Graceful Gateway

The striking new cable-stayed bridge across the Missouri River just north of Kansas City, Missouri—a welcoming visual gateway for those traveling between the city and the community of North Kansas City—features a diamond-shaped pylon that rises more than 300 ft above the water. Part of the Interstate 29/35 Connections Project, which also included the reconstruction and widening of more than 4 mi of interstate highway, the bridge was constructed within its fixed budget and was completed six months ahead of schedule. ••••• **By Patrick Cassity, P.E., S.E., and Tom Skinner, P.E.**

THE SECTION OF HIGHWAY that carries the interstates 29 and 35 from North Kansas City, Missouri, on the north side of the Missouri River, to Kansas City proper, on the south side, is heavily traveled by commuters. This section currently carries an average of 102,000 vehicles per day, and the volume is expected to be significantly higher in the near future. In recent years congestion along the corridor has had the effect of increasing travel times, fuel costs, pollution, and traffic accidents. The Missouri Department of Transportation (MoDOT) determined that these issues could be ameliorated only by increasing the capacity and safety of this stretch of freeway. Added to these concerns was the fact that the Paseo Bridge, which carried these highways over the Missouri, was more than 50 years old and had been closed for emergency structural repairs for several weeks in 2003. The MoDOT determined that an extensive rehabilitation of the Paseo Bridge would be required if this structure was to remain in use for the next 60 to 75 years.

For these reasons the MoDOT initiated the Interstate 29/35 Connections Project (kcICON), a rehabilitation and reconstruction effort that involved not just replacing the bridge but also widening and improving the roadways and intersections along a 4 mi stretch of the highway, reconstructing five interchanges comprising 18 ramps, erecting 12 land bridges, and constructing 2.04 mi of retaining walls and 0.7 mi of sound walls. The key feature of the project was the Christopher S. Bond Bridge, a cable-stayed structure over the Missouri honoring a former U.S. senator from Missouri. The design and construction services for kcICON were procured under a design/build contract.

Significant challenges were encountered in developing a design in this dense urban corridor and balancing the competing goals of the project. The community desired an easily recognizable bridge that would make a dramatic visual impression even when viewed at night. But the bridge also had to be durable enough to last 100 years and had to maximize capacity and mobility and offer safety improvements.

The MoDOT used a fixed-price, best-value approach to procuring the design/build contract. The department developed the initial design of the project in sufficient detail that most third-party approvals and environmental clearances could be obtained early while ensuring that the engineers and builders that would be bidding on the project would have sufficient flexibility to develop and refine alternatives. The price of the design/build contract for the project was fixed at $232 million, and a scoring system was developed so that the MoDOT could

CATHY MORRISON, MODOT, *BOTH*

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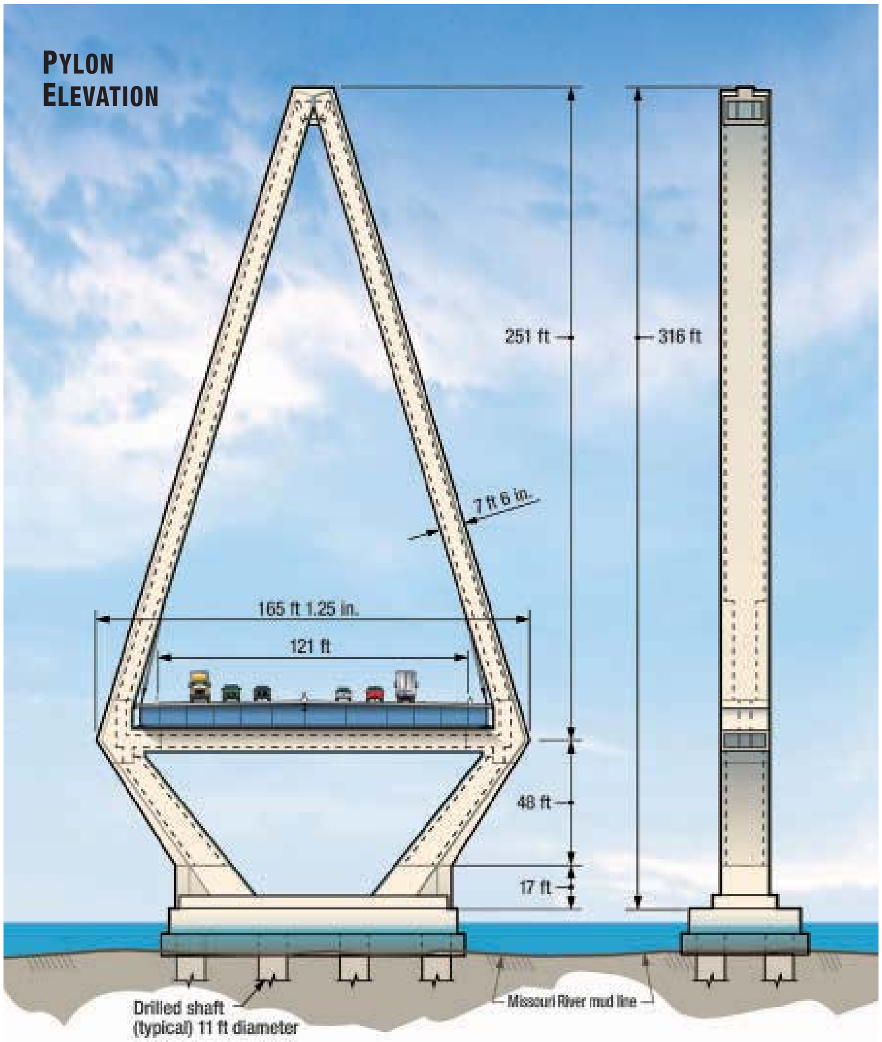
Thousands of celebrants gathered at Berkley Riverfront Park to celebrate Independence Day and to obtain a first look at the Christopher S. Bond Bridge's dynamic lighting display—and to enjoy fireworks—on July 3, 2011. The bridge lighting not only creates a moving line across the deck but also highlights the semifan arrangement of the cables, *opposite.*



following categories of the scoring system is given in parentheses, the maximum possible total score being 100:

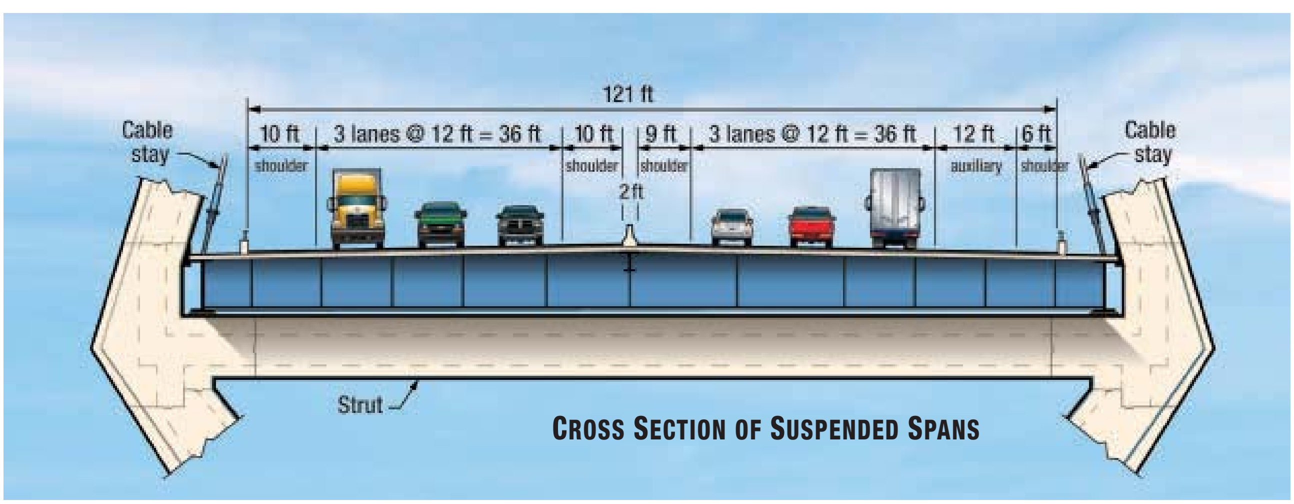
- Meeting the scope and effecting all desired improvements (30);
- Bridge aesthetics (20);
- Method of handling traffic during construction (15);
- Bridge durability (10);
- Meeting the schedule (10);
- Engaging disadvantaged business enterprises and using socially or economically disadvantaged workforces (10);
- Creating an effective public information strategy (5).

In an effort to meet the goal of working with stakeholders and the community in delivering the project, the MoDOT helped to organize a community advisory group to provide input during the design development process. The group included representatives of local municipalities, businesses, and community organizations. The MoDOT's commitment to engaging stakeholders and the community was such that it permitted members of the advisory group to attend meetings that the MoDOT held with the design/build bidders. Group members participated in reviewing the bridge designs and determining the final aesthetic score. To the best of our knowledge, this is the first time that third-party stakeholders have been given 20 percent of the say in selecting a design/build team.

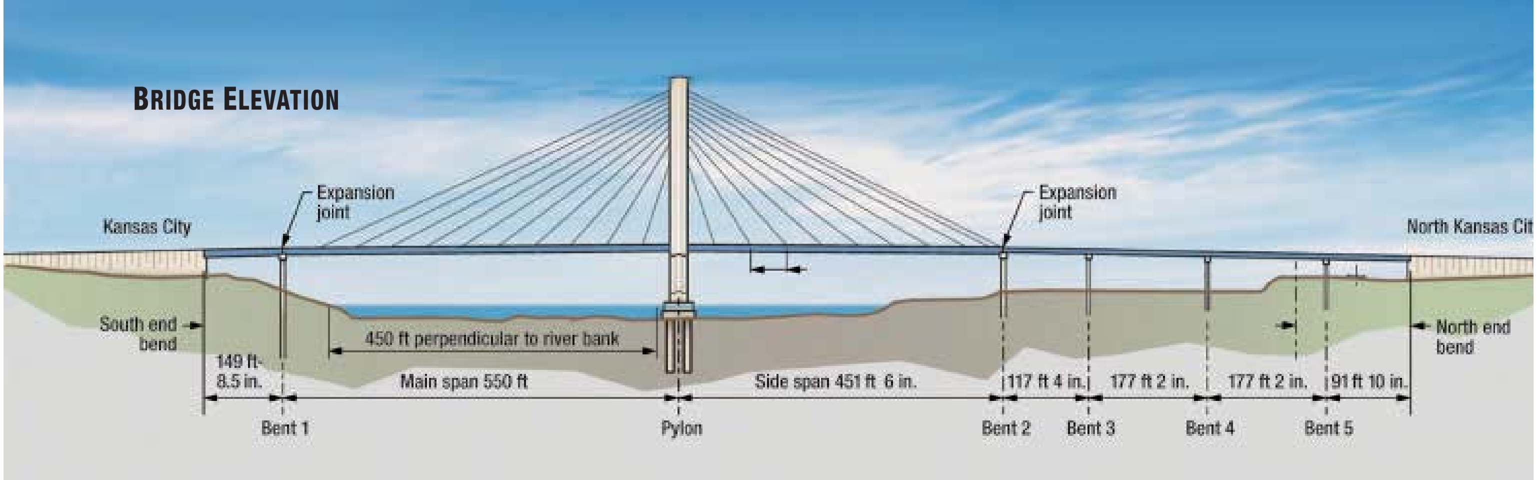
Although this type of procurement process offers significant value to the owner, it places extreme demands on the design/build teams, for in addition to developing a design that maximizes the technical score they must also meet the fixed-price budget. It also challenges the contractors to develop

evaluate the various proposals. The goals were to deliver the project within budget and to meet or beat a completion date of October 31, 2011; to provide a landmark bridge (or bridges) that could be reasonably maintained to provide more than a century of useful service; to maximize safety, mobility, and capacity in the corridor; to take aesthetic factors into consideration; and to work with stakeholders and the community in developing and delivering the project.

The maximum number of points awarded in each of the



PARSONS CORPORATION, *ALL THREE*



accurate cost estimates at the conceptual level to guide decision making as the design is being developed.

Having completed an environmental impact statement under the National Environmental Policy Act in January 2007, the MoDOT received final approval of the project's general alignment and potential scope from the Federal Highway Administration and released a request for qualifications from design/builders in March of that year. Statements of qualification from bidders were received in May of that year, and the MoDOT short-listed two teams. In November the MoDOT announced the winner, Paseo Corridor Constructors, a joint venture of Clarkson Construction Company, of Kansas City, Missouri; Massman Construction Company, also of Kansas City, Missouri; and Kiewit Corporation, of Omaha, Nebraska. Parsons Corporation, of Pasadena, California, served as the project's principal designer, and TranSystems, of Kansas City, Missouri, served as subcontractor to Parsons.

THE WINNING BRIDGE DESIGN featured a two-span cable-stayed structure with composite steel plate girder approach spans. The cable-stayed main span was to be 550 ft long, and the side span 451.5 ft long (see the figure above). The cross section of the bridge deck included three 12 ft traffic lanes in each direction with a 12 ft northbound auxiliary lane (see the figure at the bottom of the facing page).

The bridge's superstructure comprises a composite steel and concrete deck system that features precast-concrete deck panels on steel floor beams and steel edge girders. The superstructure is supported by 40 stays that radiate in a semifan arrangement from a single diamond-shaped pylon of reinforced concrete.

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The deck wearing surface is a fully replaceable microsilica concrete overlay 2 in. thick. Designed as a low-permeability protective barrier for the structural deck system, the wearing surface can be replaced once it becomes saturated with chlorides or if its condition warrants replacement for other reasons.

The high-performance (8,000 psi) precast-concrete deck making up the structural deck system is 9 in. thick, and the distance between floor beams is 16 ft 8 in. The use of high-performance concrete will help to extend the service life of the bridge to 100 years because this type of concrete has greater resistance to scaling, abrasion, and the effects of freezing and thawing than does typical structural concrete. Most important of all, high-performance concrete has very low chloride permeability, offering added protection against corrosive attack from the rebar, which often initiates the deterioration of the deck. Because the deck was precast in a factory-controlled environment, a high degree of quality control was achieved.

The deck panels were posttensioned longitudinally to impart additional strength and precompression in order to prevent cracking. The posttensioning steel is protected by a multiple barrier system consisting of the overlay, the structural concrete, ducts, and high-performance grout. Instead of metal, the ducts are made of polyethylene, a material chosen for its superior ability to prevent corrosion. The grout used was a prebagged, zero-bleed type selected to eliminate the potential for water intrusion and voids and to provide yet another low-permeability protective barrier.

The steel framing system is formed by two continuous longitudinal edge girders supported by two planes of cable stays. As noted above, the transverse floor beams are spaced 16 ft 8 in. apart. At the deck level the cable stays are anchored by anchor pipes and gusset plates welded directly to the top flanges of the edge girders along the line of the girder webs. This simple concept for connecting the cable gussets to the top flanges of the girders has been successfully implemented on many cable-stayed bridges, but the detail was subject to stringent quality criteria to ensure that it would be trouble free and offer long-term durability. These criteria included the following:

• The use of high-quality "Z" steel—steel with a low sulfur content and a tested level of ductility through the *z* axis of the plate—to ensure superior strength, ductility, and toughness, particularly against high loads acting in a direction perpendicular to the plate surface;

• The successful completion of wholly nondestructive testing of all welds connecting top flanges to cable gussets;

• The use of a high-quality replaceable sealant where the cable gusset meets the deck to preclude the possibility of crevice corrosion after the infill concrete shrinks;

• The use of a high-performance paint system involving three coats.

Dead-end cable anchors were provided at the deck level, and the jacking for the stay installation and stressing was carried out at the "live" end, in the pylon. Here the deck is supported vertically by pot bearings under the edge girders. The bearings deliver vertical loads from the deck into the lower strut, which is posttensioned to the pylon legs. The pylon was stiffened using two pairs of anchor stays that deliver the uplift forces to the anchor bent. These uplift forces are resisted by a combination of local ballast concrete in the deck and an integral connection to the bent.

The deck unit for the suspended span is a single continuous structure for 1,001 ft between the expansion joints at the bents. Most of the transverse wind and seismic loads on the structure are carried through the composite deck diaphragm back to the pylon and from there through the pylon legs to the foundations. Vertical elastomeric bearings positioned between the edge of the concrete deck and the inside face of the pylon serve to transfer the lateral loads from the deck to the pylon. Local transverse loads at the anchor bent are transferred to the bent and foundations through the integral connection. At the front bent, lateral loads are transferred through a central, guided elastomeric bearing assembly that also controls the differential deflections of the finger plate expansion joints.

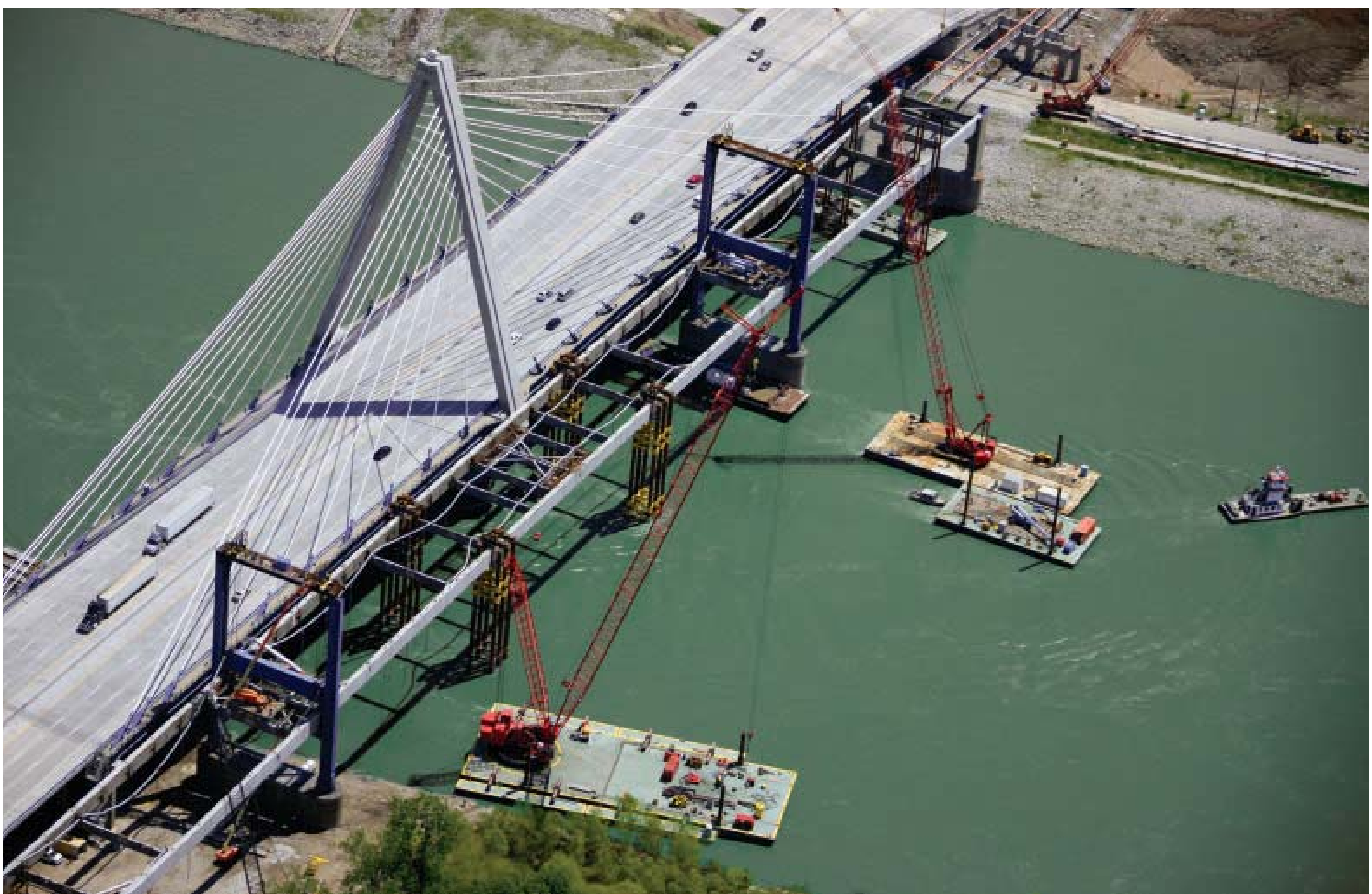
All of the longitudinal wind, traffic, and seismic loads on the main-span superstructure are delivered to a fixed connection between the deck and the pylon. The longitudinal connection is provided by a U-shaped concrete collar that engages the north- and south-facing sides of the pylon. Vertical elastomeric bearings located between the U collar and the pylon face transmit the longitudinal loads.

The concrete pylon has hollow box legs connected at the apex of the diamond and framed transversely by a strut beneath the deck (see the figure at the top of page 52). The strut provides a framing action to help resist lateral loads applied to the pylon and to resist the outward force created at the knuckle of the pylon. The inward inclination of the upper pylon legs and the corresponding inward inclination of the stays create a superstructure system that is very stiff torsionally and provides superior aerodynamic stability. The change in the direction of inclination of the legs at the knuckle made it possible for the supporting foundation footprint to be minimized, resulting in less effect on the river and significant cost savings in constructing the foundations and cofferdams.

A steel box assembly, which is composite with the surrounding concrete, anchors the stays in the pylon. The webs of the box directly carry the opposing horizontal components of the stay forces in tension. Access to the anchorage area and pylon top is provided by ladders and platforms.

In the semifan arrangement, the stays are anchored as close together as possible at the top of the pylon. This arrangement minimizes the amount of bending applied to the pylon by the

The previous crossing between Kansas City and North Kansas City, Missouri, was the Paseo Bridge, the longest self-anchored suspension span in North America at the time of its completion, in 1954. Demolition of the bridge began shortly after its closure to all traffic in November 2010 and was completed this July.



PASEO CORRIDOR CONSTRUCTORS, *OPPOSITE*; © PARSONS, RICH LA SALLE, *ABOVE*

stays. It also maximizes the cables' vertical angles, allowing for efficient stay sizes and minimizing the axial loads applied to the deck.

The cable stays are protected from corrosion in three ways. Each stay is a bundle of seven-wire strands, each strand sheathed in polyethylene and having wedge anchorages. The polyethylene here provides one layer of protection. The interstices within each sheathed strand are filled with a corrosion-inhibiting compound, forming a second barrier. Then the entire bundle of strands is enclosed in an additional corrosion and mechanical protection system that takes the form of a high-density polyethylene pipe.

The new bridge was constructed using an innovative process that saved time. After the foundation was completed, the lower pylon legs and cross-strut were constructed up to the knuckle location. The remaining portions of the pylon legs were then constructed with jump forms at the same time as the first cantilevered deck segments on either side of the pylon.

The bridge is supported on cast-in-place drilled shaft foundations that are embedded in bedrock. The alluvial river sediments are underlain by a shale bedrock formation that is well suited to such foundations.

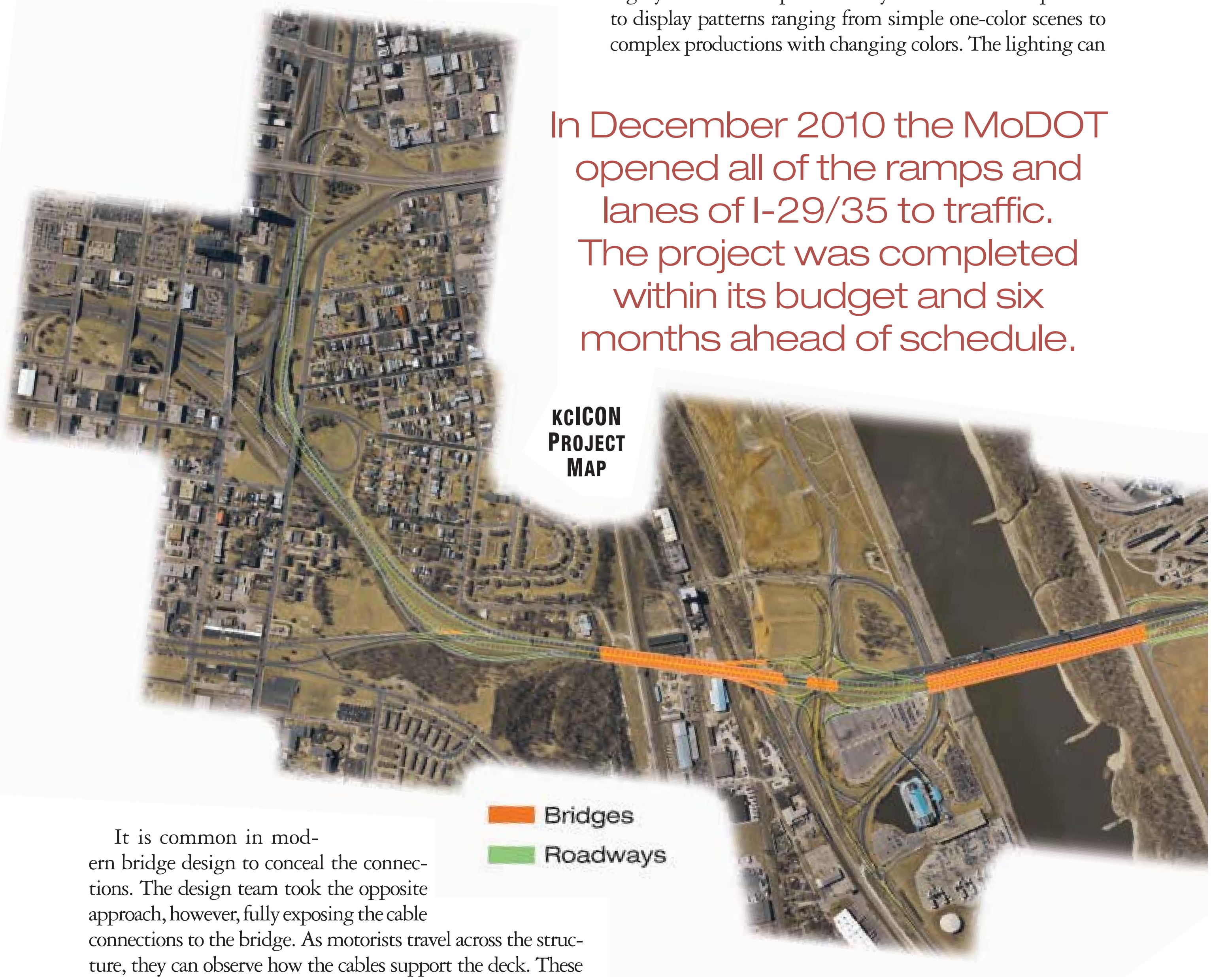
The pylon foundation takes the form of a single rectangular footing supported by a group of eight drilled shafts 11 ft in diameter. Construction of the cap above these shafts was facilitated by a concrete seal extending from the mud line to the base of the footing.

The drilled shafts were constructed with a permanent steel casing extending to the top of the shale bedrock, a 10.5 ft diameter socket extending approximately 20 ft into the shale formation. This single large footing with multiple shafts provides a robust and reliable foundation that is not vulnerable to scour and is strong enough to substantially exceed any expected vessel impact or lateral load demand. In addition to providing increased strength, ductility, and confinement for the bending stresses in the drilled shafts, the permanent steel casing facilitated construction by providing a stable environment in which to construct the rock socket.

The approach bents include multicolumn piers with a single shaft under each column. Shaft diameters and lengths varied according to the load demand at each column.

The foundation design and installation plans were verified by constructing and examining a test shaft near the main pylon at a location that was representative of the rock conditions at the pylon. The shaft was proportioned to evaluate the design values of side-shear and end-bearing forces in the rock socket by carrying out Osterberg Cell load tests. The tools and installation techniques for the rock socket of the test shaft were similar to those used for the production shafts, including a down-hole camera for inspecting the condition of the socket. The structural integrity of the drilled shafts was also verified by postconstruction integrity testing using cross-hole sonic logging techniques.

The bridge is intended to provide a unique visual statement that, it is hoped, will come to be associated with Kansas City. The bridge design, therefore, is cohesive from end to end. The lines of the approach spans and bents were developed so as to become visually integrated into the design of the suspended spans. Another distinctive feature is that the bridge is transformed at night with a unique lighting scheme. These aesthetic considerations were by no means an afterthought; the design team was intent upon delivering a bridge that would have graceful lines flowing naturally from the elegance of the structural solution. The creation of a "gateway" experience for motorists using the bridge was a fundamental part of creating an icon for the Kansas City community. The result is a unique experience for the motorist. As one approaches the pylon, the cables envelop the roadway. The lines of the cables take one's attention skyward, and the pylon serves as a focal point and true gateway through which every motorist enters and exits.



In December 2010 the MoDOT opened all of the ramps and lanes of I-29/35 to traffic. The project was completed within its budget and six months ahead of schedule.

It is common in modern bridge design to conceal the connections. The design team took the opposite approach, however, fully exposing the cable connections to the bridge. As motorists travel across the structure, they can observe how the cables support the deck. These exposed anchors create a type of visual rhythm along the elevation of the bridge and provide an additional layer of interest for observers. They also provide a system that is easy to inspect and maintain, further enhancing the durability, safety, and security of the bridge.

Given the community's desire for dramatic nighttime as well as daytime views, lighting figured prominently in the discussions dealing with aesthetics. The traditional necklace lighting used on the bridge alludes to that used in older neighborhoods in the surrounding area. The pylon and stay lighting reveals the bridge structure in a pleasing and artistic way, creating a nighttime experience that is markedly different from what one sees by day.

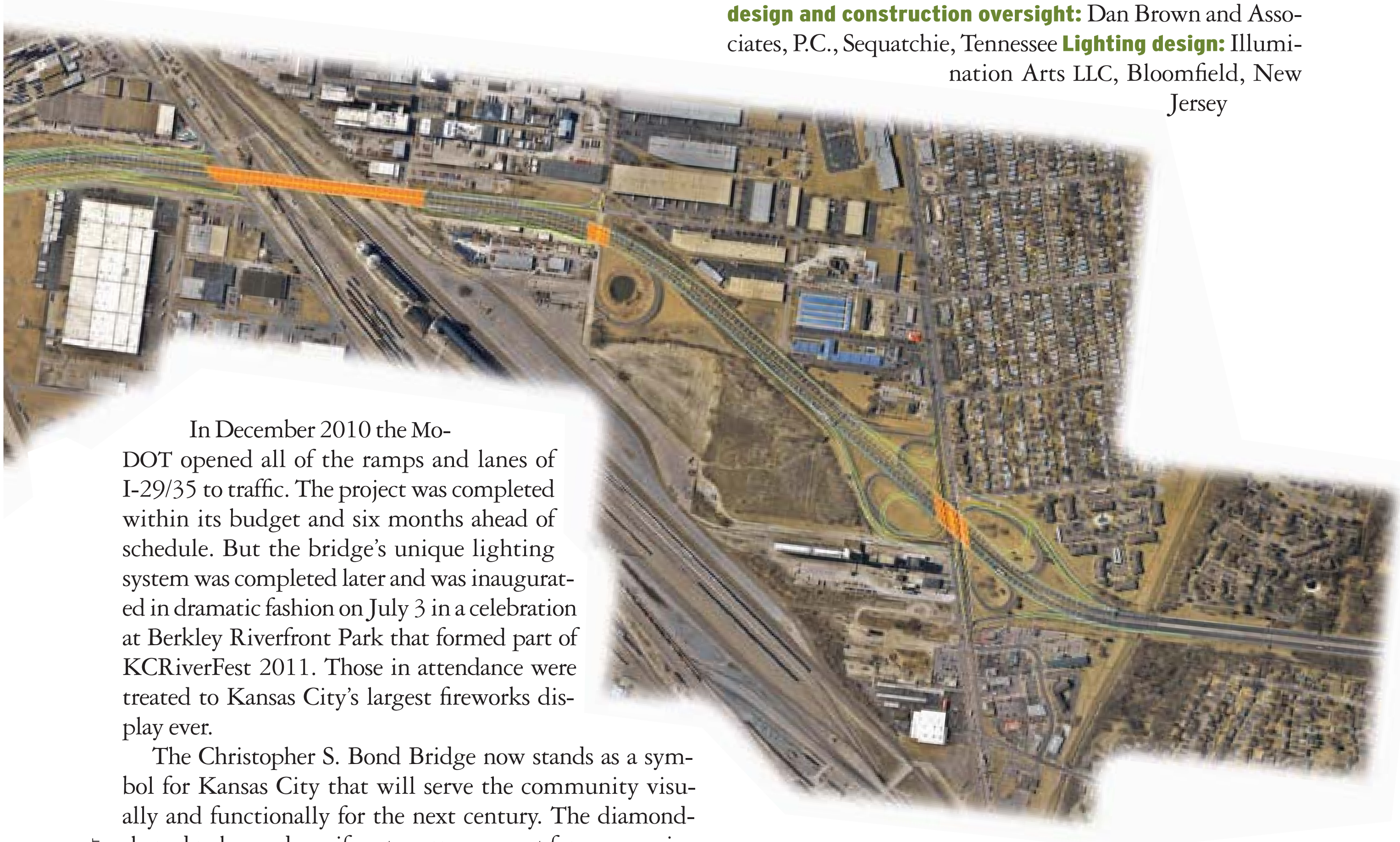
The horizontal line of the bridge across the water is enhanced by a dynamic lighting solution that creates a striking visual connection between the two sides of the river. This lighting system features necklace lights formed by light-emitting diode (LED) panels mounted on the outer sides of the edge girders. The panels change color and are controlled by a highly flexible and sophisticated system that makes it possible to display patterns ranging from simple one-color scenes to complex productions with changing colors. The lighting can be coordinated with seasonal changes and special events in the community. This active lighting system will give the structure a role and a prominence that go beyond transportation.

THE MAIN SPAN OF THE BRIDGE was constructed by the cantilever method. The design team simplified this method by specifying that the side span be erected on temporary falsework bents before the cantilever erection process began. This approach made it possible for the side-span superstructure to be built while construction was being completed on the pylon, reducing the overall construction time. The falsework supporting the side span was left in place throughout the cantilever erection to stabilize the pylon and cantilevered ends as well as to simplify geometry control.

The first step in the construction process, which began in April 2008, was to construct the pylon and its foundation. After the foundation was constructed, the lower pylon legs and the cross-strut were constructed up to the knuckle location. The remaining portion of the pylon legs was then constructed with jump forms up to the apex. At the same time, construction began of the pier table, that is, the first segments on either side of the pylon. Constructing the pier table early conferred time savings in that both the side span and the pier table could be completed while work at the top of the pylon was being completed.

Once construction of the pylon and pier table was completed, the first set of stays was connected to the pier table and stressed. From that point on, the main-span cantilever proceeded outward from the pylon in repeating cycles of work. The simple, repetitive process of cantilever erection continued until the main span was completed.

The falsework bents were removed after the anchor stays and counterweight at the second bent were completed. Once the superstructure had been erected, installation of the overlay, the concrete barriers, the railing, and the deck joints was completed.



MODOT

In December 2010 the MoDOT opened all of the ramps and lanes of I-29/35 to traffic. The project was completed within its budget and six months ahead of schedule. But the bridge's unique lighting system was completed later and was inaugurated in dramatic fashion on July 3 in a celebration at Berkley Riverfront Park that formed part of KCRiverFest 2011. Those in attendance were treated to Kansas City's largest fireworks display ever.

The Christopher S. Bond Bridge now stands as a symbol for Kansas City that will serve the community visually and functionally for the next century. The diamond-shaped pylon and semifan stay arrangement form a genuine gateway experience for motorists traveling on this bridge, which serves as an outstanding example of how creative performance-based procurement techniques, carefully crafted technical scoring criteria, and a responsive design/build solution can produce something that far surpasses the expectations and imagination of the owner and the community. **CE**

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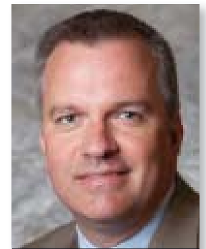
Cassity


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PROJECT CREDITS **Owner:** Missouri Department of Transportation **Design/builder:** Paseo Corridor Constructors, a joint venture of Clarkson Construction Company, Kansas City, Missouri; Massman Construction Company, Kansas City, Missouri; and Kiewit Corporation, Omaha, Nebraska **Principal designer:** Parsons Corporation, Pasadena, California **Design subcontractor:** TranSystems, Kansas City, Missouri **Bridge architect:** Touchstone Architecture, Tallahassee, Florida **Foundation design and construction oversight:** Dan Brown and Associates, P.C., Sequatchie, Tennessee **Lighting design:** Illumination Arts LLC, Bloomfield, New Jersey