HIGH-STRENGTH STEEL CREATES CONSTANT DEPTH

The use of AASHTO M270 Gr. 70W steel in conjunction with AASHTO M270 Gr. 36 and Gr. 50 steel on a through truss bridge reduced costs and improved aesthetics

By Charles E. Wood, P.E.

A SLEEK NEW CENTRAL BRIDGE WITH SUBTLE GRACE AND STYLE NOW SPANS the Ohio River between Newport, KY, and Cincinnati, replacing the historic old Central Bridge. The new bridge, a three span continuous, parallel chord, through truss carries US 27 over the Ohio River and was completed and opened to traffic in November of 1995. The new Central Bridge was designed and constructed under the authority and funding of a federal demonstration project developed for the replacement of the old Central Bridge.

HISTORY

The original Central Bridge, built in 1890-91 by the King Iron and Bridge Manufacturing Co., was the oldest existing cantilever truss bridge in Kentucky until its demolition in 1992 as part of this replacement project. This bridge, commonly referred to by bridge designers as the "Standard Cantilever Truss," served as the prototype for many cantilever truss bridges built later in the United States.

The narrow, two-lane, century old bridge had been modified and rehabilitated several times during its lifetime. Following an in-depth inspection conducted in 1980, the bridge was given an overall sufficiency rating of 5.0 (out of a possible 100.0) and the load rating reduced to three tons. Rehabilitation work contracted in 1984 extended the life of the structure (at the reduced load rating) until a contract could be let for its replacement.

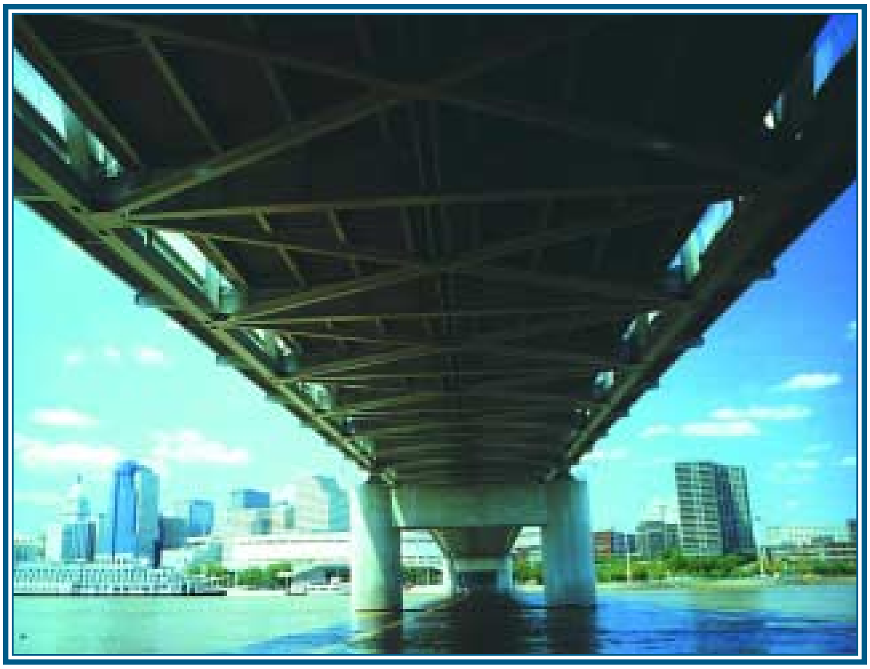
Funds for the replacement of the old Central Bridge were made available by means of a federal demonstration project legislated through Public Law 99-272 dated April 7, 1984 (an amendment to Section 147 of the Federal-Aid Highway Act of 1978.) This amendment authorized funding for the bridge replacement and other projects that would demonstrate "the latest high-tech geometric design features (including safety hardware) and new advances in highway bridge constructions" and further stated that "…these projects should use state-of-the-art technology, and all design elements, including the decking, should be designed to provide the best life-cycle costs, thereby minimizing future maintenance and rehabilitation costs…[E]xpedited procedures [should also be used] on these projects in order to demonstrate the feasibility of reducing the time required to replace unsafe bridges."

PRELIMINARY DESIGN

The FHWA Alternate Bridge Design Policy, June 9, 1988 Federal Register Notice, page 21,637, required that at least two different bridge designs be prepared and provided in the project plans as alternate designs when the construction costs for a bridge exceed $10 million. Original estimates for the Central Bridge replacement cost of a new bridge bridge in the $30 million range. In compliance with the Alternate Bridge Design Policy, conceptual plans for variations of a steel truss and a cable stayed bridge were considered for the replacement bridge.

Two basic configurations for the main bridge steel alternate were studied: a two-span continuous truss with a two span continuous girder unit at the south end and a three span cantilevered truss. Both span configurations were studied as constant and variable depth trusses. After the FHWA expressed concern regarding the non-redundant hangers necessary in cantilevered trusses, the span truss was re-studied as a continuous unit.

The cable stayed alternate study considered cast-in-place concrete, precast segmental concrete, and a superstructure of welded steel plate girder edge beams and floor beams with a composite concrete deck. Various cable and tower configurations also were included in the conceptual study.



The new continuous constant depth Central Bridge features spans of 574', 850' and 425'. It's innovative design utilizes three different strength steels to correspond to varying stress levels throughout the structure, including AASHTO M270 Gr. 70W, a high-strength quenched and tempered low alloy steel for areas subject to high stresses and negative moments.

The recommended cable stayed alternate consisted of two cable-stayed spans and a continuous flanking span using a composite superstructure.

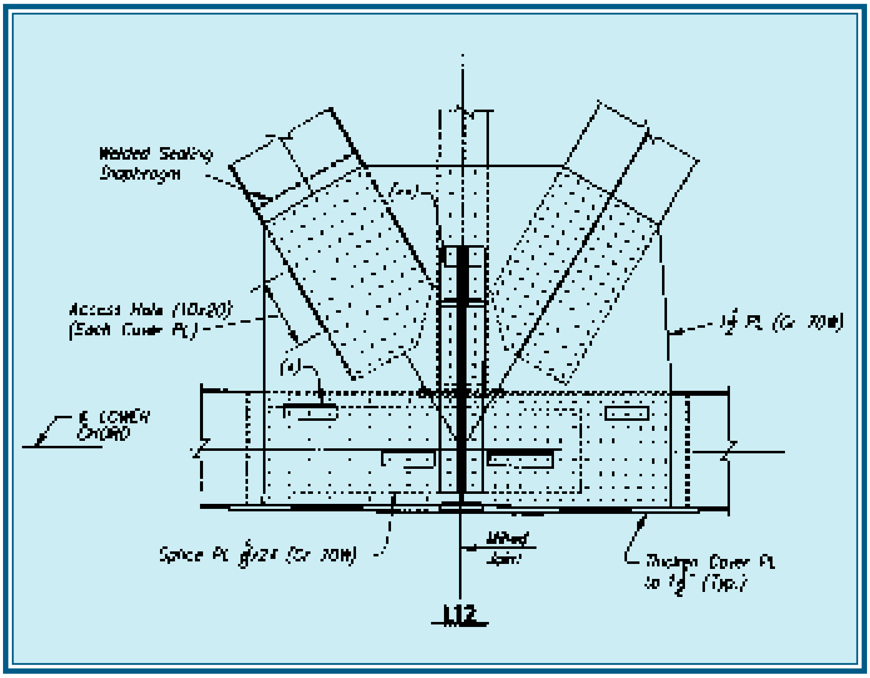
Although the Kentucky Department of Highways received eight bids for the construction contract, no bids were submitted for the cable stayed alternate. C. J. Mahan Construction Co. of Grove City, OH, with a low bid of $25.9 million, was awarded the demolition and construction contract for the steel alternate.

BRIDGE DESCRIPTION

The new Central Bridge, carrying US 27 over the Ohio River between Newport, KY and Cincinnati was designed using a team concept with Hazelet + Erdal, Inc., of Louisville, KY, serving as lead consultant, in association with Burgess & Niple, Ltd.,of Columbus, OH, and Balke Engineers of Cincinnati. This three span continuous truss has spans of 574', 850' and 425' for a total length of 1,849'. The 70' constant depth trusses spaced at 67'-0" center-to-center provide a usable deckwidth of 60'-0" with concrete barriers on each side. An 8'-0" sidewalk cantilevers from the outside of the truss on each side of the bridge.

The substructure for the main spans consists of four piers with two of the piers in the water. The main river piers, Piers B and C, are two-column units with a heavy strut beam at the top. These piers were designed without webwalls in order to maintain an open view of the panoramic Cincinnati skyline. The anchor piers, Piers A and D, are founded on steel H piles driven to rock. Both river piers have tremie seals keyed 8' into solid bedrock.

The Ohio Approach Bridge consists one 51'± P.C.I. beam simple span with an abutment founded on steel piles driven to rock. The five P.C.I. beam Kentucky Approach spans approximately 393' in total



length, are supported by four piers and one abutment, all founded on point bearing BP I 2x53 piles.

The truss members were designed in accordance with the AASHTO Guide Specifications for Strength Design of Truss Bridges (Load Factor Method). The design live load on the structure is HS25 or Alternate Military loading. The wind load is based on a wind velocity of 84 MPH. Earthquake design conformed to the AASHTO Guide Specifications for Seismic Design of Highway Bridges, 1983, using an assumed acceleration coefficient of 0.05 and design forces for Seismic Performance Category A. Bridge piers were designed for barge impact in accordance with the FHWA Guide Specification and Commentary for Vessel Collision Design of Highway Bridges, 1990, using a 15 jumbo hopper bare tow or a runway single jumbo hopper barge.

Fabricators on the project were AISC-member Stupp Bros. Bridge and Iron Co. and AISC-member Vincennes Steel Corporation. Erectors were J.F. Beasley Construction Co. and Armstrong Steel Erectors, Inc.

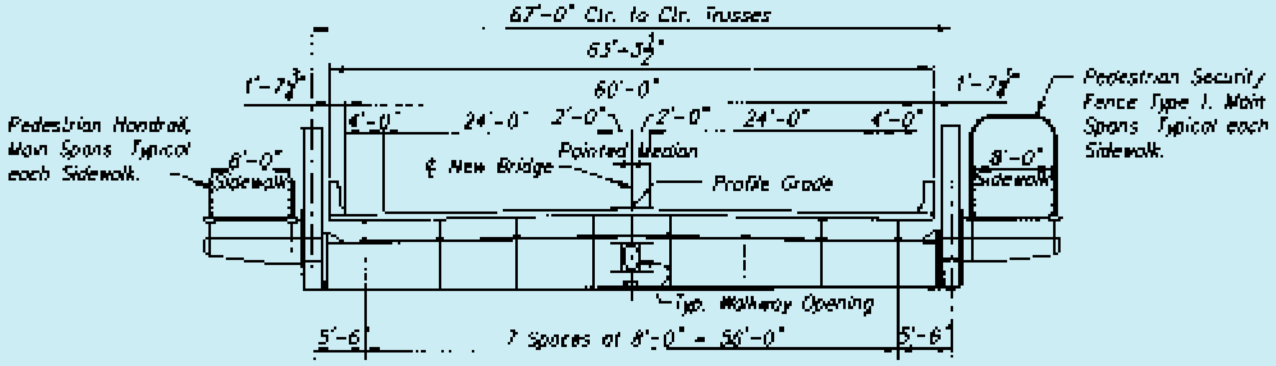
Bridge Layout Influences

Requirements of various community groups and federal agencies greatly influenced the placement of three of the four main piers and, thus, the final span configuration of the bridge. As a direct result of the Environmental Impact Study and community involvement, Pier B (north river pier) was located at the site of Pier 5 from the original bridge. Since no piers were allowed in the Cincinnati waterfront recreational area, Pier A was placed north of Mehring Wav. Coast Guard requirements for an 800'clear navigation channel located Pier C.

The location of Pier D, although not identified by any community or agency requirements, was greatly influenced by the floodwall on the Kentucky river bank. If the pier was placed south of the floodewall, the profile grade would have to be raised for the lower chord member to clear the top of the floodwall. This was considered undesirable because the approach roadway had to meet existing city streets a short distance away. Although a pier south of the floodwall would have improved the symmetry of the structure, the additional work would have cost considerably more than the P.C.I. beam girder span selected. Economics prevailed and the pier was located north of the floodwall.

The minimum vertical clearance within the navigation channel, set by the U.S. Coast Guard, is 55' above the 2% floodline (El. 474.3) and 69' above normal pool (El. 456.8) which is the average June flow. Subsequently the controlling elevation for vertical clearance was set at Elevation 529.3.

Site requirements affected the design of the floor system. A Conrail industrial track crosses



TYPICAL TRUSS SECTION

under the north end of the truss. With the need to maintain a minimum vertical clearance of 21'-0" above the railroad tracks and to meet the street grade of Pete Rose Way, only 400' from the railroad, engineers were charged with the task of minimizing the bridge construction depth. Shallow depth floorbeams provided the optimum solution. The decision to use shallow depth floorbeams subsequently affected the placement of the sidewalks on the bridge. In order to accommodate the 63'-3½" deck width and still maintain shallow floorbeams, the designers cantilevered the sidewalks outside of the trusses.

Design Details

To minimize deck participation in truss strains, the 63-3 ½" wide truss bridge deck was divided into nine four or five span continuous units. Eight lines of W24x68 or W24x76 (Grade 50) stringers support the 8"-thick composite reinforced concrete slab. Welded plate girder floorbeams (Grade 50) are spaced at 41'-0' in the north span and 42'-6" throughout the remainder of the bridge. With the exception of four floorbeams in superelevation transition at the south end of the truss, the ½"-thick floorbeam webs taper from 64" at the center to about 56" at the truss connections. On each side of the floorbeam, ½"-thick transverse stiffeners have been welded to the web. The inspection walk access hole located at the center of each floorbeam measures 30"x18".

The stringer-to-floorbeam expansion bearings utilize elastomeric pads throughout the truss. These relatively maintenance free bearings are designed to allow movement without the usual problems of rust or "freezing up" associated with steel-to-steel bearings.

Truss System

Designers selected a standard Warren truss scheme to compliment the clean lines of the parallel chord design. All of the truss members are 24"-wide with depths varying from 20" to 32". Grades of steel used in the welded "H" and scaled box truss members vary from Grade 36 in lower stressed members and bracing to Grade 7OW in the highest stressed members such as upper and lower chords. Most of the chord members and compression diagonals are sealed box members. Tension upper chords, verticals, tension diagonals, sway frames and struts are primarily "H" members.

Demonstration Project Special Features

The most unique feature of the new Central Bridge is the use of different strength steels to correspond to varying stress levels throughout the structure. Designers used AASHTO M270 Grade 7OW, a high-strength quenched and tempered low alloy steel in areas subjected to high stresses and negative moments and AASHTO M270 Grade 36 and Grade 50 in low and moderate stress level areas. Nearly 20% of the approximately 11.6 million pounds of structural steel used in the bridge is Grade

7OW, 50% Grade 50 and the remaining 30% Grade 36. The new Central Bridge is the first major truss bridge in the country to make use of Grade 7OW steel.

Both special materials and low maintenance features were incorporated into the deck. Type K expansive cement was used in the deck to minimize shrinkage cracks. Concrete using this type of cement expands against the internal reinforcement during the 7-day moist cure period and then shrinks to zero expansion/contraction, significantly reducing shrinkage crack tendencies. By reducing the number of shrinkage cracks, the amount of road salt contaminated water reaching the reinforcing steel is minimized, thus prolonging the life of the deck.

The reduced number of drains in the deck at the north end of the bridge also minimizes maintenance requirements. Due to the recreational use of the area directly below the bridge, water could not be allowed to fall freely to the ground. By taking advantage of the relatively steep grade at the north end of the bridge, designers eliminated several deck drains and allowed the water to run along the curb to a double drain at the north end. Fewer deck drains means maintenance requirements to keep the drain open will be reduced. Use of neoprene and stainless steels in the expansion dam drains at Piers A and D also help reduce corrosion potential and subsequent maintenance.

The paint system was designed for long life and low maintenance. The three-coat system consists of an inorganic zinc primer, an epoxy intermediate coat and a urethane finish coat. The epoxy intermediate coat provides the long life to the system and the urethane finish coat provides the color and ultraviolet protection for the epoxy coat. All of the primer and part of the intermediate coatings were shop applied.

A wide variety of inspection access features have been incorporated into the superstructure of the bridge. Longitudinal safety cable/handrails run full length of the truss along the upper chords and transverse inspection walkways have been attached to the struts at upper chord Panel Points U14 and U34. The safety cable, with the appearance of a handrail and designed to support the dynamic force of a falling person, meets OSHA requirements. The polyester-coated barrier strand used for the upper chord handrail cable is designed to be impermeable to the moisture, ductile and colorfast. The transverse inspection walkways consist of 1½" o.d. pipe handrails attached to the welded plate girder struts.

The floorbeams have been outfitted with several inspection access features including grab rails, clip angles to be used for foot holds, and a safety cable transverse to the deck. Small clip angles have been placed near the ends and on each side to provide safe access to the floorbeam from the lower chord, and grab rails of 1½" o.d. pipe have been installed on each side of the floorbeams. A transverse safety cable has also been installed below the stringers to allow inspectors to "tie off" their lanyards as they move along the floorbeam.

Elimination of the tall towers associated with variable depth made unusually large erection equipment unnecessary. In addition, the similarity of the shapes and alignments of the steel piece, inherent to a parallel chord scheme allowed the contractor to establish relatively routine lifting procedures to expedite fit-up.

A variety of other techniques and materials were employed to facilitate construction. All of the bolts used throughout the structure were mechanically galvanized, minimizing blast cleaning of the truss joints before painting and improving corrosion resistance. In addition, the "turn of the nut" method was used on all shop and field bolts, speeding up the construction process. Other time saving features on the bridge include the shop application of primer and the intermediate paint coat and stay-in-place forms used in the approach span decks.

Cost saving design and construction techniques were also applied to the substructure. Phase construction for the piers reduced the number of concrete column forms required. The deep pier strut beam was constructed in lifts rather than "full depth" to decrease the strength of the falsework required. The main piers were designed with individual footings, thus minimizing the size of the cofferdams and reducing the cost of these temporary structures.

Dynamic monitoring of the driving of these piles originally planned for use in the Kentucky Approach indicated unforeseen difficulties with the use of concrete piles and the plans were revised to specify steel bearing piles. This technique allowed engineers to recognize a potential problem and make necessary changes to fit the field conditions.

The large number of bridges and alternate routes available to traffic in the Cincinnati area provided a major benefit to expediting the construction of the new bridge. The contractor did not have to maintain traffic on the bridge while construction was on-going, and, in fact, was able to close the bridge and remove it completely before beginning any new construction.

Charles E. Wood, P.E., is the managing principal in charge of the Louisville office of Hazelet & Erdal/Dames & Moore. This article is adapted from a paper delivered at the 1996 National Steel Bridge Symposium.