UNIQUE
CABLE-STAY SYSTEM CREATES LANDMARK BRIDGE

by Wayne A. Endicott

It was supposed to be a simple renovation of the historic Waldo-Hancock suspension bridge over the Penobscot River. But when engineers finished their inspection of the 74-year-old structure, which carries Maine's Route 1 over the waterway near Bucksport, Maine, it quickly became evident that deterioration had reached a point where the best solution was to replace the bridge with an entirely new structure.

The requisite urgency of bringing a new bridge on line in the shortest possible time led the state to request proposals from design-build engineers. Figg Engineering Group (FIGG) of Tallahassee, Florida, rose to the challenge by designing a bridge with a unique cable-stay cradle system.

"We looked at several possibilities for the design of the bridge," says Jay Rohleder, Jr., senior vice president and project director for FIGG. "Eventually, we determined that the cable-stay option provided several key benefits. First, it would best fit the character of this historic area. Second, it would provide the most cost-effective solution to replacing the existing bridge. Third, it would be the fastest way to restore traffic to this important transportation corridor." The bridge, in fact, was completed in just 30 months from the time that the design was started.

profile **PENOBSCOT NARROWS BRIDGE** / WALDO & HANCOCK COUNTIES, MAINE

ENGINEER OF RECORD/CONSTRUCTION ENGINEERING AND INSPECTION Figg Engineering Group, Tallahassee, Fla.

PRIME CONTRACTOR Cianbro Corp./Reed & Reed, a joint venture, Bucksport, Maine

CONCRETE SUPPLIER Sunrise Materials, Division of Lane Construction Corp., Orono, Maine

PRECASTER Strescon Limited, Saint John, New Brunswick, Canada (precast pylon panels)

CABLE-STAY SYSTEM & POST-TENSIONING SUPPLIER Dywidag-Systems International USA Inc., Bolingbrook, Ill.

REINFORCING STEEL FABRICATOR Harris Rebar Boston Inc., Rochester, Mass.

Cradle system permits the continuous use of stay cables from bridge deck to bridge deck.

The main span of the bridge was completed on September 14, 2006, with the casting of a closure that joined the two balanced cantilevers at the center of the bridge.

As the team worked on the design, requests for bids were sent to several contractors. FIGG's engineers participated in contractor-candidate interviews led by the Maine Department of Transportation (MDOT) with support from the Federal Highway Administration. Ultimately, a joint venture of Cianbro Corp. in Pittsfield, Maine, and Reed & Reed of Woolwich, Maine, was selected, and they joined the team.

The construction joint venture and designer had independent contracts with MDOT, explains Rohleder, but they united to create a mission statement for the project and then worked as partners with the state agency. This unique "owner-facilitated" design-build arrangement resulted in a bridge that was both beautiful and innovative.

Community Input Was Vital

A major consideration for the design/build team was the natural desire of residents in the surrounding area to maintain the original appearance of the three-quarter-century-old existing structure. The bridge had not only provided access for commercial traffic for area businesses, such as paper mills, granite quarries, and boat constructors, but it also provided access for tourists to Maine's scenic coast. As a result, a Public Advisory Committee was formed so members of the community could provide input.

In addition, the public participated in community workshops, where they asked that the bridge design revolve around a theme of granite, which is quarried locally, and that the new structure use simple and elegant shapes.

A major challenge in gaining the public's approval was the height of the pylons needed to support the cable-stay system on the 1161-ft-long main span of the 2120-ft-long bridge. To allay their concerns, the design team made two major decisions. First, the 420-ft-tall towers were designed with an obelisk shape as viewed from the adjacent Fort Knox State Park, reminiscent of structures such as the Washington Monument, a well recognized structure that used the local granite. They also decided that one of the pylons would serve not only as a support but would

Lower pylon structures were cast in 15-ft lifts. Construction-lift articulations replicate an impression of large granite blocks to complement the actual granite at the entrance to the pylon observatory.

CAST-IN-PLACE CONCRETE, SEGMENTAL CABLE-STAYED BRIDGE/MAINE DOT, OWNER

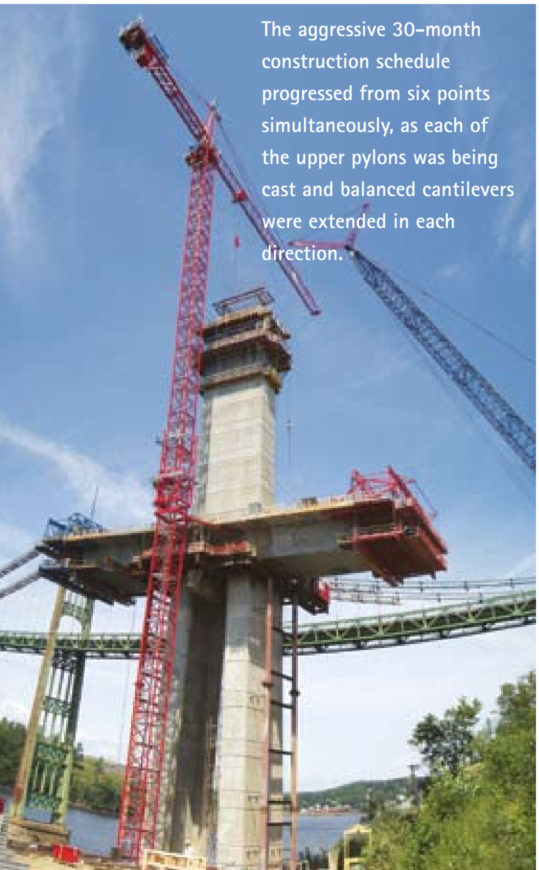
BRIDGE DESCRIPTION 2120-ft-long cast-in-place, cable-stayed concrete bridge with 1161 ft main span. The stay cables are arranged in pairs in the pylons but transition to a single vertical plane of cables at the bridge deck level. One pylon houses a multi-story observatory that is accessed by an elevator in the core of the pylon. The bridge was designed and constructed in less than 40 months, with a unique owner-facilitated design/build process. The cable-stay system uses a recently patented cradle system, pressurized inert gas, and pressure monitoring system to provide low maintenance over the 100-year plus service life of this concrete bridge.

BRIDGE CONSTRUCTION COST $68 million contain a multi-level glass-enclosed observation deck that provides 360-degree scenic views, providing a landmark destination.

Foundation design began even before the contracting team was chosen, in an effort to speed construction. The design team, which had provided the design for Florida's monumental cable-stayed Sunshine Skyway Bridge more than two decades earlier, suggested that a similar design would provide an aesthetically pleasing solution here. The cable-stay structure also would require no pylons in the water, providing clear passage to river traffic.

Patented System Created

Although cable-stayed bridges are not a new concept, the design team proposed the use of a patented cable-stay system designed by FIGG that permits the use of a continuous stay cable from bridge deck through the pylon and back to the bridge deck. The system carries the stay cable through a stainless-steel sleeve, creating a continuous cable and eliminating the need for anchorages in the pylon. This in turn reduces forces in the pylon while allowing more streamlined pylon dimensions. The number of epoxy-coated 0.6-in.-diameter strands in each stay cable varies from 41 to 73.



The aggressive 30-month construction schedule progressed from six points simultaneously, as each of the upper pylons was being cast and balanced cantilevers were extended in each direction.

Two of the cradles positioned within the pylon are shown prior to casting. The 20 cradles in each of the pylons carry the strands (from 41 to 73 per stay) through the pylon, eliminating the need for anchorages within the pylon.

The innovative nitrogen gas protection and monitoring system creates an enclosed environment of pressurized inert gas surrounding each cable stay.

Individual sleeves protect the strands of each stay cable by eliminating strand-to-strand contact. The concept of cradle saddles is not new, notes Rohleder, but in the past, they have created a "bundling" effect caused by the top strands squeezing the lower strands as cables got larger, reducing their ability to withstand impact. In the new Penobscot Narrows Bridge, each strand has its own pipe, eliminating this concern. Another impressive benefit of the system is that at any time, it will be simple to inspect, and, if necessary, pull out and replace an individual strand. This ability is expected to extend the bridge's life, which is predicted to be at least 100 years, says Rohleder.

This ability to inspect, and if necessary, replace strands, provides a major advantage, he says. In the existing bridge, cables were encased in a wrapped system that not only retained moisture but made inspection difficult at best. With the new system, inspectors can actually perform their task inside the bridge superstructure.

Monitoring System Provided

Designers also included an innovative nitrogen gas protection and monitoring system, which creates an enclosed environment of pressurized inert gas surrounding each stay cable. The system includes nitrogen gas, HDPE sheathing, reservoir tanks, anchorage sealing caps, and monitoring hardware. After each stay was installed, it was completely purged of moisture by injecting the nitrogen gas. The nitrogen gas, under 2 psi pressure, is maintained in a reservoir and sealed at each anchorage through the use of a sealing cap that contains a clear end plate. This allows a visual inspection of the anchor area. The gas reservoir within each stay will automatically recharge the gas if there is a drop in pressure. A gauge within the system will record any fluctuations in pressure, allowing MDOT to monitor the system's status and take necessary corrective action.

The bridge's pylons are 14 ft wide. The pylon containing the elevator and observatory sits atop an 80 by 70 ft spread footing that is 16 ft deep. The other pylon rests atop 288 steel piles driven to a depth of 16 ft. The cast-in-place pylons were jump-formed in 15.5 ft lifts. As each segment was completed, steel imbeds for a sole plate were included, and the cradles for the stay cables, some weighing as much as 8500 lb, were hoisted into place and the pylon segment finished.

This rendering of the Waldo-Hancock bridge over the Penobscot River shows its close proximity to historic Fort Knox, a contributing factor in the final design.

Taking Things For Granite

The new Penobscot Narrows Bridge & Observatory traverses the Penobscot River in one of Maine's most scenic areas. It is also historic, located in close proximity to Fort Knox, Maine's oldest historic fort.

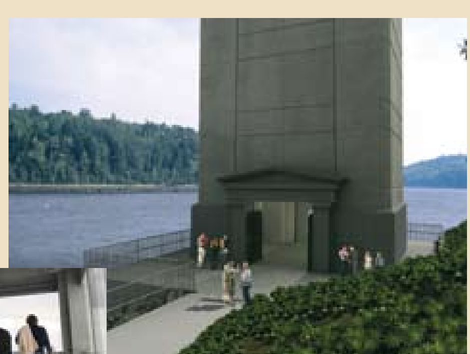
The fort, named for Major General Henry Knox, who served as the first Secretary of War and commanded the artillery during the American Revolution, was built between 1844 and 1864 and was constructed of granite. Granite quarries also dot the Maine countryside nearby. To tie the new bridge to the area, the designers used form liners and a sandblast finish to blend with the granite look.

The 15-ft-tall forms incorporated a transverse articulation at the seams, forming a band around the pylons to hide form lines between cast segments. The surface then gives the impression of large blocks that complement the granite slabs installed around the base of the pylons.

"There is a granite outcropping very near the bridge," notes Jay Rohleder, Jr. "The design was developed to celebrate granite and be in harmony with the site." The effect is further heightened by the pylons' obelisk shape, which recalls the Washington Monument and its construction from granite quarried in Maine.

Visitors to the fort will be able to take a footpath to the bridge to access the base of the pylon, then take an elevator to the observatory at the top of the pylon. Also at the entrance to the bridge is a plaque that explains the historic significance of the area and the bridge to visitors. It is estimated that the bridge will carry up to 18,000 vehicles per day, many of them tourists.

Entrance to the observatory elevator, framed in local granite, and the observation deck atop the pylon at 420 ft above the Penobscot River. The observatory will provide 360-degree views of the scenic and historic area.



After the cradles were in place, crews ran strands between the deck and pylon and back to the deck on the opposite side of the pylon. The stays were then stressed at the anchors inside the superstructure box girder. Each strand's stress is matched to the first strand, which is stressed higher than necessary because its stress decreases as additional strands are added. Total design force for stressing is between 1000 and 1900 kips per stay.

The bridge deck itself is a cast-in-place segmental box girder 12-ft 10-in. deep. It was cast using form travelers. Segments were cast in 10- and 12-ft lengths. The casting took place as part of a cycle, with one cycle consisting of casting two main span segments, two back segments, and installing a stay.

The schedule called for a cycle to be completed every 12 days. Early on, Rohleder says, the cycle was taking as long as 16 days. Later, the addition of a small crew at night to handle critical activities brought the process down to the preferred 12-day cycle. Eventually, the process was reduced to just 10 days for casting of the four segments and the stay installation.

The concrete is post-tensioned transversely in the bridge deck and longitudinally through the box girder as part of the overall bridge system.

Final cost of the project was $84 million that includes $68 million for the bridge itself. The remainder of the cost included the installation of the observation deck and elevator, as well as access roads and a parking area for visitors. FIGG estimates that the unique cable-stay system cut as much as $4 million from the final cost due to the elimination of the need for conventional anchorages.

The long-term maintenance benefits of the concrete cable-stayed design will provide Maine with reduced life-cycle costs over its estimated 100-year life span.

For more information on this or other projects, visit www.aspirebridge.org.