NATIONAL AWARD

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Arthur J. Ravenel, Jr. Bridge over Cooper River

Charleston, SC

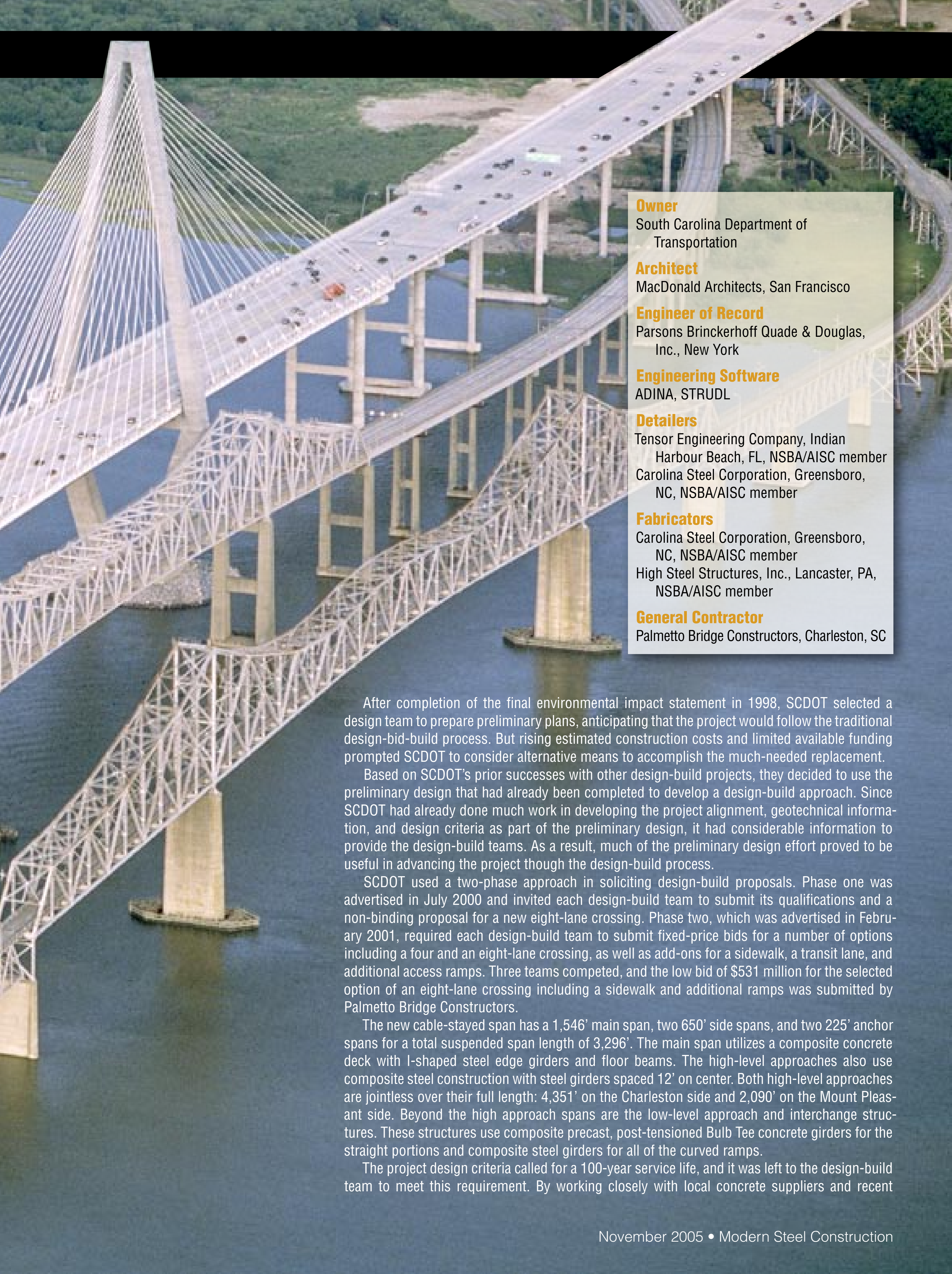
By Michael J. Abrahams, P.E.

The dramatic Cooper River Bridge—the longest cable-stayed bridge in North America—opened in July 2005 a year ahead of schedule, saving the South Carolina Department of Transportation (SCDOT) an estimated $150 million. A week of festivities, including a fireworks display, an on-deck performance by the Charleston Symphony Orchestra, and a walk across the bridge by more than 100,000 people, celebrated this bridge dedicated to South Carolina State Senator Arthur Ravenel, Jr.

The approximately three-mile-long bridge, including the main span, high level approaches, ramps and interchanges, was designed and constructed in a four year period. The bridge's main span allows for both a widening of the navigation channel to 1,000' and a deepening of the dredged depth of 10' to accommodate larger shipping vessels.

The project, which is the largest single transportation infrastructure project in the state's history, evolved from studies that began in 1988 to address the need to replace the deficient 1929 John P. Grace Memorial and 1966 Silas N. Pearman bridges between Charleston and Mount Pleasant. Also, there was a more recent need to improve shipping clearances in the upper reaches of Charleston Harbor.

Photo by Anthony Winn.



Owner
South Carolina Department of Transportation

Architect
MacDonald Architects, San Francisco

Engineer of Record
Parsons Brinckerhoff Quade & Douglas, Inc., New York

Engineering Software
ADINA, STRUDL

Detailers
Tensor Engineering Company, Indian Harbour Beach, FL, NSBA/AISC member
Carolina Steel Corporation, Greensboro, NC, NSBA/AISC member

Fabricators
Carolina Steel Corporation, Greensboro, NC, NSBA/AISC member
High Steel Structures, Inc., Lancaster, PA, NSBA/AISC member

General Contractor
Palmetto Bridge Constructors, Charleston, SC

After completion of the final environmental impact statement in 1998, SCDOT selected a design team to prepare preliminary plans, anticipating that the project would follow the traditional design-bid-build process. But rising estimated construction costs and limited available funding prompted SCDOT to consider alternative means to accomplish the much-needed replacement.

Based on SCDOT's prior successes with other design-build projects, they decided to use the preliminary design that had already been completed to develop a design-build approach. Since SCDOT had already done much work in developing the project alignment, geotechnical information, and design criteria as part of the preliminary design, it had considerable information to provide the design-build teams. As a result, much of the preliminary design effort proved to be useful in advancing the project though the design-build process.

SCDOT used a two-phase approach in soliciting design-build proposals. Phase one was advertised in July 2000 and invited each design-build team to submit its qualifications and a non-binding proposal for a new eight-lane crossing. Phase two, which was advertised in February 2001, required each design-build team to submit fixed-price bids for a number of options including a four and an eight-lane crossing, as well as add-ons for a sidewalk, a transit lane, and additional access ramps. Three teams competed, and the low bid of $531 million for the selected option of an eight-lane crossing including a sidewalk and additional ramps was submitted by Palmetto Bridge Constructors.

The new cable-stayed span has a 1,546' main span, two 650' side spans, and two 225' anchor spans for a total suspended span length of 3,296'. The main span utilizes a composite concrete deck with I-shaped steel edge girders and floor beams. The high-level approaches also use composite steel construction with steel girders spaced 12' on center. Both high-level approaches are jointless over their full length: 4,351' on the Charleston side and 2,090' on the Mount Pleasant side. Beyond the high approach spans are the low-level approach and interchange structures. These structures use composite precast, post-tensioned Bulb Tee concrete girders for the straight portions and composite steel girders for all of the curved ramps.

The project design criteria called for a 100-year service life, and it was left to the design-build team to meet this requirement. By working closely with local concrete suppliers and recent advances in service life predictive techniques, the use of low permeability concrete combined with uncoated reinforcing steel was demonstrated to provide the required service life.

The foundation bearing stratum over the entire site is characterized by a thick layer of stiff silt and clay, known as Cooper Marl, at a depth of 40' to 75' below elevation 0.0 (approximate MWL). Above the marl, the river has soft alluvial deposits. The land portions of the project have soft surficial soils inter-layered with loose, sandy material that is potentially liquefiable during an earthquake. These soil conditions made the structural design of the foundations quite challenging. In effect, the structure that the engineers had to design extended down to the Cooper Marl: piers with clear column heights of up to 146' above ground effectively extended an additional 40' to 75' below ground.

The environmental conditions in Charleston are probably among the most challenging in the United States due to the occurrence of both hurricanes and earthquakes. The design Safety Evaluation Earthquake (SEE) is a 2,500-year return period event with seismic shaking intensity similar to that found in parts of California. In addition, the South Carolina coast is an area prone to hurricanes and the associated strong winds. Ship collision loads were also a major factor for design of the main span piers and the piers adjacent to a creek on the Charleston high-level approach.

The superstructure for the suspended main span and side spans, from Pier 2W to Pier 2E, consists of two 6'-6" deep steel I-shaped edge girders and steel floor beams at 15'-8" spacing composite with a 9½" concrete deck slab. The deck is comprised of 8,000 psi precast panels, with closure strips over the girders and floor beams, and a 2" latex modified concrete wearing surface. The 126'-wide bridge deck carries eight lanes of traffic, and a 12'-wide pedestrian walkway and bikeway is cantilevered outside of the south edge girder.

The edge girders were designed for an HS25 live load, following load factor design (Strength Design Method) provisions of the AASHTO Standard Specifications and the FHWA Proposed Design Specifications for Steel Box Girder Bridges. The girders were also designed for the stay cable replacement and stay cable loss cases, following the AASHTO LRFD specifications and the fourth edition of the PTI Recommendations for Stay-Cable Design, Testing and Installation.

Replacement and cable loss load combinations in the PTI manual dominated the edge girder design. The cable replacement load case is probably not relevant for newer stay cable bridges that have individually sheathed strands and that utilize monostrand (isotension) jacking systems. It also seems to be highly unlikely that there could be a sudden, instantaneous failure of an entire stay cable on a newer bridge like this, with individually sheathed strands and ungrouted cables. Even if this were to happen, an evaluation allowing plastic hinging of the edge girder would probably be appropriate.

Except for a limited amount of Grade 70 steel in the edge girders, the main span features Grade 50 steel throughout. The unit weight of the main span steel is 42.4 psf, not including the stay cables or tower anchorages.

The high-level approaches are composite Grade 50 structural steel with a unit weight of 46.4 psf. The girders are 8'-2" deep. Typical center to center girder spacing is 12'- 0". Typical spans are 250'-0". The approaches have an overall width of 128'-10" and carry eight lanes of traffic together with a 12'-0"-wide sidewalk.

The curved steel ramps are also composite Grade 50 structural steel with an average unit weight of 60.7 psf. The girders are 6' deep, and there are typically four girders carrying each ramp. The typical ramp is 36' wide and carries two lanes of traffic. One ramp, which carries one lane of traffic and a 12'-0" wide sidewalk, is 28' wide. The ramps are continuous and vary in overall length from 1,400' to 1,800', with typical spans ranging from 160' to 240'.

David Sailors

The contractor selected two fabricators for the structural steel work: AISC member High Steel Structures for the main span and high-level approaches; and AISC member Carolina Steel Corporation for the curved steel ramps. As this was a design-build process, the development of design details on the plans included input from the fabricators so that their preferences and requirements could be incorporated into the final plans. In a typical design-bid-build process, this interaction does not occur until after completion of the final plans and award of the contract, and under those conditions may be hindered by time constraints and contractual issues. The contractor self-performed all steel erection.

All plans were made available to the contractor and the fabricators on project FTP sites. Then, in turn, the fabricators' shop drawings were posted on their own FTP site so they could be downloaded and reviewed by the designers. While consideration was given to electronic transmittal of marked-up shop drawings, this method was not used on this project. It was judged that given the team's limited experience with this methodology, the large number of shop drawings, the large number of structures and reviewers, as well as the tight schedule, a paper trail of marked up drawings would provide far better means for ensuring that all shop drawings and comments could be tracked. All FTP postings and shop drawing transmittals were announced and confirmed by e-mail so that the status of all design and shop drawings was available at all times to the entire design-build team. ★

Michael J. Abrahams is Senior Vice President and Technical Director of Major Bridges for Parsons Brinckerhoff Quade & Douglas, Inc. in New York.