness. The exterior flange is also removable for the lower 15 ft. to accommodate the installation and removal of the doors. A box truss spans between the tops of the main support columns above each door to provide support for the hoist motors and horizontal stability.

Thousands of linear feet of catwalk were coordinated between column lacing and bracing to provide access to all crane runways and service areas. Mezzanine and service areas were provided between laced column bays to maximize the usable space. This required the diagonal bracing to be coordinated with the pedestrian traffic and headroom requirements.

Since all the steel would be exposed in these structures, careful attention was paid to the coating system. The schedule and size of the structures would make field painting very difficult and expensive, therefore a shop applied zinc phosphate epoxy was chosen. This one-coat epoxy was shop applied to all steel to protect it and create the desired appearance. A light blue color was chosen that would compliment the corporate "Kvaerner Blue." Galvanized A-325 bolts were also used to reduce the amount of field touch up paint required. Since all connections would be architecturally exposed, careful attention was put into their design.

The exterior façade is a combination of split faced cmu and prefinished metal panels. The metal panels are a "sandwich" type construction with an insulated liner panel. These panels typically span 9'-0 between W16 and W18 girts spanning between the exterior columns. A translucent panel was also added below the truss level to provide natural light in the buildings.

The end result is a "state of the art" facility that coordinated 18,000 tons of exposed steel with hundreds of pieces of foreign and domestic equipment. "Although most design elements were dictated by the shipbuilding process and the equipment, the facility is ultimately impressive due to massive size of the buildings and the quantity of exposed structure," says Perseus Deputy, project architect with Ewing Cole Cherry Brott.

The exterior of the grand block is clad with cmu and prefinished metal panels.

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Structural Engineers & Architects:
Pennsylvania Shipyard Engineering & Architecture LLP (a joint venture of Ewing Cole Cherry Brott, Urban Engineers and STV Inc.)

Owner:
Kvaerner ASA

Steel Fabricator and Detailer:
Havens Steel and SMI Owen (a joint venture)

Software:
STAAD