Second Blue Water Bridge

Port Huron, Michigan

Jurors Comments

Classic concept of semi-through arch in a modern, simple and clean design...Side-by-side technologies, 60 years apart...Elegant long span structure.

As water leaves the swift-moving Saint Clair River, located at the southern tip of Lake Huron in the swift-moving Saint Clair River, it forms an international boundary between Ontario and Michigan. For almost 60 years, international access between Port Huron, MI, and Point Edward, Ontario, has been provided by a cantilever truss bridge built near the north end of the river.

The Michigan Department of Transportation(MDOT) and The Blue Water Bridge Authority in Ontario are jointly own and operate this cantilever bridge—each collects tolls from traffic entering the bridge, and traffic leaving the bridge must pass through customs and immigration on each end.

Design of the New Bridge

In 1993, the owners retained a design team to develop studies and plans for the new bridge. The first phase of the work to prepare engineering studies for the new crossing and develop a study report.

The preliminary cross-section was established as a three-lane deck with sidewalk, traffic barriers and pedestrian railing. The preferred alignment adjacent to the existing bridge was set. All project documents would be completed in SI units. The design would conform to the new AASHTO *LRFD Bridge Design Specifications* and major provisions of the Ontario Highway Bridge Design Code (OHBDC), with the LRFD wing the primary specification.

Selected Structure

For the main river crossing, a continuous tied-arch was selected with approaches of box girders and multi-girder spans. A requirement for the main bridge construction was that the work be divided equally between the owners, and that the construction be equally divided between a contractor from Canada and one from the United States in a joint venture contract dictating that two fabricators and two steel suppliers be required. A considerable effort was required during the design to ensure that the details, materials, standards and procedures in the plans were proper for construction in both countries.

The main span deck is reinforced concrete for three traffic lanes and a pedestrian sidewalk. The stringers are rolled beam sections made continuous and composite with the deck slab. The floor beams are welded I-sections with welded transverse stiffeners. Steep roadway grades (4.65%) and channel clearance requirements resulted in a shallow superstructure depth, limiting the available web depth for the floor beams, resulting in the need for intermediate floor beams between vertical locations. Welded I-members were used for the floor system lateral bracing.

Under dead load only, an uplift condition would occur at the anchor span end bearings. A counterweight was added to provide a positive reaction under all loading conditions, except the most extreme live load case, and the bearings here are designed to resist the uplift resulting from that case. The floor system at the anchor end required modification to accept a concrete counterweight. Intermediate stringers were added to the typical cross-section in the two end panels. Stringer depth was increased to 36' in these two panels to support the concrete mass. The stringers were coped over the floor beams to accommodate their increased depth.

Power-driven, rail-mounted platform travelers provide access to the underside of the deck and floor system. One traveler rests near the anchor piers at each end of the bridge, and each is capable of traversing the entire length of the arch structure. Access to the remainder of the bridge is provided by an integrated system of crosswalks, ladders, stairways, railing and handropes. The special consideration given to access inside the tie girder resulted in forced ventilation, adequate lighting and special surface finishing of the interior.

A number of steel arch bridge spans have been built, and many of these are simple spans using a horizontal steel tie member from end-to-end of the arch to resist the horizontal force of the arch, but less than six continuous tied-arch bridges have been previously used in North America.

When the vertical load on the arch varies, some flexural strength and stiffness is required, since the arch cannot change its shape to accommodate the change. The tie member is commonly supported by the arch so they can act together flexurally, and the bridge floor is commonly attached to the tie.

Since the tie girder and arch rib act together flexurally, it is possible to choose, by selective proportioning, the member that will carry most of the flexural stresses. For this design, the tie girder, which directly supports the bridge deck, was chosen to be the principal member and it is proportioned to be considerably stiffer than the arch rib.

This bridge layout consists of several basic segments: the main support framing consists of the end segments made up of the anchor spans (85 m) and those portions of the main span extending from the main pier to the knuckle joints (36 m); the middle segment or main arch (209 m) between the knuckle joints (basically independent, closed units, except for the flexural continuity of the tie girder and arch rib at the knuckle joint); steel vertical columns and hangers connect the arch rib and the tie girder; and steel floor beams supporting the steel floor stringers are attached to the tie girders.

Arch Details

The continuous tied-arch requires a number of special design considerations, as do the LRFD requirements, and the demands of the owners for this crossing.

The arch rib is a box about 1.2 m on a side made of welded steel plates, and near each end is a welded closure plate to seal the main length of the arch rib members. These sealed sections are not painted, but they have been partially evacuated, then filled with dried air and sealed. Pressure test points are located in the end portions of the members for long-term monitoring of interior pressure.

The tie girder is a steel box built up by bolting, and consists of steel plates with corner connecting angles it is about 1.2 m wide by 2.5 m deep. The tie girder is the tension member that provides the sole horizontal support for the entire arch. In addition, the tie grinder provides most of the flexural resistance of the arch segments, it is the quintessential fracture critical member. Mitigation measures were proposed in the study report to make this tied-arch structure, then under federal moratorium, acceptable to the owners. Clearly, mitigation measures translate into additional, necessary costs. If the tie were a steel box assembled by welding, it is possible that, under the impact of varying loading, a crack might propagate across the entire member (using the welds as a path from one plate to the other). For this reason, it was decided that the tie girder would not contain any welding but rather, would be assembled by high-strength bolts. Even with such measures a potential crack could propagate across one of the plates or elements of the tie girder. Therefore, as a safeguard, the tie girder was proportioned so that it could withstand the loss of any one plate or element. These measures gave the tie girder the internal redundancy desired and removed the specter of fracture-critical fabrication requirements.

Temperature changes and loads on the bridge cause movements at the supports. The main arch bearing in Ontario is fixed against sliding with the others designed for longitudinal sliding. The capacity for sliding is provided by incorporating Teflon on polished stainless steel within the bearing. At the Michigan

main pier, this bearing design accommodates movement of over 300 mm contraction and over 400 mm expansion. A tough flexible disk in compression is a part of the bearing's support for vertical load, and permits the small rotation that takes place at the support joints.

In addition to the bolting used to assemble the tie girder, all the member connections are made with high-strength galvanized bolts The paint system used on the bridge consists of a coat of zinc-rich primer, a second coat of epoxy and a top coat of light grey urethane. The primer was shop-applied to all surfaces of completed members with the final two coats were shop-applied to all, except faying surfaces at field connections.

Arch Erection

Erection from the water, which would have been difficult due to the speed of the current, was banned by the U. S. Coast Guard. The design plans included a feasible erection procedure in accordance with LRFD specifications. First, under this plan, the anchor span was erected using temporary bents and then placed a falsework tower over the main pier. Erection of the main span was accomplished by cantilevering from this point, using stays secured at the anchor pier and passing over the tower to support the river span sections.

Each half of the arch was erected by a contractor from that country. To handle the uplift created by the cantilevering, special tie rods were set into the anchor pier footing and for attachment to the tie girder at the point of the stay attachment.

LRFD Specifications

The bridge was designed using the 1994 AASHTO *LRFD Bridge Design Specifications*. The completed edition was released shortly before the start of final design. Specific project design criteria, begun during the study phase, were developed and shown on the plans. These began by establishing the LRFD as the basis for design and continued with further definition and refinement, all specific to this project.

The loadings and traffic patterns on the existing bridge had been studied by the design consultant previously, the findings were a fairly common condition, bumper-to-bumper traffic, with a high proportion of trucks over the full-length of the main bridge and approaches, waiting to pass immigration and customs. The experience with this bridge was one of the reasons that the LRFD specifications contains a "Strength II" load condition where in a special loading applicable to a specific bridge is used. The special loading condition, as selected and included in the design criteria, consist of loading any two lanes uniformly with an intensity of 24 kN/m centered in each lane with no concurrent load in the third lane or sidewalk, no superimposed concentrated loads and no impact.

None of the arch segments carries its load as an arch until the segment is closed, or joined, with the tie. Until that is achieved, the members are all merely beams requiring falsework and temporary support. The detailed erection sequence shown in the plans included: staging; falsework and temporary bracing locations; temporary bracing locations and loadings; deflections and procedures for making closures of the several segments of the tied-arch. The final design and detailing of the permanent members of the tied-arch was checked and adjusted to accommodate the loadings from the construction sequence.

The design criteria indicates the requirements for deck replaceability, and the plans include staging diagrams for the feasible procedure applicable to each part of the bridge.

Project Team

Co-Owners
Michigan Department of Transportation & Blue Water Bridge Authority

Designer
Modjeski and Masters, Inc.

Steel Fabricators
PDM Bridge and Canron Construction Corp.

Steel Erector
Canron and Traylor Brothers

General Contractors
PCL/McCarthy, A joint Venture