PROJECT

Pearl Harbor Memorial Bridge

SIGNATURE BRIDGE REPLACES ITS AGING NAMESAKE

by Roy Merritt Jr., H.W. Lochner Inc.; Wade S. Bonzon, Figg Bridge Inc.; and John S. Dunham, Connecticut Department of Transportation

When originally constructed in 1958, the existing six-lane Pearl Harbor Memorial Bridge (locally known as the Q-Bridge) was the largest bridge along the Connecticut Turnpike and included the longest plate girder span in the United States. However, the existing bridge currently suffers from structural deficiencies and can no longer accommodate today's high-traffic volumes of over 160,000 vehicles per day, nearly four times the volume of traffic it was originally designed to serve. As a result, a new bridge was needed and planning for its replacement was initiated by the Connecticut Department of Transportation (ConnDOT) in 1990.

The new $635 million, 10-lane Pearl Harbor Memorial Bridge is the focal point of the $2.0 billion I-95 New Haven Harbor Crossing Corridor Improvement Program, one of the largest multi-modal transportation improvement initiatives in Connecticut history. In addition to the new bridge, the program includes operational, safety, and capacity improvements to 7.2 miles of I-95, reconstruction of the adjacent I-91/I-95/Route 34 Interchange, and a new commuter rail station.

A Signature Solution

A context-sensitive design approach focusing on public input was employed, which included an architectural committee of key stakeholders. From this process, a decision was made to replace the existing bridge with a new signature bridge with a 100-year service life expectancy. The new bridge would continue to be named the Pearl Harbor Memorial Bridge, and the design team was tasked with creating a "memorial quality" structure commemorating the veterans of Pearl Harbor. The result was the final selection of a 10-lane extradosed bridge spanning New Haven Harbor.

I-95 northbound traffic traveling over the extradosed cable-stayed main-span bridge, one week after opening. Photo: Walsh/PCL JV II.

Extradosed bridges, while having an appearance similar to traditional cable-stayed bridges, behave differently and have several key distinctions. The extradosed design utilizes shorter towers and a flatter stay-cable inclination than traditional cable-stayed bridges, which results in the deck system being the primary resistance to dead and live loads.

For the New Haven Harbor crossing, the extradosed bridge design allowed for increasing the main span to improve navigation and minimize environmental impacts. The limited tower heights afforded by the extradosed design avoids impacting air traffic from Tweed-New Haven airport located east of the bridge, whereas the taller towers of a traditional cable-stay bridge would have likely infringed on FAA-required flight path clearances. The design was completed with bid packages prepared for two alternatives for the main span; a three-span concrete extradosed prestressed alternative, and steel composite extradosed alternative.

profile

PEARL HARBOR MEMORIAL BRIDGE /NEW HAVEN, CONNECTICUT

PROGRAM MANAGER: Parsons Brinkerhoff Quade & Douglas Inc., Glastonbury, Conn.

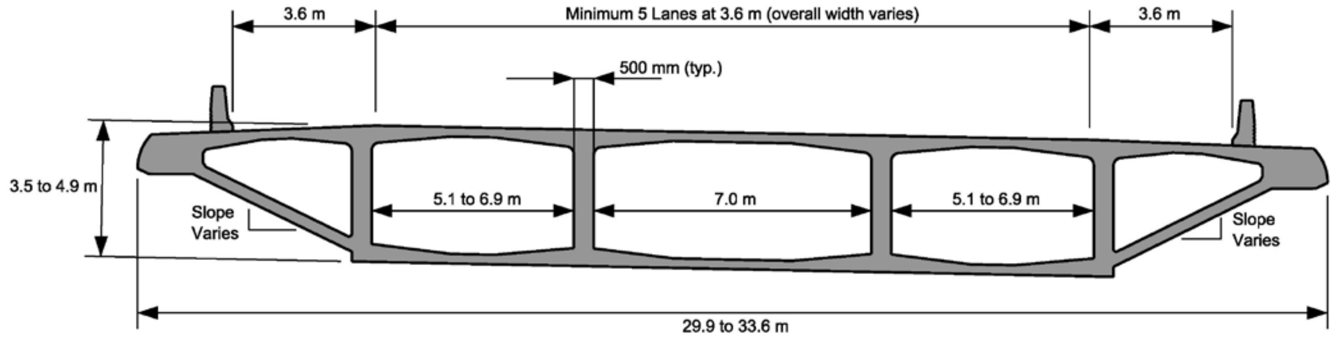
BRIDGE DESIGN ENGINEER: URS, Rocky Hill, Conn., and Tampa, Fla.

CONSTRUCTION ENGINEERING AND INSPECTION: H.W. Lochner Inc., New Haven, Conn. / Figg Bridge Inc., New Haven, Conn.

PRIME CONTRACTOR: Cianbro/Middlesex JV III and Walsh/PCL JV II, New Haven, Conn.

CONTRACTOR CONSTRUCTION ENGINEERING: McNary Bergeron & Associates, Old Saybrook, Conn.

CONCRETE SUPPLIER: The Suzio York Hill Companies, New Haven, Conn.



Typical cross section, cast-in-place segmental main span unit. Drawing: Lochner/FIGG.

The bidding process resulted in construction of the concrete extradosed prestressed concrete alternate, which began in April 2008, with construction of the northbound in-water foundations. The northbound bridge was recently completed and opened to traffic in June 2012. It is the first extradosed bridge constructed in the United States. Construction of the southbound bridge will occur following demolition of the existing bridge and is expected to be open to traffic by November 2016.

The final configuration of the bridge's harbor crossing consists of a 157-m-long (515 ft) main span with adjacent 75.85-m-long (249 ft) approach spans, providing 19.5 m (64 ft) of vertical clearance over the approximately 73-m-wide (240 ft) navigation channel. Beyond the main 308.7-m-long (1013 ft) harbor crossing, approach spans extend 484 m (1588 ft) to the west, and another 624 m (2047 ft) to the east, for an overall bridge length of 1417 m (4649 ft).

Main Span Superstructure

Segmental construction of the main span superstructure was performed utilizing the balanced-cantilever method with cast-in-place concrete segments. Concrete box segments are typically 4.36 m (14.3 ft) long, range from 29.9 to 33.6 m (98 to 110 ft) wide, and have a nominal depth of 3.5 m (11.5 ft) that increases to 5 m (16 ft) at the tower supports. Segments were constructed using high-performance concrete featuring Type III cement for high early strength, a design compressive strength of 41 MPa (6.0 ksi), and 7% silica fume to decrease permeability. The northbound and southbound concrete box-girder segments will each ultimately carry five 3.6-m-wide (12 ft) lanes of traffic, an auxiliary lane varying in width, and two 3.6-m-wide (12 ft) shoulders. During demolition of the existing bridge and construction of the southbound bridge, the northbound segments will temporarily carry three lanes of traffic in both directions.

The initial concrete segments located at the tower piers are referred to as "pier tables," and contain internal diaphragms that transfer the superstructure loads to disk bearings supported on the tower pier strut beams. The pier tables were lengthened to 15.9 m (52 ft) during construction to include the first pair of typical segments, creating additional deck area to ease installation of form travelers on both ends of the pier table. Four travelers were employed, allowing for segment construction to advance simultaneously in both directions from each tower. The 54,500 kN (12,300 kip) bearings beneath the pier tables are the world's largest disk bearings ever installed on a bridge.

Segment post-tensioning consists of longitudinal cantilever tendons, transverse deck tendons, as well as draped transverse external tendons at stay-cable locations that are deflected through the two central vertical webs of the section. ASTM A416M, Grade 1860, low-relaxation strands are utilized throughout. The four longitudinal cantilever tendons anchoring in the top slab of both the backspan and main-span segments were stressed after segments achieved a strength of 28 MPa (4 ksi), and varied in size from 17 to 27 strands. Transverse deck post-tensioning consists of four-strand tendons, typically spaced at 2.18 m (7.2 ft). The 19-strand draped transverse external tendons were provided to transfer superstructure forces to the stay-cables, and were stressed after casting the stay diaphragms and prior to installation of the stay cables.

Stay-Cable System

The northbound and southbound main span superstructures, are each carried by a series of 64 individual stay cables

CONNECTICUT DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: A three-span extradosed bridge with span lengths of 249, 515, and 249 ft built using the balanced cantilever method of construction with cast-in-place concrete segments

STRUCTURAL COMPONENTS: Twin structure each consisting of five cell cast-in-place concrete box segments, 14.3 ft long, 98 to 110 ft wide, and 11.5 ft deep supported by 64 stay cables

BRIDGE CONSTRUCTION COST: $635 million

Concrete was placed for the deck of the pier tables from pump trucks stationed on the temporary access trestle below. Photo: Lochner/FIGG.

parallel to each other in a "harp" pattern. The stays anchor in pairs to the edge beams of the cast-in-place concrete segments and to the steel anchor boxes within the tower legs.

Each stay consists of 48 individual 15.2-mm-diameter (0.6 in.), 7-wire, low-relaxation strands up to 66.5 m (218 ft) in length, each greased and encapsulated in a tightly adhered high-

Master Chief Richard Iannucci, U.S. Navy, speaks at the dedication ceremony in front of the architectural lettering at the Anchor Pier. Photo: Lochner/FIGG.

density polyethylene (HDPE) coating for corrosion protection during the strand manufacturing process. These 48 strands are, in turn, encased in a co-extruded HDPE sheathing pipe with an outer diameter of 225 mm (9 in.) that remains ungrouted during its service life.

Stay-cable strand installation was performed using the elongation method to control variations in individual strand force, and then stressed to 60% maximum ultimate tensile strength (MUTS) from within the tower anchor boxes using monostrand jacks. The 60% MUTS limit for the cable strands is higher for the extrodosed bridge design than in conventional cable-stayed bridges, which utilize an upper stress limit of 45% MUTS. Because of the geometric layout of the stay-cables and the relatively large stiffness of the box girder superstructure, the stress range and overall contribution to stay-cable force from live loads is significantly less than that of a typical cable-stayed structure, therefore justifying the use of the higher allowable cable stresses on the new extradosed bridge.

Strand stressing was typically performed in three steps. First, strands were installed and stressed individually to a force level equivalent to 15% MUTS. This low force level allowed internal "cheeseplate" type strand centering damper assemblies to be slid down the galvanized steel guide pipes near each anchorage and bolted in their final position. The second stage of tensioning was performed to approximately 50% of the final stay-cable force. A final, third stage of strand tensioning was then performed to fine-tune the strand forces to closely match the target stay force value. The adjustable anchorages were then capped and greased.

The new northbound extradosed cable-stayed, main-span bridge crosses the Quinnipiac River directly adjacent to the existing Q-Bridge. Photo: Lochner/FIGG.

Tower Piers and Anchor Piers

The main span towers and anchor piers are founded on a series of 2.44-m-diameter (8 ft) drilled shafts and capped by 3.53-m-deep (11.6 ft) rectangular footings. Each pier features three legs with heights up to 45.1 m (148.0 ft), with a horizontal strut beam supported by an intermediate column. The strut beam spans between tower legs to support the superstructure segments. Anchor piers at each end of the main-span unit feature cast-in architectural lettering with gold leaf inlay in a manner consistent with the bridge's monumental aesthetic theme. The vertical tower legs and columns have a hollow, oval shape reminiscent of the smoke stacks of a ship. The main span unit's structural scheme is unique in that stay-cables for both the northbound and southbound superstructures anchor in the shared middle leg of the tower piers.

All portions of the towers were designated as mass concrete, with a 41 MPa (6.0 ksi) mix design employed using slag cement at 75% of the total cementitious materials originally specified in order to control internal curing temperatures. The jump form

AESTHETICS COMMENTARY

by Frederick Gottemoeller

It's always exciting when a new (to the United States) bridge type arrives on the scene. The Sunshine Skyway started a period of innovation and experimentation that led, in subsequent decades, to the construction of a number of outstanding cable-stayed bridges in the United States. The Pearl Harbor Memorial Bridge will do the same.

As with the new cable-stayed bridges, a key issue will be the appropriate shape for the towers. However, the girder is also an important feature in extradosed bridges, more so than the deck of a cable-stayed bridge. Designers will have to incorporate the appropriate size and shape of the girder. Striking a good visual balance between the girder and the towers is the key to success.

The first part of the Pearl Harbor Bridge to be constructed, the northbound half, is sandwiched between the old bridge and a massive lift bridge. At this stage, it is hard to evaluate all of the facets of the design, but it is clear already that the designers have achieved a good visual relationship between the visual mass of the towers and the visual mass of the girders. The simple oval cylinders of the towers are visually strong shapes that make clear their central role in the support of the bridge. The sloped outside webs of the girders minimize their visual mass, so that they don't overwhelm the towers. Meanwhile, the slight haunch at the piers makes clear that the girders play a major role in the support of the deck.

There were additional reasons to make the towers strong, simple shapes. The towers need to hold their own against the towers of the adjacent lift bridge, against the tanks and towers of the surrounding industrial landscape, and the sheer width and length of their own bridge deck. The visual strength of their shapes allows them to assert their importance in the scene.

Finally, the exposed stay anchorages along the edges of the girder create a repetitive rhythm of smaller elements and give the bridge some details that relate its scale to its neighbors. They also make clear how the bridge works by drawing the eye to the point where loads are transferred from the girders to the stays and thence to the towers.

Extradosed bridges are now on the drawing boards and a few are under construction. It will be interesting to see how designers address this bridge type's aesthetic challenges.

system was coated with spray-on foam to insulate the surface concrete and maintain internal thermal gradients below the required 20°C (68°F). Internal concrete temperatures were monitored hourly during curing using an automated sensor system that communicated wirelessly with a dedicated internet-accessible computer.

A Grand Opening

On Friday, June 22, 2012, a ribbon cutting ceremony was held to celebrate the completion and opening of the northbound extradosed bridge. The ceremony was highlighted by a Ceremonial Veterans Wreath Dedication with four surviving veterans of the attacks on Pearl Harbor, a ceremonial ribbon cutting, and speeches from local political leaders, FHWA, and the U.S. Navy. Approximately 250 members of the public attended.

Overnight, following the ceremony, work was completed on the approach roadway temporary crossovers and the new northbound bridge opened successfully to traffic, Saturday morning, June 23, 2012.

Tower leg jump-form systems were sprayed with insulating foam to control thermal gradients during mass concrete curing. Photo: Lochner/FIGG.

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