PROJECT

PEARL HARBOR MEMORIAL BRIDGE

Stay-cable installation for the new bridge

by Wade S. Bonzon, Figg Bridge Engineers Inc.

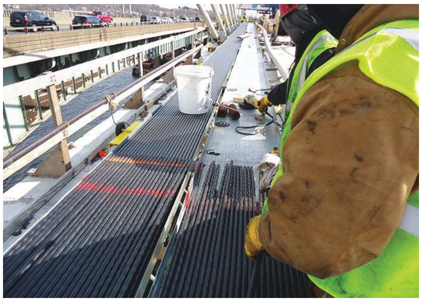
The new $635 million, 10-lane Pearl Harbor Memorial Bridge is the engineering and aesthetic highlight of the $2.0 billion, Interstate 95 (I-95) New Haven Harbor Crossing (NHHC) Corridor Improvement Program, now nearing completion in New Haven, Conn. The concrete segmental main-span unit features a 515-ft-long span over the Quinnipiac River with symmetrical back spans of 249 ft. The structure consists of twin box-girder superstructures, each supported by two planes of stay cables. Sixty-four stay cables support each girder, with the middle towers sharing cable anchorages for both box girders.

Aerial photo of the cable-stayed main span. Photo: Walsh-PCL JV II and Shoreline Aerial Photography.

To avoid Federal Aviation Administration flight path restrictions, this concrete segmental extradosed cable-stayed bridge features shorter towers than normally found on a conventional cable-stayed bridge, with correspondingly flatter stay-cable angles. In addition, the extradosed structure type allowed for a shallower section depth than a conventional box-girder superstructure, providing necessary vertical clearances for shipping traffic.

The shallow-angled stay cables apply greater load along the axis of the bridge compared to a conventional cable-stayed bridge. The structure also features a stiffer deck system than most typical cable-stayed bridges, making fatigue stresses due to live-load effects on the cables less of a concern. While the stresses in conventional stay cables are limited to 45% of the strands' minimum ultimate tensile strength (MUTS) for American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications* Service Load Combination I, the contract documents for this project specified that the extradosed cables could be stressed up to 55% of MUTS for the same load combination. Similar increases in stresses are allowed for other AASHTO load combinations.

Stripping of the stay-cable strand ends in the layout tray. Photo: FIGG Engineering Inc.



All of the stay cables are comprised of 48 individual 0.6-in.-diameter, 7-wire, low-relaxation strands, which are each greased and encapsulated in a tight fitting HDPE coating. A 9-in.-diameter, high-density polyethylene (HDPE) sheathing pipe provides the outermost layer of protection to the strands.

All stay-cable strands were stressed individually with a monostrand jack. To ensure that all strands in a stay were stressed to the same force, the elongation method was used to control strand-by-strand stressing forces. In theory, if all strands are elongated the same amount they will all carry the same force. In practice, this required careful quality control during strand preparation, installation, and stressing.

All strands needed to have their protective sheathing removed in the anchorage regions to be properly gripped by the three-part anchor wedges. The stripped length was carefully controlled so that exposed strand portions remained fully within the protective "wax box" of the anchorage, which was filled with protective grease after completion of stay stressing.

After HDPE coating removal, each strand was scored with a small v-notch reference mark in the unstressed length near each end. These reference marks were used to match elongations during stressing, so the distance between marks for each strand of the stay cable needed to be consistent to within less than +/-⅛ mm. Depending on the stay location, distances betweenreference marks varied from 114 to 221 ft.

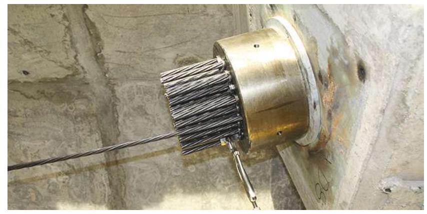
To achieve the required precision and consistency of the reference mark placements, sheet metal layout trays were set up on the bridge deck. Each tray was fabricated so that two rows of 24 strands each could be laid onto the tray snugly together, thus keeping all of the strands straight and parallel with each other in the tray. Reference marks were aligned across each row of strands using a heavy steel angle as a straightedge. Independent checks of the cut strand lengths, sheathing removal lengths, and reference mark locations were performed by the contractor and the inspector.

The sheathed sections of the strands were too wide to slide through the holes in the anchorages, so the stripped strand ends were inserted into each anchorage from the rear. This required installing strands through temporary openings in the stay pipes at deck level and at the tower entrances. Each strand was first inserted through the fixed-end anchorage at deck level and secured with a special clamping tool to keep the anchor wedge of each strand a consistent distance from the reference mark. Strands were then pushed up the length of the stay pipe to the upper access window where the strand was inserted through the matching hole in the tower anchorage and stressed using the monostrand jack. The process was repeated for each subsequent strand in a preplanned order for all 48 strands.

To maintain matching forces in each strand, the first strand was stressed to a prescribed force. When the second and all subsequent strands were stressed, each new strand was tensioned until the reference mark on the current strand physically lined up with the reference mark on the first strand. In this way, all the strand reference marks matched at the fixed-end (using the clamping tool) and at the adjustable end (by elongating until the marks aligned). This ensured that each strand was elongated the same amount.

Strand stressing was typically performed in three steps. First, all 48 strands were installed and stressed individually to a force equivalent to 15% MUTS. This allowed the internal damper assemblies to be slid down the galvanized steel guide pipes and bolted in their final position. The second

Stressing a single strand using a monostrand tensioning jack. Photo: FIGG Engineering Inc.



Fixed-end anchorage with wedge alignment clamp. Photo: FIGG Engineering Inc.

stage of tensioning was performed to approximately 50% of the final stay-cable force to monitor cantilever deflections and strand elongations for conformance with the theoretical predictions. The final stage of strand tensioning was performed to fine-tune the strand forces to closely match the target stay force value at that stage of cantilever erection. Individual strand lift-offs confirmed that all strand forces matched within a +/-2% tolerance range and that the total stay force matched the predicted force at that construction stage.

At the completion of the main span, a final round of stay-cable lift-offs were performed to confirm that all stay forces matched the theoretical forces within +/-5%, a tolerance defined in the contract specifications. The stay-stressing procedures and quality-control checks were effective: only 1 of the 128 stay cables on the project needed a force adjustment at the end of construction. This saved time on the schedule as it avoided time-consuming stay force adjustments on the project schedule's critical path.

The stay-cable installation and stressing procedures used for the new Pearl Harbor Bridge replacement project proved to be simple and robust, resulting in stays installed in conformance with the project requirements and with good construction practices. The high quality of the stay installation operation will ensure good long-term performance of a critical part of the bridge's structural system for decades to come. A

Wade S. Bonzon is a regional director in the Texas office of FIGG Bridge Engineers Inc. in Dallas.

EDITOR'S NOTE

Current practice for extradosed bridge design now limits the stay stresses at service load conditions to 60% of MUTS.