



AESTHETIC ANCHORS

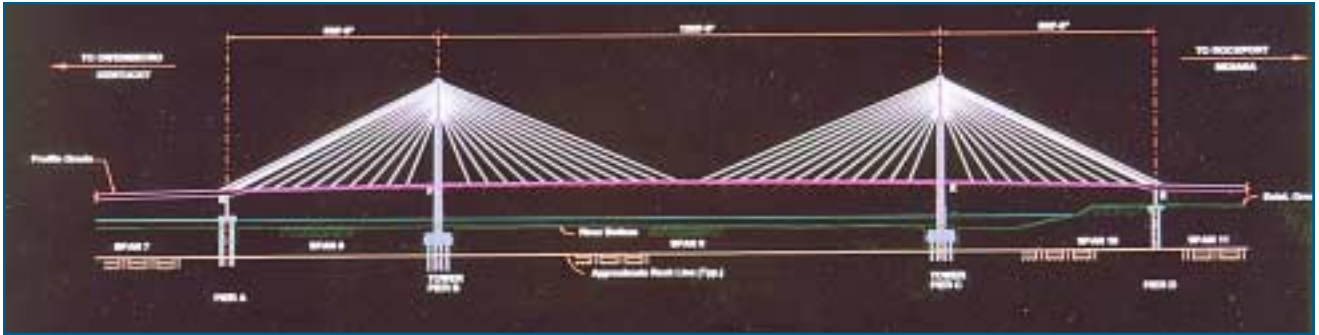
An innovative design for the anchor piers helped create an economical solution for this 1,200'-long cable stayed bridge over the Ohio River

By Steve Goodpaster, P.E.,
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WHEN COMPLETE, THE WILLIAM NATCHER BRIDGE will carry U.S. Route 231 over the Ohio River between Owensboro, KY and Rockport, IN, helping to relieve traffic congestion and open the area for more economic development. The longest cable-stayed span over the U.S. inland waterway system, this 1,200' (366 m) main span steel cable-stayed bridge was designed by Parsons Brinckerhoff for the Kentucky Transportation Cabinet (KTC).

Because of its length, the Natcher Bridge design required careful evaluation to achieve an efficient, safe and durable bridge. An innovative design resulted in a bridge that is not only cost-effective to construct but also "user-friendly" for construction contractors, inspectors and maintenance personnel.

Cable-stayed bridges are economical for span lengths of 600 feet (180 m) and greater. The KTC had identified a cable-stayed design as its preference and commissioned two engineering firms to prepare designs—



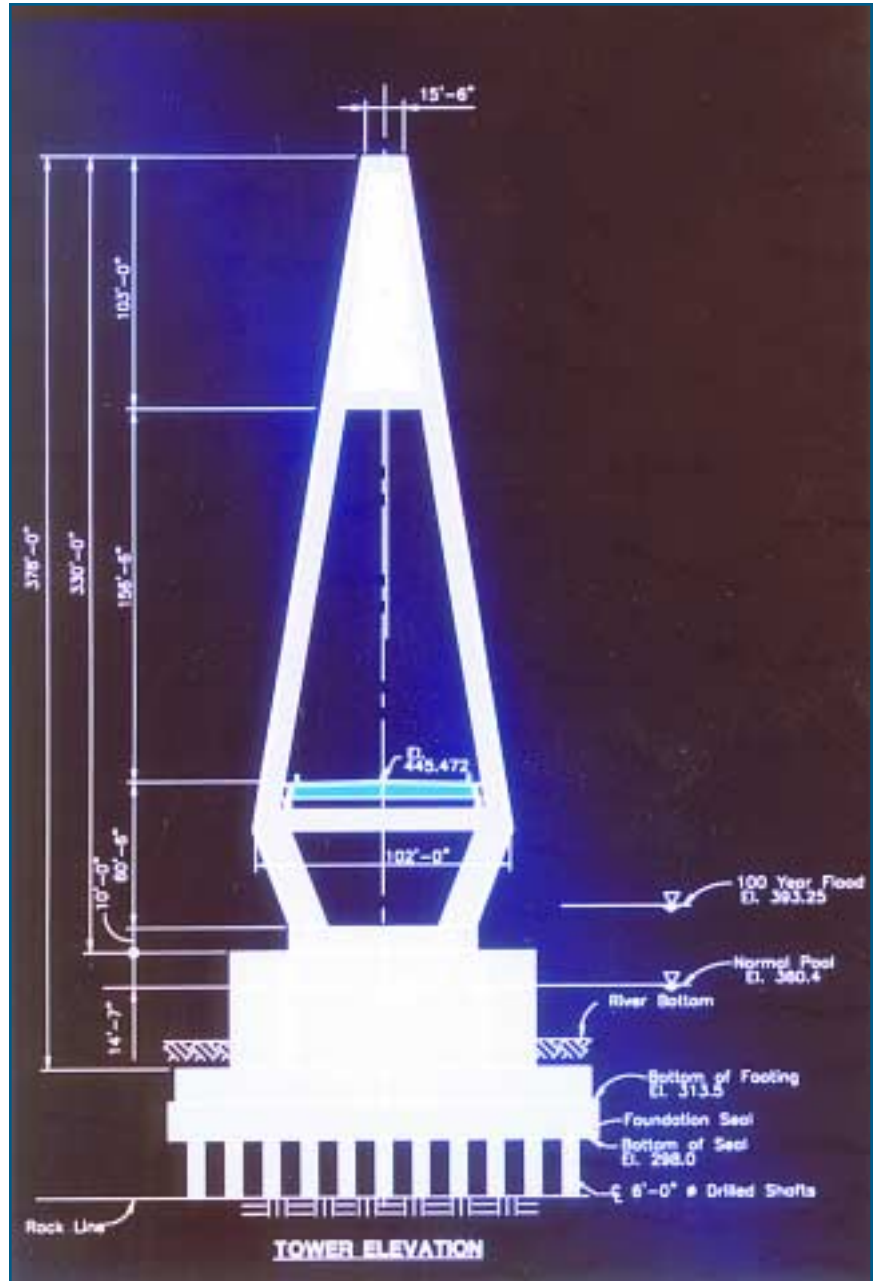
one steel and the other concrete. Construction contractors were asked to bid on either design, with two bids received for the steel alternate and one for the concrete design. The successful bid from Traylor Brothers, of Evansville, Indiana, on the steel design was \$55.5 million. A second bid on the steel alternative was \$57.6 million, while the bid for the concrete design was \$58.9 million.

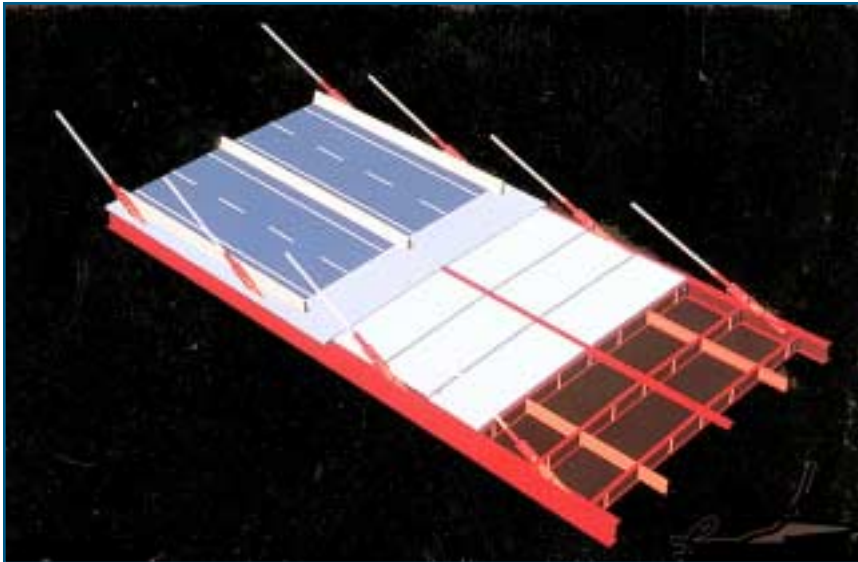
EFFICIENT STEEL DESIGN

A number of factors contributed to the efficiency of the steel design, including simple and flexible details of the stay cable to girder anchoring system, an efficient prefabricated composite steel stay cable anchoring system in the towers, continuity of the superstructure at the anchor piers with the approach girders, and concrete counterweight instead of conventional tiedowns at anchor piers. The steel industry offered many useful insights. In particular, AISC and the National Steel Bridge Alliance (NSBA) both were very helpful in organizing the quality assurance reviews from experienced steel fabricators and contractors during the design.

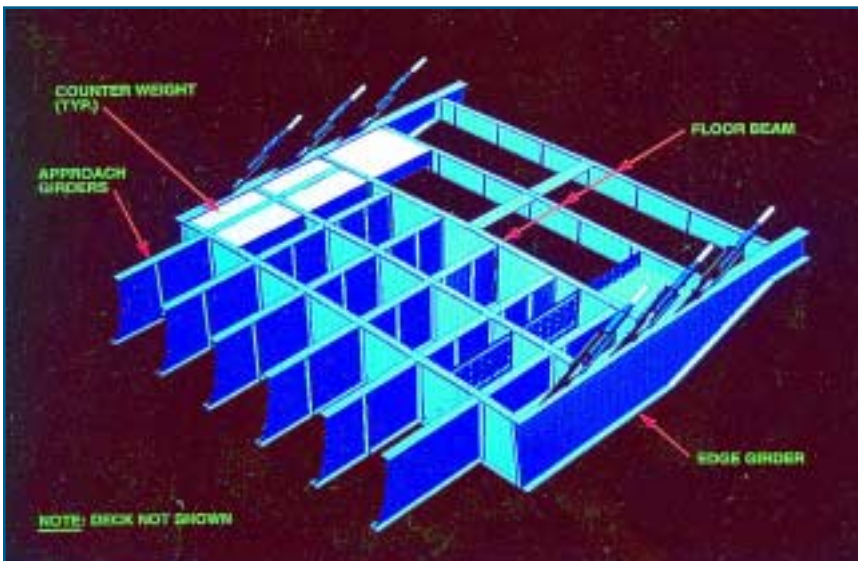
The bridge was designed in accordance with American Association of State Highway and Transportation Officials (AASHTO) Specifications. At the same time, attention to aesthetics resulted in a bridge that is beautiful and graceful without sacrificing the design objectives.

The Ohio River Valley at the project site is approximately 4 miles (6.4 km) wide between the states of Kentucky and Indiana.





Steel superstructure with precast slab



Superstructure continuity at anchor pier

Most of the area is floodplain, which gets inundated at least once a year. On the Kentucky side, a long approach consisting of embankments and relief structures allows for the passage of flood waters. The main river crossing consists of a steel cable-stayed bridge with a 1,200-foot (366 m) main span and two 500-foot (152 m) side spans and composite steel stringer approach spans. Several precast, prestressed concrete I-beam approach spans are located on each side of the main river crossing in the overbank areas.

The pile bents, T-shaped approach piers and diamond shaped towers are founded on large-diameter drilled shafts. The bridge will accommodate two lanes of traffic in each direction with a center median for a total width of almost 79' (24 m).

TOWER SHAPE CRUCIAL

The towers are the most dominant elements of a cable-stayed bridge. Their shape must be aesthetically pleasing and contribute to the bridge's aerodynamic stability. The Natcher Bridge has two identical concrete

towers supporting three superstructure spans through the stay cables, each 330 feet (100.6 m) high, rising 260 feet (79.3 m) above the bridge deck. After a careful evaluation of tower shapes during preliminary design, a diamond-shaped tower was selected for improved torsional stiffness and stability.

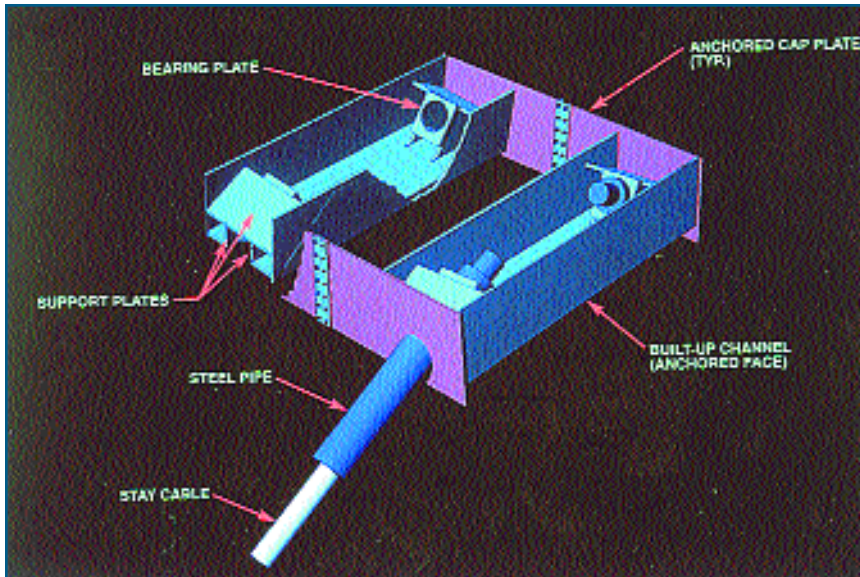
Above the deck level, each tower has two hollow inclined legs that meet at the top to form a large trapezoid-shaped chamber in which the stressing ends of the cables are anchored. The chamber will be outfitted with ladders and working platforms to facilitate inspection and maintenance. This is one of the few bridges where the cable anchors can be easily and directly accessed.

Below the deck, the tower legs bend inward and are held in position with a post-tensioned concrete tie beam. At each tower, the superstructure passes through the upper legs and sits atop the tie beam with bearings under each edge girder. Bearings at the Kentucky tower are fixed, while those at the Indiana tower allow expansion.

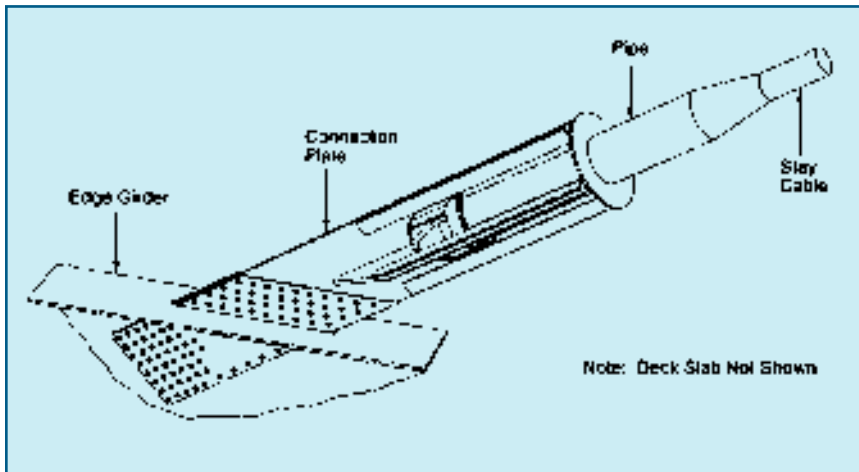
The cable-stayed superstructure consists of AASHTO M270 grade 50 steel I-shaped edge girders and floor beams made composite with the concrete deck slab using shear studs. The edge girder web is inclined at 8° to match the inclination of stay cables, and the floorbeams are spaced at 15 feet (4.6 m). The deck slab consists of 89-inch (230 mm) thick precast concrete slab panels with cast-in-place infills. To control torsion in the floorbeams during precast slab erection, a central beam is provided. A 16-inch (40 mm) latex modified concrete overlay is placed on the deck slab.

CREATIVE SOLUTION AT ANCHOR PIERS

In cable-stayed bridges, some of the most challenging design issues arise in the area of anchor piers, where a transition occurs from the cable-supported struc-



Prefabricated steel cable anchorage inside the tower pier



Stay cable anchorage to edge girder

ture to a conventionally supported structure. Many important elements are located in this area, including windlocks, which prevent relative transverse movement between the deck and anchor pier; anchor cables; counterweights and tie-downs, which anchor the anchor cables; and bearings for both the cable-stayed spans and the approach spans.

In the case of the Natcher Bridge, the cable-stayed superstructure is continuous with the steel stringer approach spans, three spans on the Kentucky side and a single span on the Indiana side. The innovative

transition from the cable-stayed back spans to the adjacent approach spans at the anchor piers offers several advantages. The dead load reaction from the approach spans reduces counterweight requirements. Expansion joints are avoided, eliminating the potential for leakage of water onto the bearings, tie downs and windlocks. Furthermore there is no relative translation or rotation between the two adjacent spans, providing a smoother ride.

In the transition area, six longitudinal approach stringers are framed into the two cable-stayed edge girders through a series of

three floor beams. Moments are transferred by upward and downward forces on these floor beams. The approach stringers, edge girders and floor beams are all 12 feet (3.7 m) deep at this location, beyond which the two cable-stayed edge girders gradually decrease to a typical depth of 5 feet (1.5 m).

The counterweights are integrated into the superstructure and placed so that their centers of gravity coincide with the centerline of bearing at the anchor pier. To increase the factor of safety against uplift to two, as required by AASHTO, the anchor piers are also provided with tie-downs designed to resist the maximum upward live load reaction without the counterweights.

STEEL-REINFORCED BEARINGS

The total length between expansion joints of the cable-stayed spans and the steel stringer approach spans is 3,378 feet (1,030 m). Longitudinal fixity is provided at the Kentucky tower. Here two brackets drop down from the edge girder and hug a heavily reinforced concrete pedestal. Steel-reinforced elastomeric bearing pads that rest between the steel brackets and the pedestal transfer the longitudinal force. Each pad has a low-friction surface that bears against the bracket so that rotation of the girder is not hampered.

One windlock is situated at each anchor pier, located at the centerline of the bridge, under the floor beam. The windlocks were designed to accommodate necessary longitudinal and vertical movement, as well as free rotation of the superstructure about the anchor pier. The lower assembly is attached to the pier cap with anchor bolts and the upper assembly is bolted to the floorbeam bottom flange.

The bridge will have a total of 96 stay cables made of half-inch (15 mm) diameter seven-wire strands, with cross ties provided to control galloping. To maxi-



Drilled shafts under installation in the Ohio River

mize economy, the specifications gave the contractor the option of using either greased and sheathed strands or epoxy-coated strands, grouted in either a black high-density polyethylene (PE) pipe wrapped with white tedlar tape or coextruded PE pipe with a white exterior. The contractor was allowed further flexibility in selecting the anchor type for the cable anchorage assemblies, which were designed to accommodate wedge, wedge socket and socket type cable anchors.

The contractor elected to use greased and sheathed strands grouted in coextruded pipe, and wedge type cable anchors, all supplied by VSL Corporation. The pipe will be provided with a spiral bead to control rain/wind-induced vibrations.

CABLE ANCHORAGES CRITICAL

The constructibility of the cable anchorages are critical to the success of a design. For the Natcher Bridge, cables are connected to the girders (non-stressing end) by a simple bolted splice between the cable connection assembly and girder web. This eliminates torsion in the edge girder, allowing the connection to be located between floor

beams. To provide for shear flow in the edge girder where the top flange has been slotted, angles will be bolted to the connection plate and to the top flange, along the slot.

The connection plate is a flat steel plate that passes through a slot in the top flange of the edge girder as an extension of the edge girder web. A bolted splice connection is chosen to avoid stress concentration and cracking of welds. The other end of the plate is cut into a tuning fork shape with two prongs, between which a thick-walled pipe is welded. The cable is installed by inserting its anchor head into the steel pipe. A ring nut or a shim plate supports the anchor head to bear against the end of the pipe.

Two additional plates are welded to the connection plate and the pipe to stiffen the pipe against squashing and reduce the required thickness of the connection plate. These plates give the cross section of the connection a cruciform shape. They are tapered and stop above the top of the cast-in-place portion of the concrete deck, which is poured around the connection plate. The cruciform shape is an

open section that allows easy access for inspection. Below the edge girder top flange, the splice connection can also be easily inspected.

The cable anchorage is located above the deck, which makes it easy for construction workers, inspectors and maintenance personnel to access the cable anchors directly without need for expensive special equipment.

The cable-to-tower connection (stressing end) consists of steel frames anchored to the interior walls of the tower head chamber by shear studs. These frames carry the horizontal component of the cable force and transfer the vertical component to the concrete. They can also transfer unbalanced cable forces during cable replacement or loss.

Each tower head contains 12 steel frames, each supporting two side span cables and two main span cables. A frame consists of two built-up channels with flanges inclined to match the slope of the inner tower walls. A cap plate with a steel pipe is welded to each end of the channels, and the inclined flange and cap plates are attached to the tower walls with shear studs.

The cable bears against inclined support plates that are sandwiched between the channel flanges. The closed chamber at the top of the tower piers provides a protected environment for the cable anchorage and is a convenient location for cable stressing operations. Platforms located at each cable level provide direct access to the frames and anchorages for inspection and maintenance.

As of June, Traylor Brothers has completed the Kentucky side approach pier foundations, some of the approach piers, and portions of the two towers. The overbank approach embankment and flood relief structures are also completed. Steel fabrication, by AISC-member Vincennes Steel, is also well under way. Detailer on the project is AISC-member Tensor Engineering Co. The bridge is scheduled to be open to traffic in the fall of 2001.

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