THE NEW CLARK BRIDGE:

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The newest Mississippi River crossing is Illinois' cable-stayed structure at Alton, erected without the serious problems that have plagued similar structures despite unique features in its design.

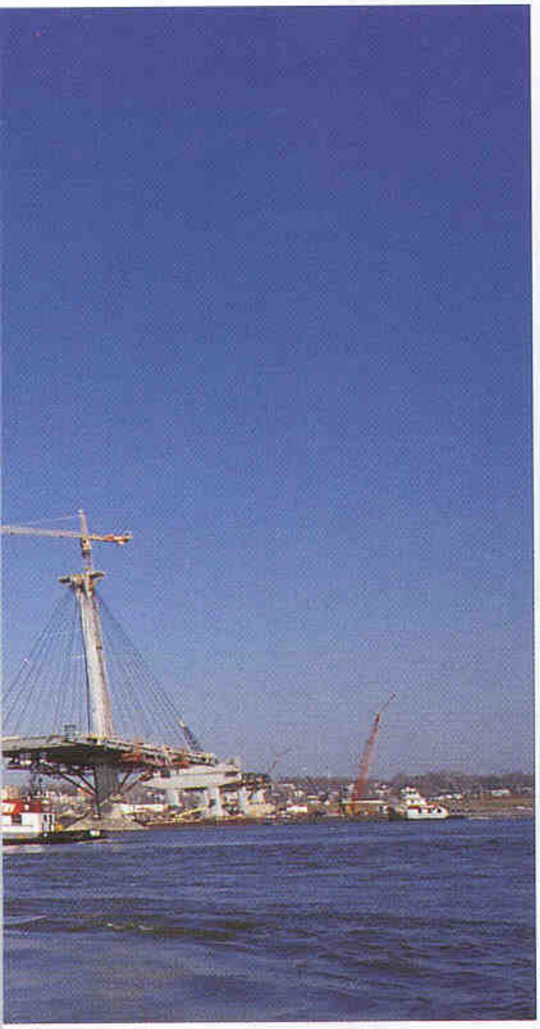
The main design difference between Clark Bridge in Illinois and its various cable-stayed cousins is the saddle-draped cable pattern that splays out from the top of the pylons to the steel edge girders. The main construction difference is that, despite the major Mississippi River floods of 1993 and challenges posed by innovations in its design, especially a challenging stay system, there were no serious erection difficulties.

The new $85 million, 108 ft wide Clark Bridge replaces a 20 ft wide 1928 truss bridge at Alton, Ill., carrying U.S. 67 over the Mississippi about 1 mi above the recently completed Lock and Dam 26. There are two traffic lanes in each direction, plus shoulders and a 10 ft wide median.

The bridge was designed by Hanson Engineers of Springfield, Ill. for Illinois DOT. The first bids for the entire 4,620 ft span were rejected in 1990 as being beyond budget. In a 1991 second round, the cable-stayed portion was awarded to a joint venture of McCarthy Brothers Construction Co. of St. Louis and PCL of Edmonton, Alberta for $34.9 million. The approaches were bid separately and were won by two other contractors (see box). Work began that July, and dedication took place in January 1994.

Even though Clark Bridge withstood the raging force of the Mississippi with no damage during the great flood, the high waters did delay construction for two months. The U.S. Army Corps of Engineers shut down the Mississippi River to all

Reprinted from Civil Engineering, August 1994



CLARK BRIDGE IS THE FIRST IN THE U.S. IN WHICH SUCH A LIGHT STEEL-FRAMED CABLE-STAYED DESIGN WAS COMBINED WITH A CABLE SADDLE TYPE OF PYLON. THE COMBINATION POSED SOME UNIQUE CONSIDERATIONS FOR CONSTRUCTION ENGINEERING AND ERECTION CONTROL. PHOTO AT LEFT ©1992 DAN SINDELAR.

SADDLE-DRAPED CABLES

barge traffic to protect the water-soaked levees from further damage due to wave action. Without barge access, barge-mounted cranes could not access the work, and without the barges, critical-path construction could not continue.

All cable-stayed bridges require separate construction engineering efforts, and McCarthy hired DGES, Inc., Olympia, Wash., to develop and support the erection engineering program for Clark Bridge. Many of the engineering issues were similar to those in other cable-stayed projects around the U.S., but several were unique. The first issue was an erection scheme shown on the plans: Analysis showed it would not meet the specification criteria. There were conflicting predictions of aerodynamic response to winds during construction, and limitations to erection posed by the critical condition of cable slip at the pylons.

The three-span (302, 756 and 302 ft) cable-stayed unit is composed of a steel plate girder frame with longitudinally post-tensioned precast concrete deck panels. The steel frame was made composite with the precast panels once the 15 in. wide gap between the panels was filled with concrete.

Each pylon is a single 283 ft tall mast located on the roadway centerline, similar to Florida's Sunshine Skyway except that 22 cables are draped over a saddle atop each pylon. They radiate from the saddles to the steel edge girders as they would for a more traditional A-frame configuration. Rather than being anchored at the pylon, the cables are continuous from edge girder to edge girder. Prior to grouting, the cables were restrained at the pylon head only by friction. To keep the strand from slipping at the pylon head, the four anchors at each stage had to be stressed simultaneously in small increments with four jacks.

Clark Bridge is the first in the U.S. in which such a light steel-framed cable-stayed design was combined with a cable saddle type of pylon, and the combination posed some unique considerations for construction engineering and erection control. The parallel epoxy-coated strand cables were grouted into a polyethylene (PE) sheath. The cable saddle region was sheathed in steel pipe. Impregnated grit was required in the epoxy coating to increase friction in the saddle as well as to develop bond in the stay anchor. Cables were anchored to the outside of the edge girders by steel anchor boxes bolted to the girder webs.

The McCarthy/PCL contract began just above the waterline. In planning for construction, we sought to use conventional, proven heavy construction methods as much as possible rather than invest in expensive special equipment and methods that would hinder productivity and add to the capital cost. The pylons were cast with conventional gang forms, which were handled first with a barge-mounted crawler crane and later a tower crane for each. Pylon construction was labor-intensive because of varying cross sections and rebar congestion.

The pylon saddle is a special stainless-steel fabrication set as a unit. Concrete placement below this unit required special care, aided by use of support and alignment frames. Prior to placing the saddle, a special set of cable stays was installed to support the initial steel framework for the deck. The Missouri pylon went up right behind the Illinois pylon, using the same forms.

Although the deck is made up of precast modules, the 56 ft long deck section at each pylon was cast in place, and is considerably thicker than the precast sections. The steel framework for the deck was fixed at the pylon, and misalignment here would affect the entire span. We devised special erection jigs to support the 25 ton transverse girders. These girders support the entire deck framework, carrying the parallel edge girder loads into the pylon stem. Next we installed the first field sections of the edge girder and attached the special cable stays to the transverse girders. This created a derricklike transverse support structure for the main edge girders.

During construction, the transverse-girder/stay system was supplemented from below by a tetrahedron of pipe supports that helped limit deck movement and cable slip. These temporary units were post-tensioned to both the deck and pylon stem, but the high compressive loads required for fixing these supports to the deck caused the dry pack grout bed on the deck to fail. We substituted tapered plastic shims as bearings and seated the post-tensioned bracket against them. The plastic was easy to fabricate despite having a 15,000 psi compressive strength.

The cables are epoxy-coated strand anchored with a conventional wedge system, with split shims used for coarse adjustment and a ring nut for fine adjustment. The proprietary design, by Dywidag Systems, Inc., Lamont, Ill., for the anchor included a socket pipe designed to work as a friction device for load transfer after cable grouting. The strand wedges took only the construction dead loads.

Stays were prefabricated to length on shore by threading the strands through the PE sheathing and saddle pipes, then attaching the sockets and anchor plates on each end. After delivery via special carts and a barge, the tower crane lifted the saddle pipe while the barge cranes handled the deck anchors.

The stay system was the most challenging part of the entire project. Working with epoxy-coated strand, especially strand with grit, was problematic at best. Equipment and procedures had to be modified to deal with the idiosyncrasy of the strand and anchorage system. Variability of strand coating thickness, grit-clogged wedges and variable grit coverage along the strand added to the normal problems of variations in seating forces on the wedges. On this project, we found that the appeal and appearance of epoxy-coated strand that has been evident in laboratory experiments and field trials was largely lost in actual application.

PYLON CONSTRUCTION WAS LABOR-INTENSIVE BECAUSE OF VARYING CROSS SECTIONS AND REBAR CONGESTION.

Final stay grouting and taping are significant cost items for these structures. Here, however, the inaccessibility of the stay PE pipe at the pylon saddle made field taping impossible by conventional means. Workers used special cable wrap for local hand taping. The top saddle pipes had to be grouted from both ends at the same time, then postgrouted twice to push out all signs of bleed water. Production with conventional grout equipment was too slow, so we batched and delivered the grout as ready-mix.

DECK ERECTION

Planning and executing deck erection is a unique characteristic of cable-stayed bridge construction. Erection has to be planned to an exacting degree to determine the camber for fabrication of the edge girder, and to establish the stress and geometric profiles for the completed bridge. In addition, cable slip at the pylon head had to be checked at each stage. We developed a detailed erection program, prescribing some 300 steps in a comprehensive erection manual that included general requirements for measurement and control.

The typical module is a 35 by 100 ft deck unit comprising two edge girder elements, two transverse steel floor beams, four precast deck panels and one cable pair. Rather than erect the steel one girder at a time, we assembled the modules on barges, off the critical path, before lifting into place with a barge-mounted crawler crane and derrick for bolting and alignment.

We checked deck grade after release of the cranes. This is one of the areas where cable slip influenced erection. Normally, any small warp at the bolted edge girder joint could be corrected later with cable pull. Here the steel had to be checked for grade before the cables were installed to ensure that any additional pull to achieve grade would not slip the cables over the saddle. Several edge girder joints had to be adjusted for closer tolerance, but most sections were erected to within 0.5 in. of target elevation.

Cables were initially stressed against the bare steel frame. Since steel weight amounted to less than one-third of the total weight, and stay cables are typically stressed to about one-third ultimate under total dead load, the cables had to be installed at a force of about one-tenth ultimate. The light load affected both the slip condition and the effectiveness of the anchor wedges,

A CAST OF CONTRACTORS

Just as it took several sets of engineers to shepherd the new Clark Bridge across the Mississippi River, it took several sets of contractors. In addition to the joint venture of McCarthy Brothers Construction Co., St. Louis, and PCL, Edmonton, Alberta, separate contractors completed the substructure, each approach and the extensive lighting.

Although the 1993 flood caused no physical damage, the U.S. Army Corps of Engineers sent survey crews to check the structure throughout the emergency. The two-month ban on barge traffic "still cost us money—up in the six figures," says Ted Downey, McCarthy senior project manager. "We still had to pay for the cranes and barges, and we couldn't tell our salaried people to just go away."

It could have been worse, except that he and other McCarthy engineers are, as Downey describes it, "river-savvy." They obtained permission to widen the levee and perch their construction office compound atop it. "We did have some trailers and equipment down on the riverbank, but were able to pull them out with no trouble."

As if to overcome the memory of the muddy floodwaters, Clark Bridge emerged as one of the prettier bridges along the Mississippi. The cables, wrapped in tape to protect the polyethylene sheaths from ultraviolet rays, are bright yellow. And some of the $410,000 spent for lighting went for purely decorative 150 W metal halide lamps that parallel the cable stays. Another circuit lights the pylons from their bases with 150 W and 1,000 W metal halide lamps, and a third circuit of 100 W lamps, also metal halide, outlines the outer edges of the Missouri and Illinois approaches.

The cable-stayed spans take up 1,360 ft of the bridge's total 4,620 ft. Hanson Engineers, which has a long history of designing bridges for Illinois DOT, detailed them as conventional welded steel plate girder spans with 9 in. cast-in-place decks reinforced with epoxy-coated rebar. Unlike the cable-span decks, which were topped by 2 in. of silica fume concrete, the approach span decks carry traffic as cast.

All piers and decks, both cast-in-place in the approaches, and precast slabs in the cable-stayed spans are reinforced with epoxy-coated rebar. "We've been using it throughout Illinois for several years, and have had good experience with it," says Earl Doerr, Illinois DOT senior resident engineer.

The Missouri approach crosses eight spans, each about 200 ft long, constructed by Massman–Ben Hur of Kansas City, Mo. The abutment, seven piers, steel girders and deck were completed after the two-month flood delay for approximately $24.2 million.

The Illinois approach was complicated by the need to add a berm behind the levee to stabilize the roadway embankment against liquefaction from earthquakes, and relocation of five railroad tracks and part of State Route 143 to provide an adequate connection in Alton, Ill. The 11 approach spans—10 spans at 154 ft and one at 115 ft, are nearly identical to the Missouri spans. They were constructed by Keller/GenCon of Edwardsville, Ill. for $14.7 million.

A fourth contractor was responsible for the substructure at the center spans. Midwest Foundations, Inc., Tremont, Ill., drove some 42,000 ft of piling and completed the reinforced concrete transition piers and the two main pylons to 20 ft above the water level. They finished the $11.3 million substructure in August 1991. The electrical contractor is Wissehr Electric Co. of Belleville, Ill.—*RR*

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which would not bite through the epoxy coating. As the deck panels were added, cable force increased and the ensuing bite of wedges was uncontrolled. We had to deal with epoxy tears and slipped wedges in the midst of construction by externally power seating each strand wedge to ensure bite into the strand steel. We soon modified procedures to provide for power seating immediately after stay stressing, before the precast panel loads were added to the structure.

Deck grade was the primary means of erection control, with cable forces checked against targets at each stage. Variances in the final forces were measured against the full final dead load after addition of the concrete panels. The panels are 10.5 in. thick, reinforced with epoxy-coated rebar. The joints over the edge girders were cast only after the following steel framework was set in free cantilever. This sequence ensured maximum compression in the deck concrete when the following set of cables was installed.

One of the many special erection items developed for Clark Bridge was the set of floor-beam counterweights suspended from the leading edge of construction prior to casting the transverse joints and post-tensioning the slabs. The weights emulated the presence of precast panels, and they helped avoid the interim deck-cracking problems experienced on past cable-stayed bridges.

Clark Bridge has no free joints. The back span is rigidly connected to the anchor piers, the main deck is fixed at the pylon and the main span is continuous. Therefore, there was no expansion/contraction joint to allow adjustment at main span closure. We determined the final field section length just prior to erection, and computed the final opening based on a history of thermal movement. Although we made provisions for jacking the opening with jacking/pulling lugs built into the last segments, predictions were reliable and jacking was not needed for closure.

Even with all the necessary modifications to the assumed erection procedure, no design changes were required in the deck framing and no temporary bracing was required during erection. This is a credit to Hanson's design engineers, Tom Havenar and Bill Lueking, who opted for compact sections and adequate bare steel section strength instead of minimum steel weight. At other cable-stayed bridges, costs have risen because temporary bracing posed unreasonably tight erection constraints, negating any savings in material.

Fortunately for all involved, Clark Bridge avoided the recent pattern of troubled high-tech bridge projects in the U.S. The contractor emphasized simplicity in construction, the engineers developed plans that addressed the essential requirements of construction and offered a specific reference for bidding and building the work. This was a partnered job without the formal process, proving once again that people matter more than process.

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