PROJECT

Sarah Mildred Long Bridge

The movable midspan, elevated clearance, and reduced number of piers of this replacement bridge over the Piscataqua River improve marine navigation

by Jeffrey S. Folsom, Maine Department of Transportation

Built in 1940, the original Maine–New Hampshire Bridge spanning the Piscataqua River between Portsmouth, N.H., and Kittery, Me., served as the critical backup route between Maine and New Hampshire if traffic were disrupted on the Interstate 95 Bridge upstream. In 1987, the Maine–New Hampshire Bridge was renamed to honor Sarah Mildred Long, an employee of the Maine–New Hampshire Interstate Bridge Authority for 50 years.

Three decades later, on March 30, 2018, a replacement bridge, also named for Long, opened. Its innovative design would have made her proud. The previous structure had five main truss spans, including the vertical lift span, along with 15 roadway spans on the Portsmouth side and seven on the Kittery side. The new Sarah Mildred Long Bridge has twin segmental-concrete approach spans in a stacked configuration leading to a single-deck hybrid movable span at its center.

The new structure's design, which provides a unique concept for a segmental bridge, improves the skew angle and width of the navigation span as well as safety and efficiency for vehicles, rail lines, and maritime vessels. With the new bridge, maritime vessels can navigate the Piscataqua River while the upper segmental-approach superstructure carries U.S. Route 1A (Bypass) and the lower segmental superstructure connects Pan Am Railways, a railroad system for the Northeastern United States, to the Portsmouth Naval Shipyard. The movable hybrid span rises to allow passage of tall vessels and lowers to railroad-track level for trains to cross, remaining at the vehicle level in its resting position. The Portsmouth, Me., approach spans extend over Market Street and the Pan

The new Sarah Mildred Long Bridge between Maine and New Hampshire over the Piscataqua River features twin segmental-concrete approach spans in a stacked configuration leading to a single-deck, hybrid movable span at the bridge's center. Photo: FIGG Engineering Group.

profile

SARAH MILDRED LONG BRIDGE / PORTSMOUTH, NEW HAMPSHIRE, AND KITTERY, MAINE

BRIDGE DESIGN ENGINEERS: FIGG Bridge Engineers, Tallahassee, Fla., and Hardesty & Hanover, New York, N.Y., a joint venture

PRIME CONTRACTOR: Cianbro, Pittsfield, Me.

POST-TENSIONING CONTRACTORS: GZA GeoEnvironmental, Boston, Mass.; Sebago Technics, Portland, Me.

Am Railways' Newington Branch railroad tracks. The Kittery approach spans cross Bridge Street.

Selection of a segmental concrete solution helped project leaders achieve many of their goals for the bridge. It allowed them to fine-tune both horizontal and vertical alignments to improve the navigation span, meeting geometric standards related to both railroad and vehicular traffic, and it minimized the impact of the project on the environment, historic and archaeological sites, and nearby properties. The use of concrete also offered a context-sensitive, aesthetically pleasing solution.

Throughout the design process, the team gained insight from extensive public involvement and government agency outreach to the community, regulatory interests, and ship pilots. This input helped guide designers and contractors to a design that meets all of the project goals while creating a striking design with a unique lift concept that can serve as a template for future projects of this type. Details of the design and construction of the lift tower foundation can be found in a Concrete Bridge Technology article on page 34 of this issue.

Project Partners, Funding, and Vendors

The replacement bridge project was a partnership among the Federal Highway Administration, the Maine Department of Transportation (MaineDOT), and the New Hampshire Department of Transportation, with MaineDOT serving as the lead agency. Funding for the $165 million project was aided by a $25 million Transportation Investment Generating Economic Recovery (TIGER) grant for the railway portions. The project was the second in a "Three Bridge Agreement" between Maine and New Hampshire to address their jointly owned bridges spanning the Piscataqua River.

The new bridge was designed by a joint venture of the specialty bridge design firms FIGG Bridge Engineers and Hardesty & Hanover, and it was delivered through a new construction manager/general contractor method, in which a construction manager (Cianbro Corporation), chosen through an RFP process, was an active participant in the design process.

Design work began in late 2012. Early on, Cianbro provided constructability reviews and input on scheduling parameters, cost elements, and other factors. The goal was for the construction manager to provide a reality check on the constructability and economy of the design as it evolved.

When Cianbro became construction manager, the owners and Cianbro negotiated a construction contract, with the intent that if they could agree on a price, Cianbro would also be the general contractor. If no agreement were reached, the owners would advertise for competitive bids. Cianbro prepared cost estimates at 30%, 60%, and 100% design plan reviews. The estimate prepared at 100% was the basis of negotiation. The final pricing and negotiations resulted in a few plan and specification changes that were incorporated into one final released-for-construction set of contract documents. It was at that point that a construction contract was signed and Cianbro became the general contractor. Construction commenced in late 2014.

Improving Maritime Clearance and Accessibility

Clearance and accessibility for maritime vessels were among the primary concerns tackled by the design team. The original bridge offered just 10 ft of clearance in the closed position, which meant that bridge openings were frequently required so maritime traffic could pass. In 2008, the bridge opened 2637 times, with an average traffic delay of 9.5 minutes per opening. The new bridge offers 56 ft of vertical clearance in its resting position. As a result of the increased vertical clearance, 68% fewer openings will be required with the new structure. The bridge can remain at its resting position, the vehicle level, almost all of time because only 10 trains typically use the lower-level tracks each year.

The previous bridge provided only 175 ft of useable width for maritime traffic, forcing tugboats to disengage from larger ships before passing through the span. To improve accessibility for ships approaching the open span, a new alignment was created that provides a 15-degree skewed crossing to the bridge (the original crossing skew was 25 degrees). The alignment change increases useable width to 250 ft.

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The larger opening was achieved with a 4770 ft reverse curve on the approach bridge on the New Hampshire side and a 5200 ft radius curve on the Maine side, which connects back into the existing alignment. This design allows the next generation of cargo vessels to pass through the span with tugboats engaged.

Span Design

The new bridge features 11 upper vehicle spans: 160-270-270-320-320-35 (tower span)-300 (lift span)-35 (tower

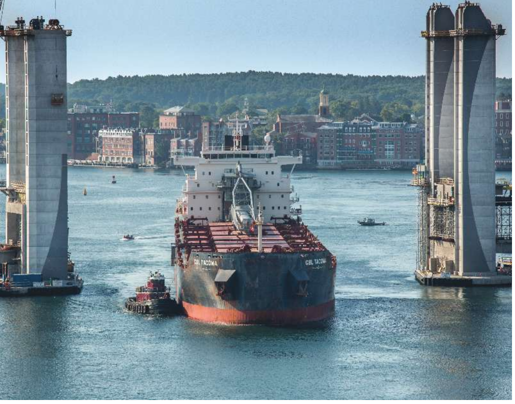
MAINE DEPARTMENT OF TRANSPORTATION AND NEW HAMPSHIRE DEPARTMENT OF TRANSPORTATION, OWNERS

BRIDGE DESCRIPTION: 1990-ft-long bridge with twin segmental-concrete approach spans in a stacked configuration leading to a single-deck, hybrid movable span at the bridge's center. The lift span is supported by four 200-ft-high precast concrete towers at the span's corners.

STRUCTURAL COMPONENTS: 229 precast concrete segments in 11 upper vehicle spans: 160-270-270-320-320-35 (tower span)-300 (lift span)-35 (tower span)-200-320-200 ft; and 126 precast concrete segments in 16 lower railway spans: 60-100-160-160-160-160-135-65-35 (tower span)-300 (lift span)-35 (tower span)-65-135-160-160-100 ft. Each tower consists of 21 precast concrete match-cast segments.

BRIDGE CONSTRUCTION COST: $165 million

AWARDS: 2018 International Bridge Conference Special Award of Merit; 2018 *Roads and Bridges Magazine* Top Ten Bridges



A ship passing through the movable span during construction shows the added width for maritime traffic and the size of ship that needs to be accommodated. Photo: Maine Department of Transportation.

A new alignment was created for the replacement bridge, reducing the crossing skew to 15 degrees for approaching ships. Photo: Maine Department of Transportation.

The upper vehicular spans feature precast concrete segmental box girders with depths varying between 8 and 13.5 ft and base widths varying from 15 to 16.75 ft. Photo: Maine Department of Transportation.

span)-200-320-200 ft. The lower railway level consists of 16 spans: 60-100-160-160-160-160-135-65-35 (tower span)-300 (lift span)-35 (tower span)-65-135-160-160-100 ft. Many of the railway level's span lengths are approximately half the length of the vehicle level to accommodate the heavier (Cooper E80) required live load. The goal was to maximize span lengths on each level to reduce the number of piers in the waterway.

The 160 ft length for the railway spans is significant for a segmental bridge and allowed for only an intermediate monoshaft pier to be used at the midspans of the upper level's 320 ft lengths. As a result, 11 fewer piers were needed in the waterway, and an existing median pier on Market Street was eliminated, improving the gateway span leading into downtown Portsmouth.

The upper vehicular spans feature precast concrete segmental box girders with depths varying between 8 and 13.5 ft and base widths varying from 15 to 16.75 ft. The lower railway spans consist of precast concrete segmental girders varying in height from 9 to 11 ft, with top flanges of 19 ft and base widths varying from 11.33 to 12 ft. The single-level lift-span deck is 42 ft 7 in. wide, with two lanes separated by a 5-ft 7-in.-wide median that contains the railroad tracks.

Each lift tower consists of 21 precast concrete segments cast at the project site using match-casting procedures. Photo: Maine Department of Transportation.

Modified Tower Drive System

Several options were considered for the drive system to operate the central 300-ft-long streamlined box-girder lift span. Typically, two options are available. With a span drive, the machinery is located on the span, raising and lowering itself with the span. With a tower drive, the machinery, located at the tops of the towers, raises or lowers the span. For this project, a hybrid design provided the best of both worlds.

The operating equipment is located at the base of the four 200-ft-tall precast concrete towers, on each corner of the span. The machinery was placed at the bases, providing easy access for maintenance and inspection. Similar to a span drive, the equipment uses uphaul and downhaul ropes to physically pull the span up and down and does not rely on the friction of the counterweight sheave to move the span. As with a tower drive, the equipment is enclosed within the towers, including mechanicals, wiring, and even the maintenance stairway. The counterweights were built with steel plates inside a steel box. Steel was selected after evaluating it against other options, such as lead, to determine the cost-benefit ratios and compare densities to the total heights of the materials that would be needed. The towers feature glass windows that provide ambient lighting for maintenance crews and also allow drivers to see the counterweights moving when the span is raised and lowered.

The lift span features guide rollers that run on plates attached to the towers to maintain the transverse and longitudinal position of the span as it is raised and lowered. The span joins at the primary (vehicle) resting level with a standard finger joint. Openings allow the tower rails to pass through the span and continue down to the railroad level. At that point, a plate with mitered rails connects to the tracks. It was challenging to detail this configuration because joints usually are not designed to have tracks pass through them and continue below.

Cost Efficiency of Precast Concrete Towers

Precast concrete was chosen for the towers after all possibilities were evaluated. This option was most efficient and cost effective because all the equipment and setup needed for erection, post-tensioning, and epoxy joining for the tower segments were already on site for the precast concrete segmental superstructure.

Each tower consists of 21 precast concrete match-cast segments. Tower segments were cast at the project site using standard segmental concrete match-casting procedures. Forms were stripped from wet-cast segments and moved into place to serve as a match-cast segment. After the first three segments were erected and adjusted to the proper line and grade, a 3 ft starter segment was cast below to establish the baseline erection geometry. This was necessary to begin erection of the tower segments. The match-cast precast concrete tower segments needed to be placed on top of the cast-in-place footing. To ensure the correct starting geometry, the segments were erected on temporary supports and properly adjusted, with a short closure pour between the precast concrete tower segments and the cast-in-place footing. Erection geometry was monitored and adjusted as necessary to maintain erection tolerances. The towers were capped with a precast concrete tower cap with cast-in-place concrete topping.

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AESTHETICS **COMMENTARY**

by Frederick Gottemoeller

The Sarah Mildred Long Bridge is an impressive bridge that meets a set of complex functional requirements while achieving a high level of visual quality suitable for its location within an area that encompasses two historic cities and an attractive natural setting. Meeting both the functional and aesthetic requirements of the project within a reasonable budget required innovation in layout, design, contracting arrangements, and construction. That the design, construction, and client team was able to meet all of these requirements so successfully is a credit to all involved.

Projects with this kind of functional complexity often have a corresponding and unattractive visual complexity. The old bridge was an example of that type of design. On the new bridge, concrete segmental construction offered a solution to the aesthetic challenges. On the spans, it allowed for fewer piers and simplified the appearance of the girders. On the towers, it eliminated the usual cross bracing and concealed the lifting equipment. At the same time, the haunched girders, which are deeper at the piers where the forces are the greatest, and the solid towers, rising from a massive base, provide an impression of great strength. This impression is reinforced by the simple but robust modulation of the concrete piers.

There is also a kind of delicacy at the tops of the towers, which taper to reveal the counterweight sheaves. Because the sheaves are a visual feature, the design conveys that the bridge is meant to move. The sheaves are round, and things that are round rotate. Why else would they rotate but to lift the center span? Finally, the vertical strips of tower windows that show the counterweights moving are visual compensation to drivers stuck in the traffic backup as a ship or train passes through the crossing. Sarah Mildred Long would indeed be proud of the bridge bearing her name.