Merit Award: Medium Span

Columbus Gateway Arch Bridge

The Columbus Gateway Arch Bridge is located in Columbus, IN and carries I-65 over SR 46. The structure is part of the overall SR 46-corridor improvement project extending east from I-65 to downtown Columbus. The corridor is undergoing major reconstruction to create an attractive "front door" to the city of Columbus. The bridge is the west anchor point of the corridor and forms a gateway entrance into the city. The new bridge carries four lanes of traffic and is 292' long and 137' wide. The arch structure replaces an existing four-span conventional steel girder bridge.

During the design and construction phase, constraints were placed including that it had to a signature-type structure. The design also had to maintain the vertical profile of I-65, along with maintaining the horizontal alignment of I-65 and the existing 40' median. The overall structure depth had to be equal to or less than the existing depth. The design also had to allow unobstructed site lines for a new single point interchange below the bridge. During construction, one lane had to be open in each direction.

Design and Construction Solutions

The basket-handle arch ribs extend up through the median of I-65 and merge at the crown. The ribs are supported on steel piles driven to bedrock and battered at a 45-degree angle to resist the arch thrust. The use of battered piles eliminates the need for a tension tie and dramatically improves the overall

redundancy of the structure. The innovative composite deck system consists of a biaxially post-tensioned, cast-in-place deck spanning longitudinally between transverse post-tensioned, steel box girders that are spaced at 19'-9" centers. Post-tensioned concrete structural parapets stiffen each edge of the decks. The 137'-long transverse girders are supported by cable-stays located in the plane of the arches and cantilever 48' outward from the stays.

Phase I of construction consisted of closing the inside two lanes of I-65 and constructing the arch rib foundations and erecting the ribs. Phase II and III consisted of demolition of the existing bridge and construction of the new superstructures, one-half at a time. Traffic was maintained on the existing west superstructure during Phase II and the newly constructed east superstructure during Phase III. The transverse beams were erected in two separate field sections and supported by falsework

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Owner:
Indiana Department of Transportation

Designer:
J. Muller International, Chicago (NSBA Affiliate, Member)

Consultant:
Woolpert Consultants, Indianapolis

General Contractor:
Milestone Contractors, Columbus, IN

Detailer:
Vincennes Steel, Vincennes, IN (NSBA Member)

Fabricator:
Vincennes Steel, Vincennes, IN (NSBA Member)

Erector:
Harmon Steel, Indianapolis, IN

and the existing piers during Phase II and III. The superstructure was constructed to the final vertical profile grade of I-65 with no camber. In Phase III, the two transverse girder field sections were field welded together and the transverse post-tensioning tendons at the girders were stressed. Stressing of the transverse tendons lifted the transverse beams off of the two outside rows of falsework. Phase IV consisted of a two-stage stay stressing sequence to pull down the ribs while maintaining the vertical geometry of the superstructure. Following Phase IV, the two inside rows of falsework had been effectively disengaged and the superstructure was entirely supported by the ribs and abutments.

Analysis and Design

The structure was analyzed using a three-dimensional finite element model so that the two-way behavior of the superstructure and the three-dimensional behavior of the ribs could be adequately characterized. The rib geometry was optimized by fitting a compound circular curve through the theoretical equilibrium dead load thrust polygon in order to minimize self-weight moments in the rib. Live load influence surfaces were developed to determine worst case live load positions for design of the superstructure, ribs, and hangers. The critical buckling modes of the ribs were identified using nonlinear finite element analysis to verify adequate global stability of the structure. The bridge was designed to satisfy ultimate strength design criteria in the case of failure or loss of a cable-stay hanger.

Conclusion

The Columbus Gateway Arch utilized three key creative innovations to meet the project constraints: 1) The use of cable-stay hangers to facilitate transfer of the superstructure dead load into the ribs; 2) The use of a 45° battered pile foundation to eliminate the need for a tension tie and dramatically improve redundancy of the structure; and 3) Overall structural achievement in developing a uniquely configured signature structure that satisfied severe geometric constraints and maintained one lane of traffic in each direction on I-65 during construction.

The efficiency of the structural system is demonstrated by the fact that the structure cost only $185/ ft2 including staged construction items and $150 per sq. ft. without. The bridge was constructed over a period of 16 months. The structure will stand for years to come as a landmark and testament to the commitment of the city of Columbus toward engineering and architectural excellence.