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Highway in the Sky

Welders assembling sections of stainless sheathing for cable stays on the Veterans' Glass Skyway Bridge (model shown at left).

Building bridges with welding.

By RICHARD MANDEL, senior editor

Bridges are a hot topic when American infrastructure is discussed. A 2005 "report card" issued by the American Society of Civil Engineers reported that, the percentage of the nation's 590,750 bridges rated structurally deficient or functionally obsolete decreased slightly from 28.5 percent to 27.1 percent between 2000 and 2003. That report noted that it would cost $9.4 billion a year for 20 years to eliminate all of the deficiencies on bridges across the U.S., and said that term under-investment is compounded for the long term by the lack of a federal transportation program.

There are two new bridges, however, that will open to traffic within the next 8 months.

Advanced design presents challenges

For medium length spans (those between 500 feet and 2,800 feet), cable-stayed bridges are becoming the design of choice (see sidebar, Differences between suspension and cable-stayed bridges). Such a bridge is nearing completion in Toledo, Ohio. It will carry heavy, interstate traffic across the Maumee River, to and from industries in Detroit and surrounding areas. An existing drawbridge will remain for local traffic use.

The new bridge, known as the Veterans' Glass City Skyway Bridge, was designed by the Figg Engineering Group (www.figgbridge.com) for the Ohio Department of Transportation. It is a concrete segmental bridge that features twin cable-

Preparing to weld stainless steel sheathing tubes in the warehouse using a semiautomatic welding system.

stayed main spans of 612 feet on either side of a single pylon. A cradle system, an innovation for cable stay bridges, carries the strands in the cable stays from bridge deck, up through the pylon and back to bridge deck. The cradle is made from stainless steel, as is the sheathing for the cable stays, so they can withstand the extremes of weather, the freeze and thaw cycles, in northern Ohio, and the salts used on the roads during winter. Unique welding operations had to be established to build and assemble the sheathing.

Each cable stay comprises a bundle of smaller, epoxy-coated steel strands that range from 82 strands to 156 strands. The first six stay cables, those closest to the pylon, are 18-in. in diameter, while stays seven through twenty are 20-in. in diameter. Most recent cable-stayed bridge projects used high-density polyethylene pipe to protect the strands, and the pipe is covered with tape to protect the plastic from the deteriorating effects of ultraviolet radiation. The use of stainless steel cable sheathes on the Veterans' Glass City Skyway Bridge, while more expensive, was envisioned as having a better life cycle and esthetic. It also is the first use of stainless steel sheathing in the U.S.

Constructing the sheathing

The sheathing began in lengths of 30 feet supplied by Swepco Tube Corp. in Clifton, N.J. The tube was trucked to Custom Polishing and Manufacturing Inc. in Springfield, Mo., to receive the specified brushed #4 finish in a circumferential direction. Each segment then was put into plastic bags and trucked to project site where they were stored in a warehouse until they were needed.

In the warehouse, an assembly line was set up to assemble three-segment lengths of sheathing. Backing rings were TIG welded to one end of a pipe, a collar was slipped into place to ensure roundness, then the second pipe was fitted onto the ring and TIG welded. The collar then could be removed, and a semiautomatic orbital welder, Magnatech's Pipeliner II **(www.magnatech-lp.com)**, was installed to perform the final welding from the bottom to top on one side, after which the system was moved to opposite side and the process repeated.

Manual Carballo, a Figg senior engineer who was involved with the project, explained that the automated welder was chosen because it could be steered manually with a joystick. This was an advantage because, the joints were not perfect fit, Carballo said.

Differences between suspension and cable-stayed bridges

Cable-stayed bridges require less cable and can be built out of identical, pre-cast concrete sections, so they are faster to build than suspension bridges.

A cable-stayed bridge is made of cantilevered deck segments that can be built outward from the towers that hold the cables that support the deck. The cables for a cable-stayed bridge can be fabricated separately, and brought to the construction site.

A suspension bridge is built in stages: First the towers are completed, and then steel cables are be strung across the entire length of the bridge. The cables for a suspension bridge typically are spun in place.

The deck of a cable-stayed bridge is in compression, as it pulled towards the towers, and has to be stiff against buckling at all stages of construction and use. These bridges are well balanced, so their terminal piers have little to do except to hold the ends of cables in place and balance the bridge's live loads.

The deck of a suspension bridge hangs from the suspension cables, and has to resist bending and torsion. Because the structure essentially is flexible, engineers must ensure that they can withstand the effects of traffic and wind.

For example, if there the daily flow of traffic across a bridge is to a large city on one side, the live load on the bridge can be asymmetrical. That is, it could have more traffic on one side in the morning, and more traffic on the other side in the evening. That condition produces periodic torsion, and the bridge needs to be able to resist the effects of fatigue that might result from such an alternating load.

A suspension bridge's main cables attach either to terminal piers at each end of the span, or are anchored directly to the ground beyond the piers. In the latter case, the cables often pass over the piers, which have to redirect the cable's tension. In both cases, the four anchorages of a suspension bridge are often massive constructions that are designed to withstand the tension of the four cable-ends.

Once the three segments were assembled, the 90-foot tube was moved to another station for dye and pressure testing. After testing, the pipe joints were polished to match the rest of the pipe.

The next step was to install the stays. Only 70 feet of stainless steel sheathing would be needed for the stays closest to the pylon, but the longest stay, reaching to the very top of the pylon, is more than 650 feet long. The 90-foot sections were bought from the warehouse either trimmed down, or to be further weld-assembled on the bridge deck, to cover the longer stays.

"The tricky part was that the crew had to find a part of the bridge that was straight for 600 feet, with no vertical curve, because we did not want to weld the profile of the bridge onto the pipe," said Carballo. A ventilated, portable welding shed was built on-site to protect the joint that was being welded from the elements. After each section was welded and polished to match the surrounding finish, the area was pressure washed and the welds passivated so there would be no staining over time. The weight for the shortest stay's sheathing is approximately 2,000 pounds, while the longest weighs approximately 24,000 pounds.

The first stay has been in place since summer of 2006, and has been through a few winter storms. "I haven't seen any staining on the welds, or anywhere else, for that matter," said Carballo. He also notes that, "In Toledo, there's a very good pool of ironworkers and welders, so we weren't teaching rookies how to weld stainless steel." Figg Engineering also brought in a Magnatech representative to train the weld crews how to use the Pipeliner II welding machine.

Spanning the Narrows

The second bridge that is under construction is being built over the Tacoma Narrows in Washington State at a site well known to civil engineers. On July 1, 1940, after two years of construction, a 5,939-foot-long suspension bridge linking the communities of Tacoma and Gig Harbor opened to traffic. That bridge, which became known as "Gallopin' Gertie," collapsed just four months later during a 42-mile-per-hour windstorm that flexed and twisted the bridge's deck until it snapped. Movie footage shot as the disaster took place is still shown to engineering, architecture and physics students as a cautionary example.

A replacement suspension bridge, that opened in 1950 was better designed for the high winds seen in the Tacoma Narrows, and remains in service. A new bridge, scheduled to open in a few months, is being built parallel to that second bridge to help carry traffic that has increased over the last five decades.

A company in Korea is constructing the deck of the new bridge in 46 segments. The segments are made as complete cross-sectional units, and range from 80 feet to 157 feet in length. They have an average weight of 450 tons. As each segment arrives at the bridge site, it is lifted from the carrier ship and attached to the bridge suspender cables. Four keyways then are installed in the corners of a joint face, to align the segments and to minimize shifting during assembly.

The deck was designed with a stiffening strut to

Set-up on bridge deck in Toledo, Ohio, for welding lengths of sheating together inside site-built work shack.

reduce the torsional flutter that caused the failure of the original bridge. During construction in Korea, the strut's top chord was welded to the deck to become an integral element. When a deck segment is assembled to another, the trusses are bolted together, and then longitudinal ribs are bolted together, temporarily, to hold the deck sections together.

A welding crew joins the 5/8-in. thick deck plates together with one, 73-foot, continuous transverse weld across the deck. The weld is a complete penetration joint weld, and the crew performs the task using flux core for root passes, and submerged arc for final welding. Preheat to a minimum of 100 degrees C. was done with oxy-acetylene torches on all main members that were welded.

Other than the use of ceramic backing during the welding, there are no exotic materials used. The project uses 440V power sources that are typical for heavy construction.

Four crews usually are working at one time. One crew works from each of the bridge's land anchorage points toward the center of the bridge, and two crews work from the center out toward each of the land anchorages. The area has significant annual rainfall, so tents are erected over the joints that are being worked and the uphill side of the work tents is sealed so that rainwater does not run beneath them.

Wind gusts to 70 mph have been recorded through the area during the construction, reminding crews that the winds in Tacoma Narrows are still a force to be reckoned with. While the wind gusts may increase the heart rate for a few of the construction workers, the new bridge shows no signs of being another "Gallopin' Gertie." ■

Installing the backing ring to a section of stainless sheathing.