New York Route 367 over Bentley Creek

Village of Wellsburg, New York

Jurors Comments

...brings old iron together with new high tech materials (FRP) to extend the service life of a bridge in this quiet country setting. Innovative concept to extend the life of old steel bridges...

There are approximately 19,000 steel truss bridges in the United States, most of which were built over 50 years ago and have not had the benefit of regular, thorough cleaning. It was not until recently that bridge owners gained an awareness and appreciation for a good inspection and maintenance program. Cleaning structures of de-icing salts and other debris was virtually unheard of in the early years of these structures. Critical structural elements were allowed to deteriorate as a "natural" course of events. Even under these harsh conditions, many truss structures have demonstrated the longevity of steel as a building material by surviving and performing satisfactorily for the better part of the past century.

With an increased effort placed on inspection and load rating, however, some of these bridges have been identified as being structurally deficient and marked for replacement. Because of their age, it is often accepted that these bridges are at the end of their useful life. The project described in this submission provides credible evidence that this is not necessarily true. Though a steel bridge may be 60 years old, the employment of new technology, such as super-light advanced composite decks, can rejuvenate and extend the service life of "tired" steel bridges a point the deck replacement at Bentley Creek illustrates perfectly.

Project Objective

Remove the 14 Ton weight restriction as quickly as possible to satisfy the public's demand for highways without impediments to local commerce.

Project Description

The 1940s vintage bridge carrying New York State's Route 367 over Bentley

Creek in Chemung County found new life with the installation of a lightweight fiber reinforced polymer (FRP) composite deck. Though it was considered a prime candidate for replacement due to its age, condition and 14 ton weight restriction, the service life of the bridge has been extended by an expected 30 years by merely replacing the deck, performing some minor steel repairs and painting the structure.

A 32 psf FRP deck replaced the 170 psf original concrete deck and excessive courses of asphalt wearing surfaces that had been added over the years. Because the new deck is radically lighter than the original deck the bridge load ratings were almost doubled, raising them higher than the original design. This was possible despite the fact that the structural steel had suffered some section loss and corresponding loss of strength. A total dead load of 265 tons was removed.

The deck itself rates much higher than the bridge. It meets a L/800 deflection requirement with an inventory load rating of HS85 (154 tons). Proof tests indicate that the actual load capacity of the deck is even greater than these analytical ratings.

The entire rehabilitation project was conducted by the New York State Department of Transportation's (NYSDOT) in-house maintenance staff over the course of two construction seasons. During 1998, the old deck was removed, areas of extreme section loss were repaired and a temporary steel grate deck was installed. In 1999, after the structure was painted under contract, the temporary deck was removed and replaced by the FRP deck. The deck replacement operation was completed in less than 30 calendar days, proving that rapid installation would be a huge benefit in urban areas where it is especially desirable to minimize disruption to traffic.

Unique aspects of the project

The project was the first application of a FRP deck on a truss bridge on a state highway system. Due to this lack of precedence, many innovations were developed, these included:

• Deck to steel attachment—a pre-cast polymer concrete haunch with a bolted connection between the floor beams and the deck;

• The sizing and design of the deck section to match "existing" thickness so that approach modification was minimized;

• Eliminating the need for using the existing stringers for support; 4. modular deck assembly (6 panels covering a 25' × 141' area);

• Load carrying deck panel splice details;

• FRP curb (behind the steel box beam railing); scupper frames cast into FRP deck;

• FRP sidewalk (which reduced the dead load by 32 tons); and

• Field cut FRP filler panels between the deck and sidewalk to protect the bottom truss chord from water intrusion, prolonging the life of the structure.

Benefits

A deck replacement can be done in much less time than a bridge replacement project, therefore reducing the negative economic effect felt by local users and improves safety. Deck replacement is also done with less environmental impact by eliminating any in-steam channel work and disturbance to vegetated areas. The strategy may be able to be used to save an otherwise obsolete structure. In cases where the structure has historic significance, it can make rehabilitation a feasible alternative when it might not have been previously. A comparison of actual costs to replace a similar truss suggests that there is substantial economic benefits as well. The value of this project was $876,0001 versus $2.3 million for designing and constructing a similarly sized truss replacement.

The benefits of installing a FRP composite deck onto a steel truss bridge are manifold:

• Shortens project development time to implementation;

• Dramatically improves load ratings;

• Removes a hindrance to local com merce;

• Protects structural steel from the weather;

• Improves feasibility of rehabilitating historic structures;

• Short duration, less disruption to traffic, affecting goodwill, economics, and safety;

• Environmentally friendly;

• Cost savings over replacement; and

•Extends service life with minimal effort.

Though the amount of new structural steel was minimal on this project, the successful rejuvenation of this 60 year old truss makes a convincing argument that steel is a very durable and long lasting construction material.

Project Team

Owner:
New York State DOT

Designer:
Wagh Engineers, P.C.

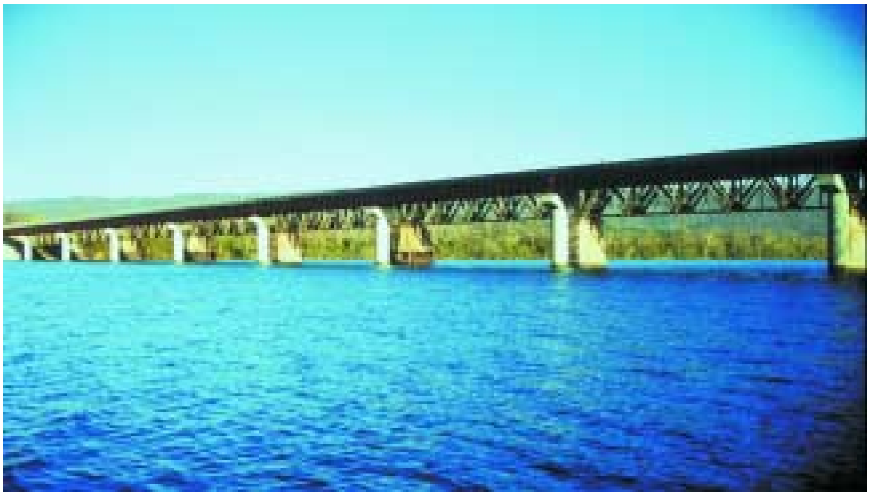
Steel Erector:
New York State DOT Bridge Maintenance

General Contractor:
New York State DOT Maintenance

Merit Award: Railroad

CSX Bridge over Tennessee River Slough

Bridgeport, Alabama



The new CSX Bridge spans over the Tennessee River Slough at Bridgeport, Alabama and is a modern single-track railroad structure, 1469' in length, with ten simply supported, steel composite deck plate girder spans and a ballast deck. The bridge is located on the CSX Nashville-Chattanooga main line, an sees an average of 27 trains per day. Bridgeport is located in the northeast corner of Alabama, approximately 30 miles downstream from Chattanooga, Tennessee. The new bridge replaces an historic deck truss structure on a separate parallel alignment.

The new span layout has two end spans at 147'2" and eight interior spans at 146'10" between piers. The actual girder span between bearings is typical in all ten spans, and is 144'0". The steel superstructure is a redundant system with four deck plate girders spaced on 4-ft. centers that are composite with a reinforced concrete deck. The girders are 9'4" deep and use ASTM A709 Grade 50W weathering steel.

The substructure consists of hammerhead piers with circular columns founded on steel H-piles. Each pier column is 7'6" in diameter with an average column height of 45'. The geology of the site is karstic with variable weathering of limestone and dolomite. The rock is variable and contains voids that are filled with soil. Due to the variability of the rock and soil, dynamic testing of piles were used to verify pile capacities. Piles were driven to lengths of up to 200' in some locations. The use of steel piles were shown to be very effective in developing required bearing capacity and in having splicing capability to accommodate the variable rock profile.

Overall, this state-of-the-art railroad bridge design incorporated strength, function, economy, safety, constructability and aesthetics. Specific innovative features that were included are:

• Use of Grade 50W weathering steel for initial economy, long term low maintenance and aesthetics;

• Use of bolted stiffener and bracing connections for improved fatigue resistance;

• Use of four girder system for redundant fatigue and fracture considerations;

• Use of solid plate diaphragms with access holes for ease of fabrication;

• Use of dual inspection walkways within outside girder panels for ease of access and inspection;

• Use of uniform girder span layout for economy of repetition;

• Use of economical span lengths for plate girder design, balancing superstructure and substructure costs;

• Use of circular reinforced concrete pier columns for strength, hydraulics and economy.

The existing bridge is an historic structure, and will be kept and maintained by the city of Bridgeport as a pedestrian bridge providing access to an island in the Tennessee River at this location. The bridge was originally constructed in the early 1850s and has portions of the original masonry piers and abutments still in use. The original bridge had timber trusses and has been modified several times over the years. During the Civil War, the bridge was the focal point of several conflicts between Union and Confederate forces vying for its strategic importance in transportation and communication. The bridge superstructure was destroyed and rebuilt twice during this period. Five of the deck truss spans were reconstructed last in 1910, and the other four spans in 1930. These existing spans are all steel pin-connected deck trusses. General bridge deterioration and related high maintenance costs have lead to the need for replacement. The new plate girder bridge built along side the old historic truss bridge illustrates the state-of-the-art in modern railroad bridge design as contrasted by the slender clean lines of the new and the deep busy appearance of the old.

Numerous other environmental issues had to be mitigated in order to obtain a permit for the new bridge including avoiding two archaeology sites adjacent to the new alignment on the island, wetland impacts on the island and threatened and endangered species impacts in the river.

Final design was completed in February 1997, and the construction contract was awarded in April 1997. Construction began in May 1997 and was completed in November 1998.

The CSX Bridge over the Tennessee River is an economical and aesthetically pleasing design with low maintenance weathering steel girders and slender circular pier columns. It combines the required strength, function and serviceability with a clean slender appearance that blends well with the natural river environment and wooded riverbanks.

Project Team

Owner
CSX Transportation

Designer
HDR Engineering, Inc.

Steel Fabricator
Carolina Steel Corporation

Steel Detailer
Carolina Steel Corporation

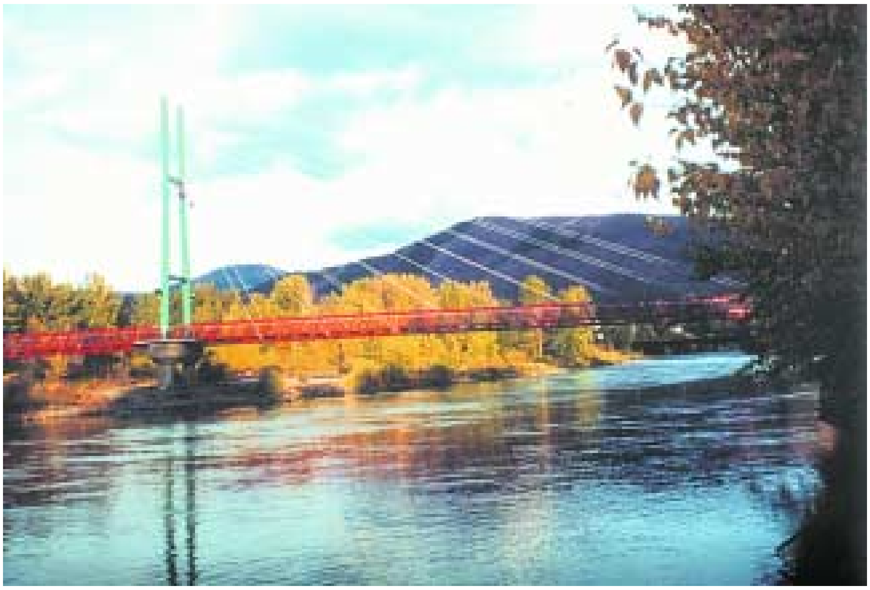
Steel Erector
Scott Bridge Company, Inc.

General Contractor
Scott Bridge Company, Inc.

Merit Award: Special Purpose

California Street Bridge

Missoula, Montana



Missoula is known as Montana's bicycling town. The city of Missoula has long been a supporter of non-motorized transportation, and has been proactively developing a system of trails, bike-lanes and side-walks. A bicycle/pedestrian bridge across the Clark Fork River has been a need in this area of town since an aging structure was torn down at the California Street location in the mid-1980s. Additionally, the river has been a substantial obstruction to travel about town for wheelchair users. In 1996 the city of Missoula hired our firm to perform a study of constructing a new bridge. That study evolved into the design of the California Street Bridge project.

The project consisted of the construction of a new bicycle/pedestrian bridge and included the following key elements:

• Developing and evaluating alternatives;

• Preparing an environmental assess ment; and

• Preparing construction documents.

The bridge provides a connection between two extensive city trail systems. That system includes a trail system that parallels the river and connects to an extensive city-wide network of non-motorized facilities. Even though this is the site of a previous bridge crossing, the location was re-evaluated to verify that California Street was still the optimal location for the bridge. The preferred site and type of structure was determined through an extensive consultant led public involvement process involving the entire community. Once the structure type and location had been determined then detailed plans were developed to construct the project. The study and environmental assessment began in 1996. Construction of the bridge started in the fall of 1998. It was dedicated and opened to the public in October 1999.

Applications of Technology

While cable-stayed structures are not a new construction method, this choice was selected for this site because it provided both a cost-effective method to span the river at this location and an aesthetically pleasing structure. The use of cable-stay in combination with a steel truss permitted the resulting structure to be relatively thin for the 400' span crossing. This also proved to be less costly than other options investigated in the conceptual stages of the project. It was estimated that the structure cost 30% less than a more conventional bridge design.

The construction staging and assembly areas available for use were limited. Use of the truss bridge design permitted assembly of major elements either on the ground or off site. The could later be assembled over the river. The design was accomplished so that the superstructure elements of the truss, floorbeams and deck could be constructed incrementally. The truss portion was designed to be self-supporting, to facilitate erection and to permit the connection of the cable-stayed portion after bridge erection and before casting of the concrete deck surface.

Technical Value

The use of the truss in combination with the cable-stayed method of support demonstrates the ability to erect a bridge over a very large river without use of unusually large equipment or disruption to a sensitive river setting. The incremental construction method was also important in that it facilitated the construction and minimalized the disruption to the surrounding land users. The elements of a composite concrete deck, steel trusses and the cable-stays act integrally to provide the efficient use of materials within the structure.

Social and Economic Considerations

Missoula is known as Montana's bicycling town because of its extensive use of non-motorized forms of transportation. Missoula is home to the University of Montana which also generates significant interest in pedestrian and bicycle use within the community. This crossing provides a critical route for residents traveling between residential areas of Missoula to the downtown area. This bridge also serves as a key link in the non-motorized network that serves the University and other areas of town.

The bridge is also located near a large apartment complex used by people who experience mobility impairments. The trail system and bridge design permit easy access for wheel chair bound users to cross the river. Prior to construction of the bridge these users were restricted to using buses or some other vehicle to cross the river because of the lack of other wheel chair compatible crossings.

The bridge was sponsored by the city's Redevelopment Agency to increase the city's pedestrian trail system and is viewed as a vital link to revitalizing the riverfront area in Missoula. The bridge is a critical link between trail systems that extend widely on each side of the river, as well as up and down its shores.

The selection of the location and bridge type were both key elements of the design process. The city's objective was to involve as much of the community as possible in the process so that acceptance and use of the bridge would be maximized. Our team made extensive use of computer based visualization methods to provide the public with technically accurate views of how different types of bridge structures would appear at various locations. Several innovated public coordination efforts were conducted where citizen input was solicited to develop the concepts for the structure. The citizens actually provided input for the type and location they preferred. The final selection was made and computer generated renderings completed prior to construction. The actual structure duplicates the conceptual plans developed in the early stages, from the detail of color to major elements.

Complexity

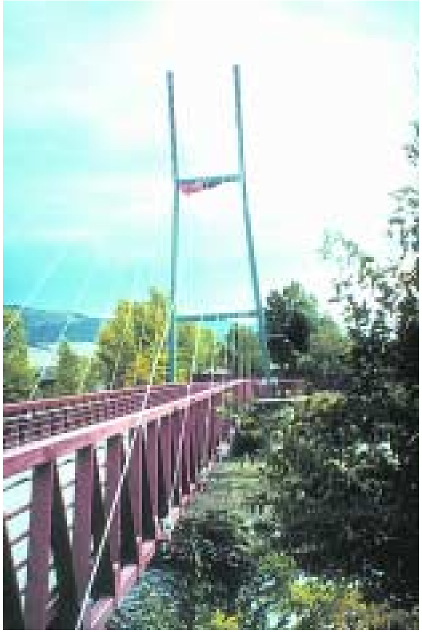
The design of the foundations, especially the center pylon foundation, required careful design and planning to take advantage of an island in the river. Each support is founded on drilled shaft concrete foundations. Earlier attempts on other projects to use this type of foundation along the Clark Fork River in Missoula had resulted in significant cost overruns when large boulders were encountered in construction, this time special care was taken to properly locate and design them to minimize possible construction problems.

The erection sequencing had to be developed in detail to balance the construction loads on the truss and cable-stayed elements. A casting pattern was developed to cast the concrete deck of the bridge without displacing the truss. Tensioning of the cables to provide the correct profile for the bridge deck also required careful planning and execution.

The site had limited area to use for staging the construction. The design was developed to permit segmental erection of the structural elements. This permitted the partial assembly of large pieces prior to erecting them over the river. The truss was erected in four pieces and bolted together over the river and the cable-stays fastened afterwards.

Meeting the Owner's Expectations

The Owner had limited funds with which to erect this structure. Yet they wanted an attractive structure that would enhance this area and attract people to the trail system. They also faced significant public concern over the aesthetics of the new bridge. All of these hurdles were over come as a result of the consultant's approach to the public involvement and design processes. The resulting structure is about 30% less costly than other available options. It has resulted in a spectacular looking structure that supports a pedestrian live load of 85 lbs. psf.



Project Team

Owner
City of Missoula

Designer
Carter & Burgess, Inc.

Steel Fabricator
Egger Steel Company

Steel Detailer
JDB Detailing

Steel Erector
Iroquois Industrial, Inc.

General Contractor
Bodell Construction Co.

Merit Award: Special Purpose

Bloomington Ferry Pedestrian Bridge

Shakopee, Minnesota

The original Bloomington Ferry Swing Bridge was closed in 1976 due to structural deterioration and rebuilt in 1977 with a new superstructure on the original center pivot pier and abutments. This bridge was closed to vehicular traffic in 1995 and replaced with the new Trunk Highway 169 (TH 169) crossing over the Minnesota River approximately one-half mile upstream.

As part of the Minnesota Valley State Trail System a pedestrian/bicycle crossing over the Minnesota River was originally planned to be incorporated into the new TH 169 river crossing. However, during the Environmental Impact Statement process conducted as part of the TH 169 project, the U.S. Fish and Wildlife Service and the Minnesota Department of Natural Resources indicated that the new TH 169 crossing was not a suitable environment for pedestrians and bicyclists. These agencies recommended that the trail cross the Minnesota River elsewhere. The decision was made to use the old Bloomington Ferry Bridge as a pedestrian/bikeway bridge. However, the existing bridge, if utilized, would have required a great deal of renovation and maintenance to remain in use. Estimated costs associated with this work led to the conclusion that repairing and renovating the old bridge was not a cost-effective, long-term solution. Therefore, the decision was made to construct a new pedestrian/bikeway bridge at the location of the old Bloomington Ferry Bridge.

A bridge type study was prepared for this location and proposed several structure types and aesthetic treatments. Several site constraints had to be overcome for this project, including:

- developing a structure that provided an unrestricted opening for the Minnesota River (the old bridge, with its center pier, caused problems with ice flows and mobility of boaters);

• keeping the proposed structure above the 100-year flood elevation;

• wide seasonal fluctuations in river elevations;

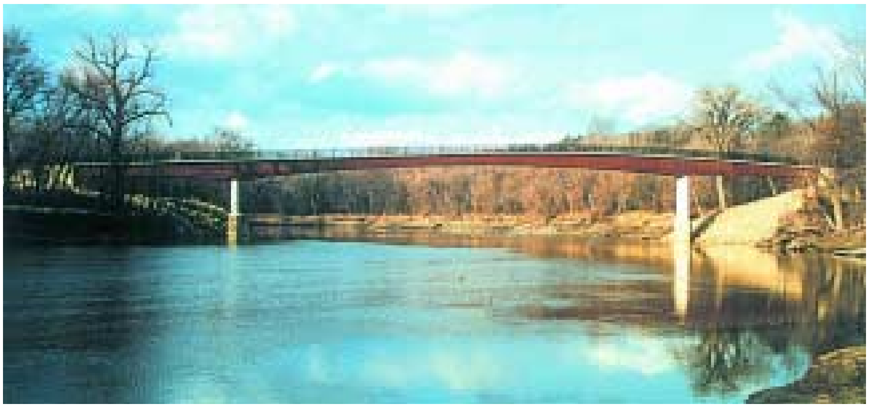
• maintaining difficult site grades and meet current bicycle design standards; and

• retaining aesthetic views of this environmentally sensitive area within the Minnesota Valley Wildlife Refuge.

A three-span parabolically arched welded steel plate girder structure with a cast-in-place concrete deck was selected for the site. In order to fit the site constraints of the river banks, and the need to provide an unrestricted opening for the Minnesota River, span lengths of 90'-255'-90' were selected. This end span ratio of 0.35 created a difficult uplift problem for the designers to overcome. Several options were developed and evaluated during the design process to account for the uplift. The chosen solution was a combination of a concrete counterweight at the abutments and a thickened concrete deck in the end spans. This solution required the designers to provide a construction sequence to assist the contractor. During erection of the beams, the contractor was required to provide a temporary tie-down system at the abutments until the counterweights were poured.

The steel girder consisted of a parabolically arched bottom flange and varied from a web depth of 66" at the center span and abutments to 120" at the piers. Due to the Minnesota River's wide seasonal fluctuation in river elevations, the contractor constructed cofferdams to facilitate construction of the piers, which were located at the edges of the river. Even with the aid cofferdams, the contractor was unable to work in the river at various times due to seasonal flooding.

To complement the aesthetics of this project site, cut stone treatments on the



abutments and piers and decorative ornamental metal railings were utilized. Unpainted weathering steel was chosen for the girders. The use of unpainted weathering steel girders enabled the designers to satisfy the need for both a functional and aesthetically pleasing structure, with clean lines, that will complement the heavily wooded natural setting in which the bridge is located.

This project utilizes a conventional type of bridge structure in an innovative use of span lengths and formed shape. A span length of 255' for the center span pushes the limits for a conventional pedestrian girder. This use of simple conventional methods of a counterweight and a thick end span deck to overcome the uplift forces at the abutments allowed the designers to maximize the center span length while utilizing simple and easy methods to overcome difficult erection and construction issues.

An important aspect in bridge engineering is the use of materials in the correct shapes and proportions for the specific site location. This project achieves that goal at this environmentally sensitive area.

Project Team

Owner
Minnesota Department of Transportation

Designer
SRF Consulting Group

Steel Fabricator
PDM Bridge

Steel Detailer
Trevian Projects LTD.

Steel Erector
High FIve Erectors, Inc.

General Contractor
Lunda Construction Co.

Garden State Parkway Interchange 159

Bergen County, New Jersey

Improvements to Garden State Parkway Interchange 159 in Bergen County, New Jersey, provide a much-needed direct connection between the southbound Garden State Parkway and eastbound I-80, an important commuter route to New York. Previously, this was a circuitous route taken either through several local streets or via NJ Route 17. This project has relieved severe peak-hour congestion on local streets as well as regional congestion extending to NJ Route 17.

The new ramp alignment includes an eight span, continuous, sharply curved, and horseshoe-shaped 834’ long curved monocell steel trapezoidal box girder superstructure with a radius of 230’.

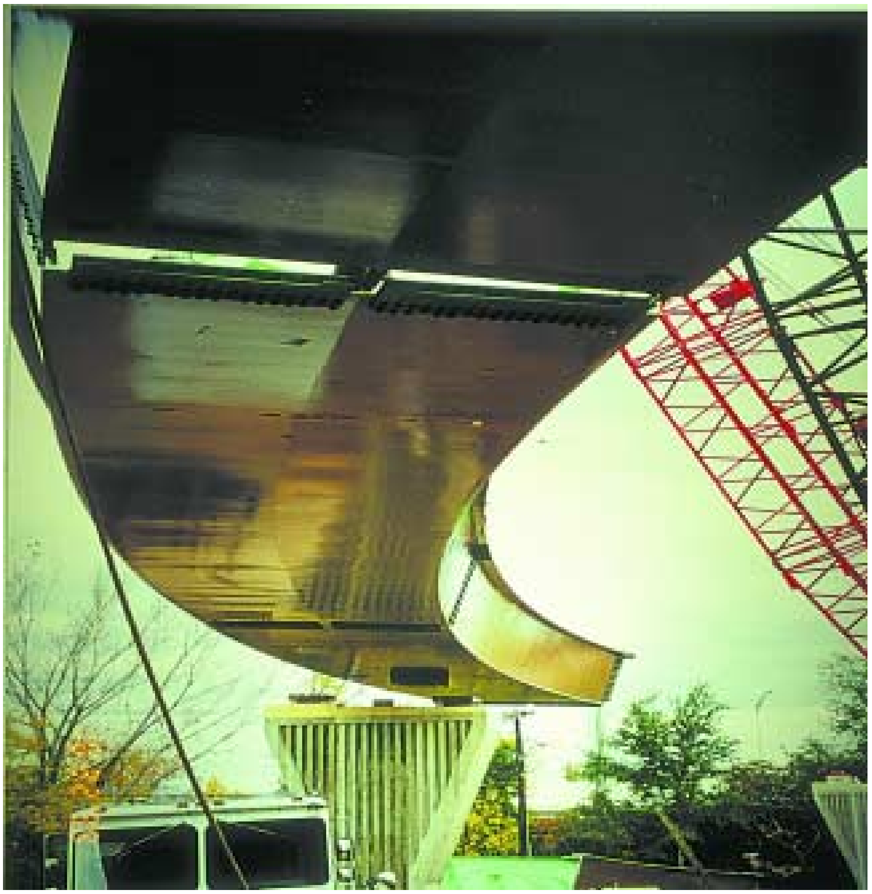
Opened to traffic in January 1998, this bridge is the first monocell box girder vehicular bridge in New Jersey. The solid stainless steel reinforcement used in its deck was also another first in New Jersey. This usage represents the largest quantity of stainless steel reinforcement in a transportation project in the United States.

The project was completed six months ahead of schedule and at a total cost of $8,339,000, less than one percent over the bid amount of $8,260,000. This slight increase was due to additional roadway barriers.

Several innovative features were incorporated into the project to address the many challenges posed during design and construction phases. Providing for thermal movements without introducing large stresses was a major challenge in such a sharply curved structure. The superstructure was designed with fixity at the abutment ends only, therefore allowing for unrestricted thermal movements at all other interior supports. At the same time, seismic movements and forces had to be accommodated without penalizing only the abutments. We developed a method that would both engage one of the interior piers to share seismic forces while still allowing for design thermal movements. The deck slab is the top flange of the box structure and for economics, a non post-tensioned reinforced concrete deck slab was also specified. Recognizing that future deck slab replacement would be impossible without closing the bridge a new method to extend the life of the deck was necessary. This resulted in the use of solid stainless steel reinforcement for the deck slab at a small increase in initial cost.

Community involvement meetings were held and a great effort was expended to assuage the concerns of the several immediate neighbors to the project. As a result, restricted hours for steel H-pile driving, monitoring vibrations during pile driving and the construction of a permanent detour route for oversized vehicles on an adjacent property were all incorporated. Special architectural treatments were specified within the substructure in order to enhance the appearance of the box girder, and paint schemes were carefully considered to achieve the best adaptation of the structure to the environment.

This complex yet aesthetically pleasing structure was built well ahead of schedule due to the environment of teamwork that prevailed among the designer, client, and contractor for the entirety of the project.



The first curved steel monocell box girder vehicular bridge in New Jersey was successfully constructed with no significant problems and opened to traffic, providing a much needed link between two major commuter routes.

The Garden State Parkway (GSP) is, at once, both a major north-south route on Interstate Route I-80, as well as a major east-west route intersect in Bergen County—a densely populated area of northern New Jersey. Until completion of this ramp, the southbound GSP had no direct connection to eastbound I-80. The previous, indirect circuitous connection was through several local streets and signalized intersections, or via NJ Route 17, another heavily traveled commuter route. This created a source of severe morning peak hour congestion on the affected local streets. Regional traffic on the already congested NJ Route 17 was seriously affected by commuters bound for New York who used Route 17 to access Route I-80. Various studies firmly established the need for a direct link between the two arteries.

The new direct connection ramp from the southbound GSP to eastbound I-80 is an extension of the existing off-ramp at Interchange 159. The new ramp passes under the I-80 bridge in the westernmost span, runs parallel to the southbound GSP and curves sharply in a loop to connect with eastbound I-80. The single lane ramp crosses over a light industrial area on a sharply curved viaduct with a 230' radius.

The new off-ramp crosses the existing I-80 overpass structure under its westerly span. The existing west abutment is a stub abutment on steel H-piles. The front row of piles is battered and the vertical underclearance in this span is limited. Therefore, retaining the large sloped fill, in order to construct the new ramp, posed another challenge. This was overcome by construction of a cast-in-place soil nailed retaining wall, another first in New Jersey roadway construction.

The ramp structure is an 875' long (measured along the centerline) horseshoe shaped eight span continuous steel monocell trapezoidal box girder made composite with a cast-in-place reinforced concrete deck slab. The 24' roadway is superelevated at 6% and has 1'6" barrier curbs on each side. The box girder web plates are spaced at 12'6" on centers at the top, resulting in 7'3" wide deck overhangs.

The span arrangement (measured along the bridge centerline) consists of six interior spans of 118'5" each with end spans of 78'9" and 85'9". The vertical profile of the ramp is a constant 0.5% upgrade ascending from the GSP to Route I-80 EAST BOUND.

The semi-stub abutments are conventional reinforced concrete, supported on 140 ton capacity steel H-piles. Tapered solid wall piers, shaped to accentuate the trapezoidal shape of the superstructure, also have special architectural surface treatment.

Project Team

Owner
New Jersey Highway Authority (Garden State Parkway)

Designer
Parsons Brinckerhoff-FG

Steel Fabricator
Tampa Steel Erecting Co.

Steel Detailer
Tensor Engineering Co.

Steel Erector
Archer Steel Construction Co., Inc.

General Contractors
Railroad Construction Co. (The RCC Group)

Merit Award: Reconstructed

Merritt Parkway over Route 123

Norwalk, Connecticut

The Merritt Parkway was originally constructed between 1934 and 1940. The design of the parkway included more than 70 bridges. The Merritt Parkway got its name from Congressman Schuyler Merritt, who was one of the highway's earliest and most persistent advocates. The intent of this parkway was to provide a clear and unobstructed drive in a "park-like" setting from the Housatonic River in Stratford, Connecticut to the New York state line that was free of heavy commercial trucks.

To go along with the parkway theme, a Highway Department staff architect named George Dunkelburger designed the facade of each bridge. The designs range from Neoclassical to Art Dec. No two bridges along the parkway have the same design, but many features such as the State Seal are duplicated. Most of the bridges are rigid frame structures that were designed to provide slender lines meant to prevent the steel frame from competing with the architectural features of each design. These bridges are a monument to the art of combining form and function.

The bridges of the Merritt Parkway have been celebrated for many years by the citizens of Connecticut. They have also been awarded the status of being listed on the National Register of Historic Places. At this time, many of the bridges are reaching the end of their service life. This has brought about a need for rehabilitation of these beautiful structures.

Rehabilitation Need

The condition of the 65 year old bridge had become a concern, although the real driving force behind the project was the need for acceleration and deceleration lanes on the parkway. This required the widening of the bridge on each side in order to accommodate the new lanes. The widening consisted of 17.75' extensions of the original bridge. The original bridge framing was salvaged and re-painted and the original abutments were also rehabilitated. The new bridge extensions would cover all of the original architectural features of the bridge, therefore it was decided to replicate the features of the original bridge with modern building material such as welded steel.

Some thought was given to re-creating riveted steel frames to exactly match the original, but it was felt by the design team that if George Dunkelburger had the use of modern welded steel he would have used it.

Bridge Information

The Route 123 Bridge is a single span rigid frame structure with a reinforced concrete deck. The approximate dimensions and information about the bridge are as follows:

- steel rigid frame with integral abutments;
- span: 66'; skew: 38 degrees;
- six original riveted steel frames spaced at 11';
- four new welded steel frames spaced at 9';
- frame web depth at abutments: 3.5'; and
- frame web depth at mid-span: 1.5'.

Innovative Design Features

The Route 123 Bridge is not a typical highway structure. In a day where stringer span bridges are the norm, this bridge stands out as a unique and sophisticated structure. The original bridge was constructed in the 1930s. It has many unique features that had been lost over the years where lowest possible cost designs won out over more innovative and more visually appealing designs.

Integral Abutments: Many states are moving in the direction of jointless bridge design using integral abutments. Recent articles have stated that jointless bridge technology was pioneered in the 1950 in several states. The Route 123 Bridge was designed and built almost twenty years before these more modern jointless designs. The bridge has functioned well for over 65 years, which is the greatest test to this technology.

Rigid Frame Design: The structural system of the Route 123 Bridge consists of a single span steel rigid frame. There are many advantages to this type of design. The foremost advantage is the ability to produce very elegant slender structural members over the span. The Route 123 Bridge has a mid-span frame web depth of only 18". This is remarkable considering the span is over 66' and the frame spacing is 9' on center.

Haunched Web Profile: The original riveted frame was constructed with a haunched section. This not only provided a slender flowing profile, but it also mimicked the moment diagram of the bridge. This variable haunch allowed the design of the new frame to include a constant flange cross section over the entire length of the frame (including the vertical legs). This greatly reduced fabrication expenses by eliminating flange transition splices.

Hidden Bolted Field Splices: The original design of the Route 123 Bridge included field splices located near the inflection points along the span. This was not a visual problem since the splice rivets were visually lost in the continuous riveting of the structure. The new structure is a welded steel frame that is very clean in profile. The design was modified from the original by shifting the bolted splices down into the column legs that are cast integral with the abutments. This provided a clean bolt free look to the fascia frame. The designers feel that had the engineers of the 1930s had modern welding technology available to them they would have opted for this type of clean design.

Welding Details: The design of a rigid frame requires the development of details that are not common to conventional modern stringer bridges. The elbow and base plate details carry significant moments. The design team wanted to avoid sharp angle point connections at the elbows in order to limit the possibility of stress concentrations. The resulting curved flange elbow joint has a combination of ring compression and ring tension that induces compression forces in the web. Diagonal stiffeners were designed to carry these forces between the flanges. The base plate moments had to be transferred from the relatively small flanges into a large base plate. A design welding a simple base plate on the end of the frame would require a very thick plate in order to accommodate the large bending stresses in the base plate. By designing a stiffened base plate the anchor bolt forces are transferred to the flanges through vertical fillet welds in place of trying to transfer force through the base plate. The design of the elbow and base plate was based on information published in Omer W. Blodgett's book, *Design of Welded Structures.*

Aesthetic Considerations

The Route 123 Bridge, as well as the entire Merritt Parkway, is listed on the National Register of Historic Places. The Connecticut DOT has made an effort in the last ten years to maintain, restore and preserve the historic character of the landscape and bridges. Many citizens of the area are familiar with each individual bridge along the parkway with their unique features ranging from ornamental ironwork of fig leaves, to castings of Pilgrims and Indians, all of which provide a whimsical experience while driving the parkway. The design of the Route 123 Bridge frame provides slender lines that are inconspicuous and unobtrusive. It is well known among architects that dimensional scale of structural elements is a key feature as to how a structure is interpreted.

The structural frame with the haunched webs is an important part of the aesthetics on the Route 123 Bridge. The Maryland DOT *Aesthetic Bridges User Guide* states that, "Haunches are important visually because they make the bridge seem thinner by reducing the average depth while leaving the length the same. Haunches visually demonstrate the flow of forces in the bridge." The steel frame on the Route 123 Bridge achieves this aesthetic standard. The steel frame is clean and simple and it does not try to compete with the architectural finishes on the parapets and wing walls.

Summary

The following items summarize the design of the Route 123 Bridge:

- The design includes a steel rigid frame structure that is cast integral with the abutments.
- The frame design with the haunched web produces a constant flange size and a mid-span depth of only 18" for a 66' span.
- The bolted splices are concealed within the integral abutments.
- Unique stiffening details were developed at the frame elbows and base plate.
- The bridge was designed to replicate the original historic structure using modern steel fabrication techniques.

Project Team

Owner
Connecticut Department of Transportation

Designer
Connecticut Department of Transportation

Steel Detailer
John Metcalfe Company

General Contractor
Watertown Construction Company

Franklin Square Bridge

Brooklyn, New York

The 200' Franklin Square Bridge is part of the Manhattan approach to the Brooklyn Bridge. Due to its trapezoidal span, each of the six pin-connected eyebar trusses that support the bridge have a different span. Since 1883, various alterations have increased dead load significantly. Preliminary analysis suggested, and subsequent sophisticated analysis proved that, the bridge wasn't safe. The New York City Department of Transportation (NYSDOT) issued an emergency contract for retrofit to the consulting engineer who performed the analysis. The final design employed six steel arches founded into the original masonry abutments to support the six wrought iron trusses.

Replacing the trusses was ruled out by the client because of the bridge's historic importance; in addition, the bridge had to remain open. The restoration of an historic structure was accomplished in an emergency situation and under stringent traffic restrictions. The client's request that the consulting engineer use arches to support existing trusses was unusual, as well as adding additional complexity. The engineer's design neither altered nor compromised the elegant appearance of Roebling's original structure, despite its complex geometry and outdated materials.

The Manhattan approach to historic Brooklyn Bridge incorporates a 200' bridge over Franklin Square in Manhattan at the junction of Pearl and Cherry Streets. The bridge's supporting structure consists of six pin-connected eyebar trusses. Each truss has a different span, because the bridge is trapezoidal in plan. Transit tracks, supported on an open steel structure, were removed and replaced with a reinforced concrete deck. The original Belgian block roadways and wooden pedestrian promenade in the center were both replaced with thicker concrete decks.

In preparing a design for the re-decking of the Brooklyn Bridge approaches, the engineering consultant performed an analysis of the Franklin Square Bridge using the current dead load. Appearances to the contrary, it revealed that the bridge trusses were overloaded. Alterations made to the bridge over its lifetime, to accommodate an increase in the volume of vehicular traffic, had increased dead load significantly.

John Roebling designed the truss members of the Franklin Square Bridge as part of his original Brooklyn Bridge scheme using materials that date to that era. The trusses were made of wrought iron common for the 1880s, but not today. Since wrought iron offers excellent ductility and consistent strength, and has superior resistance to corrosion, the bridge was able to sustain the increase of applied loads without incident since 1883, its trusses showing no visible signs of distress.

The pins connecting the truss members were made of carbon steel, a forerunner of today's A36 steel. In the simple elastic analysis requested by the client, some of the pins were found to be stressed beyond the yield threshold and, in some cases, beyond the full plastic moment capacity. The lack of visible distortion in the pins suggested that a redistribution of the forces in the eyebars was taking place. The engineering consultant deduced that there was reserve strength not indicated by the preliminary analysis, which was insufficient to determine the actual safety of the bridge.

The engineering consultant chose to perform a more sophisticated sequential failure analysis, because of the uncertainties involved. The loading was increased in steps until overall yield of the bottom chord was reached. The results of this analysis showed that the reserve against full yield was inadequate. NYSDOT issued an emergency contract to the engineering consultant for design and construction of a retrofit to provide adequate support for the increased loads.

Aesthetic and Technical Complexity

In addition to meeting safety requirements the retrofit structure would have to be attractive, in keeping with the elegance of the original bridge. It was given that the original historic trusses should not be altered in appearance. Replacing the trusses was ruled out for another reason: the bridge had to remain open to traffic.

The final design employed six steel arches spanning the full length of the bridge to support the original six wrought iron trusses; the arches were founded into the original masonry abutments. While steel arched bridges are not uncommon, the client's request that the engineering consultant use arches to support the existing trusses, in order to minimize traffic interference and for aesthetic reasons, was unusual and contributed significantly to the complexity of the project. The results more than made up for the challenge of the arch solution: the appearance of the bridge was improved by adopting this scheme over the original girder scheme.

Innovation

The arches, in which no members were perpendicular to any other members, were an extension of Roebling's complex geometry.

One way to conceptualize the design approach is to visualize that the original steel trusses of the Franklin Square Bridge were supported on falsework from underneath during construction. In the 1999 retrofit design, the engineering consultant used steel arches as permanent falsework to support the historic structure above. The trapezoidal plan of The bridge required arches with six different spans, reflecting the six different trusses above, ranging from 147 to 190'. Furthermore, the panel points on the trusses above were arranged in a pattern that was skewed to the axis of the bridge. The truss verticals, which were strong compression members directly supporting the floor beams, were used as the element into which a vertical force was introduced to relieve the trusses. Because the pattern of these vertical members was skewed to the bridge the posts set on top of the arch had to conform to this pattern.

The singular arch geometry, with virtually no members perpendicular to any other members, was a detailer's nightmare. Usually, the floor beams on a skewed bridge are made perpendicular to the main carrying members to simplify the geometry. Roebling was not so kind as to retrofit engineers, who had to extend the geometry of his original design into the much more complex geometry of an arch structure.

Respect for Original Design

The advantages of working within the limits of Roebling's geometry were that it maintained the appearance of the bridge and visually enhanced the unequal curvature of the arches. The arches added a curvilinear element to the structure that contrasted with the lattice of the wrought iron trusses and are reflective of the masonry arches crossing other streets. Working with the client, a color scheme was selected to delineate new structure from old, so that the historic and retrofitted portions were easily identifiable.

Arches were composed of three elements to facilitate erection and designed to stand alone.

It was desirable that all the arches be sprung at the same elevation and that the crowns be as close as possible to the existing structure above. As a result, the arches all had different radii. Each arch was composed of three elements, which were spliced together in the field to facilitate erection. The arches were designed as three centered arches with the radii changing at the splice points and selected to approximate a parabolic shape. In order to reflect the solid plate top chord, the arch ribs were I-sections fabricated from steel plate; bracing and columns were rolled sections with webs pierced to reflect the lattices of the existing bridge.

Pre-calculated loads were jacked into the arches at the interface between the columns and the truss panel points. Because the arches and trusses behave differently under temperature changes, these forces were calculated to relieve the bridge without lifting the truss off its bearings on hot days, while providing adequate support on cold days. The arches were further designed to stand alone without the stiffening effect of the trusses.

Social and Economic Considerations

Design and construction decisions favored traffic safety and convenience.

The arches were erected with limited lane closures. The six arch ribs were erected in six nights, with the street below the bridge closed from 9:00 p.m. to 6:00 a.m. Only one lane above the bridge was closed, so that the truss above the arch being erected could be used to lift the rib into its final position. Other work was performed with only partial closure of the street below, minimizing the effect of the construction on automobile traffic. Traffic safety and convenience was also enhanced by the design itself. The use of arches left the entire width of the street open without columns or piers, which a traditional temporary shoring scheme would have required.

Project Team

Owner
New York City DOT

Designer
Weidlinger Associates, Inc.

Steel Fabricator
Harris Structural Steel Co.

Steel Detailer
Graphics for Steel Structures

Steel Erector
Koch Skanska, Inc.

General Contractors:
Koch Skanska, Inc.

Merit Award: Moveable Span

Ray Nitschke Memorial Bridge

Green Bay, Wisconsin

The Main Street Bascule Bridge crossing the Fox River in Green Bay, Wisconsin, was experiencing ongoing, expensive machinery problems and increasing misalignment due to unknown foundation problems. Originally constructed in 1929 the bridge had become an historical landmark, however, in the summer of 1992, the City of Green Bay had decided to replace the four-lane bridge with a new bascule span on a different alignment to the north. The designers of the replacement bridge faced and met numerous technical and aesthetic challenges.

A study of options for the new crossing, authorized by the Wisconsin Department of Transportation (WisDOT), included the investigation of various channel and approach roadway alignments, as well as alternatives for the bascule span, the deck type and the drive system. After the final design had been started, in July 1995, WisDOT decided to accelerate the schedule. The project team completed the design in April 1996, several months ahead of the original schedule.

The new double-leaf rolling lift span provides better approach alignments, incorporates a number of new technologies and has been designed to preserve many of the aesthetic attributes of the original bridge. Named after the legendary Green Bay Packer linebacker, Ray Nitschke, the new bridge was opened to traffic in October 1998.

Unique or Innovative Aspects

New or innovative technologies employed in the replacement bridge included the first use of exodermic grid for the bridge deck and the first use of a closed loop hydraulic drive system on a bascule bridge. Another unique and challenging aspect of the project was the use of the metric system.

The exodermic deck, a proprietary system, incorporates a reinforced concrete deck that is cast on top of and composite with a steel grid and the floor beams. This deck system has excellent riding characteristics and low maintenance costs in comparison to open grid decks. The deck system makes maximum use of the compressive strength of the concrete and the tensile strength of the steel grid. The horizontal shear is transferred between the concrete and the grid through partial embedment into the concrete of the steel grid tertiary bars and studs. The concrete slab is 114 mm thick and the total deck thickness is about 246 mm. The concrete is cast full depth over the floor beams and studs are welded to the floor beam to achieve composite action with the floor beams. The deck system spans between floor beams, spaced at 4.1m, eliminating the need for longitudinal stringers.

The hydraulic motor drive, a closed loop hydraulic system, consists of one hydraulic power unit, two hydraulic power motors and two rack and pinion sets per bascule leaf. The motors are coupled to the pinion shaft by the use of a shrink disc, allowing the easy removal of the motor from the shaft for maintenance. The hydraulic power unit allows differential load sharing between the pinions of the same leaf. The hydraulic motors are capable of smooth rotation at very slow speed, which allows very reliable and smooth span control during acceleration, full speed and span seating. Routine maintenance includes checking fluid levels, filters and leaks. This system has the lowest maintenance requirements of the three systems studied.

Economic Benefit or Cost Effectiveness of Design

The estimated construction cost for both of the proposed bridge types, Scherzer bascule and Trunnion bascule, was determined to be very close. The project team decided to use a Scherzer bascule since most of the movable bridges in WisDOT District 3 are Scherzer's, it was believed that in keeping with the familiar bridge design maintenance would be somewhat easier.

Structure Configuration

Each leaf consists of two main girders, 1880 mm deep at the center break and 4300 mm deep at the pinion. The girder flanges vary from 30 mm x 480 mm at the tip to 90 mm x 600 mm at the pinion. Each leaf rolls on a 3 m radius tread casting. The floor beams are spaced at 4.1 m and vary in depth from 1200 mm at the girder to 1376 mm at the center of the roadway. The 2.4 m sidewalks on each side are supported on brackets and cantilevered from the girders. The counterweight is supported by a combination of three vertical beams and two horizontal trusses. Each leaf is braced by a series of three longitudinal cross frames and lateral bracing at the bottom of the floor beams.

Aesthetic Considerations

In deference to the original bridge and its landmark status, the design team incorporated a number of architectural features from the original structure in the design of the new bridge. The new tender tower replicates the octagonal shape of the original tower and includes a clay tile roof of the same type as was used on the original operator's house. A decorative terra cotta cornice from the original house was also salvaged and reused. The design team designed a steel railing to closely match the railing on the original structure and the tender tower was stained red to match the color of the Neville Public Museum and the old C&NW Railroad Depot. Accent lighting installed along the edge of the bridge deck serves further to highlight the structure at night, in particular the graceful arch of the main girders.

Type of bascule

The team considered two types of conventional bascules, a Trunnion bascule and a Scherzer bascule—the type eventually selected. Trunnion bascules pivot about a fixed shaft or trunnion, whereas Scherzer bascules roll backwards as they rotate open. The Scherzer bascule is supported on heavy tread plates. Gravity and pintles, otherwise known as gear teeth, in the tread plate prevent the bridge from moving out of line as it rolls open. The drive machinery is mounted on the movable leaf between the girders. The Scherzer bascule requires a slightly smaller opening angle than the trunnion bascule because it moves away from the channel as it opens.

Roadway deck

Engineers evaluated three roadway deck types: conventional open steel grid, steel grid half-filled with concrete and exodermic. Each deck type was evaluated against three criteria that included first cost, maintenance cost and ride quality. The exodermic deck was chosen for this project based on a reasonable first cost, low maintenance cost and excellent riding characteristics. The exodermic deck is heavier than an open grating deck, but it can span greater distances than either an open grid deck or half-filled grid, thereby simplifying the floor framing.

Mechanical drive system

The project team examined three types of mechanical drive systems: a traditional electric motor and gear drive system, a hydraulic cylinder system and a low-speed/high-torque hydraulic motor drive system. The hydraulic motor system was determined to have a slightly higher first cost than the hydraulic cylinder system, but less than the gear drive system. Maintenance and operational advantages led to the selection of a low-speed/high-torque hydraulic motor system for this project.

Foundation

As the design of the superstructure and mechanical and electrical systems progressed, the team performed a alternative foundation analysis to determine the optimal foundation type for the bascule piers. The new bridge was analyzed in accordance with FHWA HEC-18 and determined to have potential local scour to depths of nearly 14 m in the vicinity of the bascule piers. Soil conditions from the river bottom to the top of bedrock were found to be extremely poor. The selected foundation type was 2.4 m caissons, socketed into sound rock.

Project Team

Co-Owners
Wisconsin Department of Transportation and the City of Green Bay

Designer
Parsons Brinckerhoff

Steel Fabricator
PDM Bridge

Steel Detailer
Tensor Engineering, Inc.

Steel Erector
Hi-Boom Erecting, Inc.

General Contractors
Lunda Construction Company

Consulting Firm
Graef, Anhalt, Schloemer and Associates, Inc.

Merit Award: Medium Span

State Route 52 over Clear Fork River

Morgan County, Tennessee

Situated in the Big South Fork National River and Recreation Area the bridge is a four-span welded plate girder structure with spans of 145'/220'/350'/280'. The superstructure is composed of four girders spaced 12' on centers, supporting a 42'wide composite concrete slab. Rising over 200' above the river, with only limited workspace for cranes, weights needed to be held to the minimum practical. Using HPS 70W steel helped achieve this.

Because the bridge site was located in a national park and near a historic district it was necessary to develop a project that minimized impacts both physically and visually on the surrounding area. Accordingly, the approach roadway and bridge combined to limit alterations to the landscape by virtually eliminating excavation. Additionally, the bridge design provided for erection of steel girders from the existing road network supplemented by incremental launching of sections comprising the third pier's negative moment section and span four. Further, aesthetic considerations were accomplished through the use of unpainted weathering steel, to blend into the forest setting and use of rustication strips at 10" intervals vertically on the pier columns to enhance the visual proportions of their extreme heights.

Optimization and Innovation in Design

Optimization of design must start at the initiation of the design process. With a length of 995', a totally jointless bridge was not practical. Further, abutment one, on the low end of the 2.24% grade, was founded on rock. Pier one, 63' in height and only 145" from the first abutment, was determined to be easily deflected $1^3/_8$", the maximum possible displacement, without any significant moment addition at its base. Similarly, the second and third piers, with column heights of

183' and 124' respectively, could also deflect the maximum amount based on thermal movement accumulations presuming that the first abutment was fixed. Calculations also indicated that the force developed by gravity loads acting on the frictional resistance of sliding bearing surfaces would exceed the force required to deflect the piers. Accordingly, it was decided to design the bearings at the first abutment and all piers as fixed. Expansion bearings and a roadway expansion device were placed only at the second abutment.

The next consideration for optimization was selection of a web depth and thickness. Generally speaking, in spans up to 350' transversely stiffened girders are more economical than transversely and longitudinally stiffened girders. Further, optimization is achieved when the depth to thickness ratio is at the maximum allowable limit. In this case a 96" deep, $^{3}/_{4}$" web was chosen for the non-hybrid HPS 70W section over the second and third piers. In the positive moment section, analysis was required to determine the minimum allowable thickness of the web. The 96" grade 50W web was only $^{1}/_{2}$" thick.

Constructability

In order to utilize the smaller reasonable section in the positive moment regions it was necessary to break the positive moment pours into segments remembering that, as a slab section is poured and cured, subsequent stresses are accumulated on the resulting composite section.

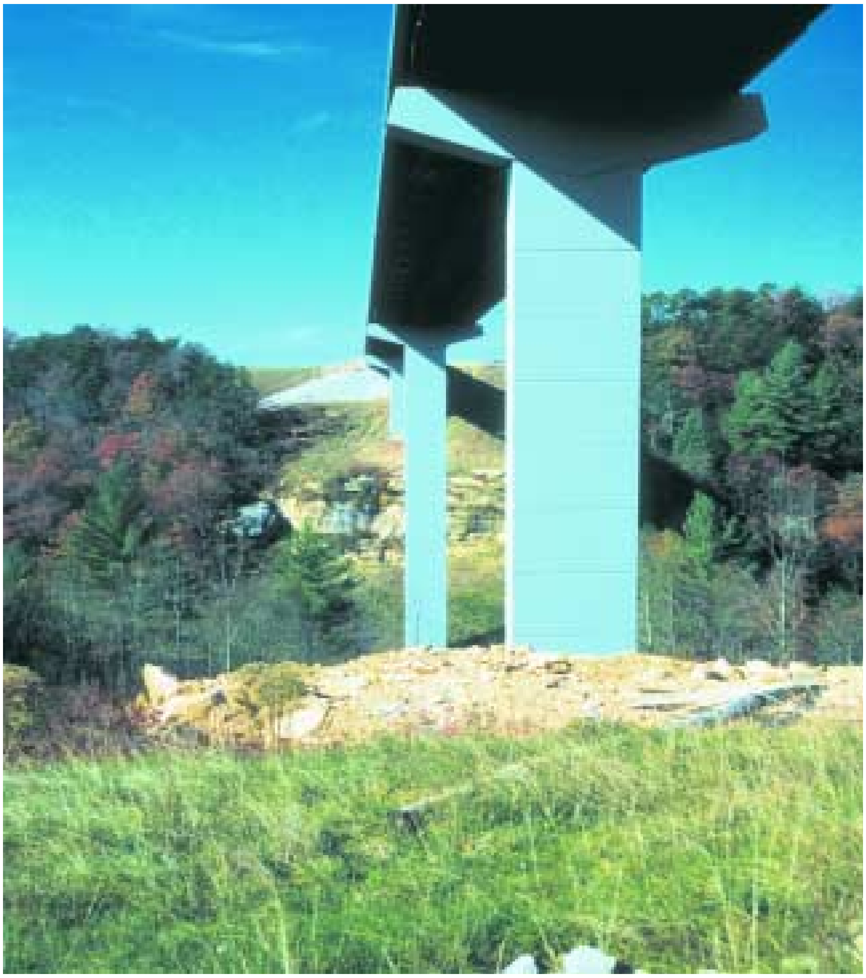
Span one and span two, up to the dead load inflection point near the second pier, were designed as non-hybrid using grade 50W steel. The negative moment sections at the second and third piers were designed solely of HPS 70W, while the positive moment sections of spans 3 and 4 were designed as hybrid girders, utilizing grade 50W webs and compression flanges while using HPS 70W in the tension flanges. All stiffeners and cross frame material are grade 50W.

Utilizing HPS 70W for the pier sections at the second and third piers reduced their lifting weights 30% over a grade 50W design.

Economics

The overall cost of the girders for the Clear Fork River bridge, in place, was $1.03 per pound, vs $1.18 per pound for a similarly designed all HPS 70 bridge constructed previously even though the girders were fabricated at the same plant, shipped further and were more difficult to erect. Stockpiled prices for HPS 70W steel for both bridges were $0.30 per pound. The completed cost for the complete structure was $95.34 psf.

In conclusion, State Route 52 over the Clear Fork River project was a textbook example of how sensitivity, careful planning, astute design and innovation can come together to create a virtually maintenance free, economical, environmentally sensitive and monumental bridge crossing.



Project Team

Owner
Tennessee DOT

Designer
Tennessee DOT Division of Structures

Steel Fabricator
Trinity Industries

Steel Detailer
Alabama Structural Detailers

Steel Erector
J. S. Rollins, Inc.

General Contractor
J & M, Inc.

Merit Award: Medium Span

Wes Smith Bridge

Index, Washington

Community involvement was critical in selecting the replacement for an existing landmark bridge in Index, Washington. The new Wes Smith Bridge, named after a local resident that has lived and worked in the town of Index for 80 years, is a steel tied arch bridge with bolted box tie girder, welded box arch, Vierendeel struts, cable hangars and drilled shaft foundations. The steel coating consists of thermal metalized spray galvanizing.

While a concrete arch alternative was competitively bid against the steel alternative, the concrete arch was not cost competitive due to the remote site and requirement for significant shoring to be placed in the river.

Community

Index is a small community located on the bank of the north fork of the Skykomish River. The bridge serving this town is vital to its existence and is recognized as a signature of the town. The only other access to the town is a 25 mile long primitive gravel road not suitable for emergency services or school bus travel. The existing bridge was a 220' long, single lane, steel truss with a timber deck. Even though this 1917 bridge had been rehabilitated in 1980 it was classified as structurally deficient and functionally obsolete.

After numerous meetings of the Citizen's Advisory Committee it was decided that the new bridge would be two lanes wide with sidewalks on each side and would be built on the same alignment as the existing bridge. The preferred structure type was an 80 m tied arch, allowing for a long span with minimal structure depth and no supports in the river. The visual impacts of the arches above the roadway complimented the steep canyon walls.

Aesthetics

The aesthetics of the arch were considered when developing the structural systems for the arch. Vierendeel struts were used to provide maximum views of

the surrounding mountains. The barrier at the edge of the roadway was eliminated and combined with the pedestrian railing to better provide views up and down the river. Sidewalks were provided on both sides of the bridge for easy access for local town residents.

Temporary Detour

The existing truss was used as a temporary detour during construction so that the new bridge could be built on the same alignment as the existing bridge. A crane located on each bank of the river relocated the existing truss. There were no supports required in the river to accomplish truss relocation. Total roadway closure was six hours, with traffic temporarily diverted onto a gravel county road.

Structural Details

Four 1.8 m diameter drilled shafts were used to support the arch with one at each corner of the bridge. The steel box arch section was sized to accommodate erection and inspection. Splice locations were selected based on the maximum size member that could be delivered to the site. The tie girder is a bolted steel box so there is redundancy in the tension member. Steel transverse floor beams were used to support the cast in place concrete deck. The continuous concrete deck acts as a horizontal diaphragm, eliminating the need for cross-bracing the floor system. Vierendeel struts were selected to laterally brace the arch while maintaining open views of the surrounding mountains.

The end floor beams were designed with a full moment connection to the arch and tie intersection. This connection reduced the effective length factor to allow a reduction in the number of vierendeel struts required. The interior floor beams had flange connections to stabilize the tie girder and prevent longitudinal movement between the tie girder and floor beam at the top flange.

The bearings were designed to allow for movement during construction so that the tie girder would support the load. After the deck was placed, the bearings were fixed so they would provide lateral support to the drilled shafts. The fixed bearings provided for the longitudinal seismic force to resist the soil at each abutment.

Construction Sequence

The construction sequence identified in the plans allowed erection to take place without impacting the environmentally sensitive north fork of the Skykomish River. A full member lay down was completed at the fabricator before holes were drilled in the cover plates to assure members would fit in the field.

The tie girder was erected first using temporary supports at the edge of the river. Tie-downs at the abutments were used to eliminate supports in the river. Arch sections were erected using falsework supported on the tie girder. A hydraulic jacking system at the top of the falsework towers was used to jack the arch up into final position to install the last arch section. Cable hangers were installed and the arch falsework removed. The hangers were adjusted for final geometry and load by adjusting the bolts at deck level. The construction was completed without requiring falsework in the river, which is habitat for the endangered Chinook salmon and Bull trout.

Pedestrian Elements

The Wes Smith Bridge is located at the edge of the town of Index. It receives frequent use by pedestrians and sightseers. The river is a popular white water rafting destination so river views are important. A combination pedestrian/traffic barrier was placed at the edge of the structure to provide a pedestrian friendly facility with good views both up and down the river. The sidewalk opens between the hanger system and roadway to provide additional width of sidewalk and allow pedestrian to cross from one side of the bridge to the other as river rafters float by.

Coating System

The county had a strong desire to achieve a durable and low maintenance structure. The coating system used on the new bridge is a shop applied thermal spray coating of aluminum and zinc. The splice plates and reinforcing steel were hot-dip galvanized. These coating systems provide both barrier protection and galvanic protection minimizing future maintenance costs and ensuring a long structure life.

Steel Alternative Cost Comparison

A concrete tied arch alternative was designed and competitively bid against the steel tied arch alternative. Six bids were received, with five of the six bidders bidding the steel alternative. The low bid on the steel alternative was $2,562,597, 9% lower than the concrete alternative bid of $2,808,605. All of the five steel bids were at or below the concrete alternative bid. The concrete arch was not cost competitive due to the remote site and requirement for significant shoring to be placed in the river during tie and arch erection.

Project Team

Owner
Snohomish County

Designer
HNTB Corporation

Steel Fabricator
Oregon Iron Works

Steel Detailer
John Newell & Associates

Steel Erector
J & S Construction

General Contractor
Mowat Construction Co.

Merit Award: Medium Span

Trunk Highway 61 over Gooseberry River

Lake County, Minnesota

Trunk Highway 61 (TH 61) runs along the scenic north shore of Lake Superior in Minnesota. The highway crosses the Gooseberry River within Gooseberry Falls State Park, which attracts 580,000 visitors annually. Built in 1922, the old bridge over the river consisted of a 150' arch shaped deck truss with 60' beam spans at both ends. A third arch was added, in 1937, to accommodate a 30' roadway with 5' sidewalks on both sides, which act as viewing platforms for waterfalls located west and east of the bridge. A visitor center is located near the north end of the bridge and there is also an additional roadside parking at the south end, both of which make the area around the bridge heavily congested with pedestrian traffic and cause safety concerns.

By 1990, the bridge was badly deteriorating. An arch type bridge was chosen for replacement in order to maintain the look of the old bridge from both the upper and lower falls, where it frames the river gorge scenery. The new bridge would be built in conjunction with a new visitor center located away from the road.

The new bridge consists of a 154' main steel arch span supporting a 14" deck slab with three concrete slab spans on both ends varying in length from 16 to 24'. The cross-section for the main span consists of 2 box shaped fixed arches 42.5" deep by 29.5" wide. In order to maintain bridge access for pedestrian viewing of the waterfalls, and at the same time reduce pedestrian traffic on the highway, an 8' walkway was provided at deck level on one side of the bridge with another 8' walkway suspended below the bridge on the other side. These walkways connect with trails that run throughout the park. Tubular steel sections were used for the pier columns, spandrel columns, the struts that brace the arches and the tension members which suspend the walkway underneath. A slab span system which runs between the pier and spandrel cap beams was chosen to reduce superstructure depth and to be more aesthetically pleasing. The new pedestrian railing was designed to look similar to the old rail for historic reasons. During the Great Depression, rock walls located at the south abutment of the old bridge had been built by the Civilian Conservation Corps. These walls were saved and the new abutment, directly adjacent to the old, was constructed with a rock facing to match the old wall.

TH 61 is the only road along the north shore to Canada and no practical detours are available. This coupled with a tightly confined area made stage construction a requirement. Due to the steep slopes and an environmentally sensitive area the contractor was constantly challenged during construction.

Project Team

Owner
Minnesota Department of Transportation

Designer
Minnesota Department of Transportation

Steel Fabricator
The D.S. Brown Company-Lewis Engineering Division

Steel Detailers
The D.S. Brown Company-Lewis Engineering Division and Tensor Engineering Co.

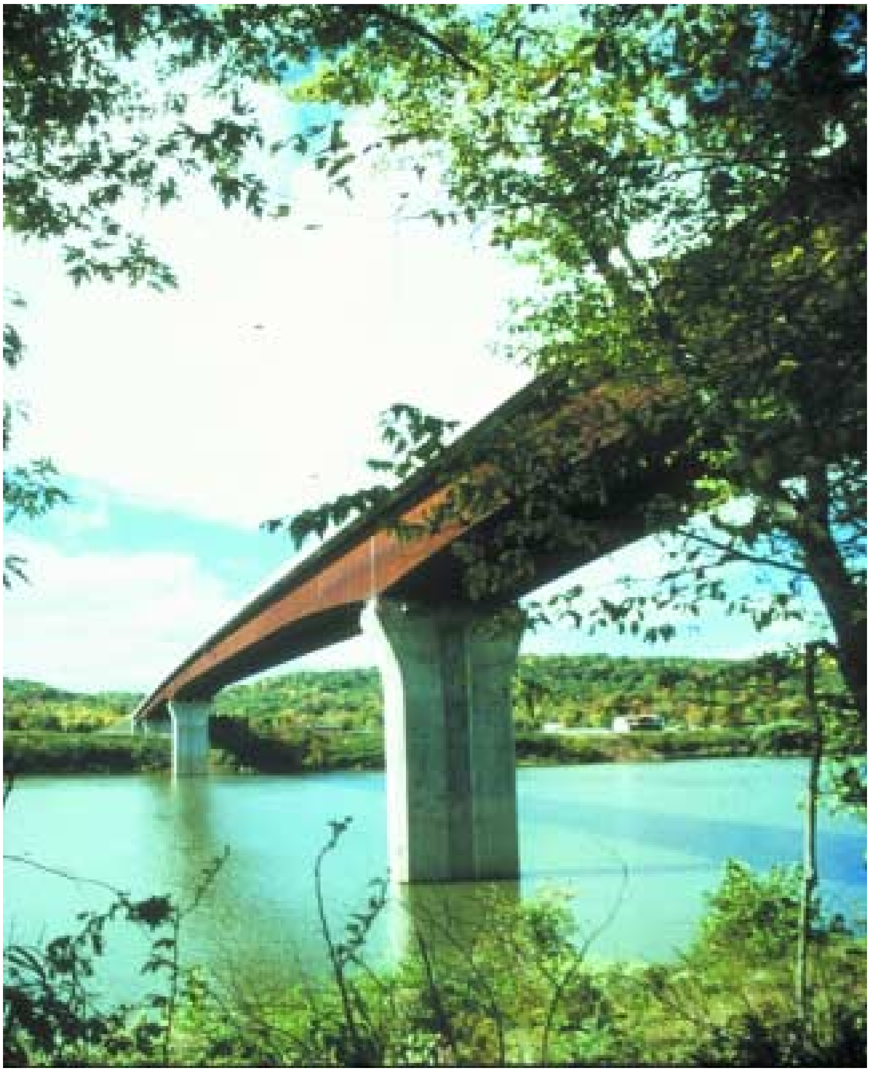
Steel Erector
M.A. Mortenson Company

General Contractors
M.A. Mortenson Company

Merit Award: Long Span

Lower Buffalo Bridge

Buffalo, West Virginia



This $21.8 million project connects US 35 to WV62 over the Kanawha River near Buffalo, West Virginia. The bridge site is in the Kanawha Valley of Putnam County, West Virginia, halfway between Charleston, the state's capital and largest city, and Huntington, the second largest city in the state. The broad Kanawha Valley is surrounded by rolling hills and dotted with farming communities and newer suburban areas.

Although Putnam County is one of the fastest growing counties in the state of West Virginia, there was no bridge crossing the Kanawha River within miles of Buffalo. The new Lower Buffalo Bridge opens up some of the best land in the state to economic development and provides a direct connection to a new US 35 upgrade under construction and I- 64.

The bridge had to be completed and open to traffic by mid-1998 to allow for the new Toyota manufacturing facility in Buffalo to ship state-of-the-art engines. The bridge also had to span the navigable Kanawha River with minimal falsework and span over areas on both banks with known archeological deposits.

Environmental Concerns

The flood plain area at the Lower Buffalo Bridge site is an established archeological dig site with numerous Native American campsites and artifacts. An environmental consultant for the West Virginia Department of Transportation (WVDOT) performed both phase one and phase two archeological surveys at the proposed bridge site and identified archeologically sensitive areas on both riverbanks. Construction activity for a new bridge over these sensitive areas was limited to the depth of cultivation (about 30"). Excavation and foundation work could not begin until after an extensive phase three survey was completed.

Rather than perform the lengthy phase three survey work, the WVDOT decided to design and build a five span structure with the piers and abutments located outside of the archeologically sensitive areas. The Lower Buffalo Bridge, with and overall length of 1,850' and spans of 269', 394', 525', 394', and 269', easily clears the sensitive areas. The use of a steel girder superstructure allowed great flexibility in locating piers and abutments.

Features of the Structure

The Lower Buffalo Bridge is on a tangent alignment. The approach roadway on the west bank of the Kanawha River has a 330' radius curve with a spiral. The roadway grade is 3% on the west side and 5% on the east side on a 790' vertical curve. The profile grade provides a 68' vertical clearance from normal river pool elevation to the bottom of the steel girders, and the two river piers provide a 500' wide navigation channel.

The bridge section has two 12' traffic lanes, two 6' shoulders and concrete parapets. Right-of-way was purchased adjacent to the bridge for a future dual structure. A constant deck cross slope of .02%, and the use of a box girder superstructure, allows for a future structure to be easily built with a widened four lane roadway.

The bridge superstructure consists of twin haunched composite steel box girders on 20' centers supporting a reinforced concrete deck with parapets. The box girder webs are plumb and on 10' centers with 4'-4" deck overhangs. The steel box girder profile haunches over the piers and smoothes out into parallel flange boxes at midspan. The two steel box girders are supported on curved columns.

Details of the structure include a clean and uncluttered box girder underside, interior box lighting, complete inspection access and the use of Grade 50W steel throughout. Additionally, identical box girders with a symmetric span arrangement permit significant duplication in fabrication. Constant 36" wide top flanges simplified the installation of stay-in-place forms.

The structure is fully continuous from abutment to abutment. Expansion and contraction is accommodated by the use of steel finger joints with neoprene troughs at the abutments and guided steel pot bearings at the two approach piers and abutments. The two river piers have pot bearings fixed against temperature movement. Full depth box girder interior stiffeners permit the vertical reaction over the piers to remain aligned with the supporting column throughout the range of temperature movement.

None of the 3,200 tons of Grade 50W structural steel used to fabricate the bridge was fracture critical. To provide redundancy, permanent cross-frames throughout the length of the bridge were designed to transfer the weight and live loading from one box to the other in the event that a girder section was cracked and became unserviceable.

Another example of the structure's technical originality was the use of large, torsionally rigid box girder field sections to reduce the number of individual field pieces and field bolted connections. The designers located field sections to limit shipping pieces to 100 tons or less. Actual shipped pieces ranged in size from up to 92 tons and 113' long. By choosing a twin box girder superstructure the designers were able to minimize the number of field bolted cross-frames connections between girder lines. A shop installed top lateral bracing system, which was designed to support the box girder sections on their side, provided excellent torsional rigidity during shipping and erection.

The use of unpainted weathering steel for the bridge provided corrosion resistance, reduced shop fabrication time, eliminated the need for future maintenance painting and enhanced the overall appearance of the structure. The burnt sienna color of the unpainted weathering steel complements the rural landscape. The color of the steel girders contrasts with and delineates the lighter gray and dark shadows of the piers and deck fascia. The overall appearance is that of a structure that truly belongs in a valley landscape.

The bridge design provides an attractive, proportional and balanced structure. Although the box girder sections are 10 to 13' deep at midspan and haunch to 18' over the piers, the long spans give the impression of a slender ribbon stretched from bank to bank.

Conclusion

Steel fabrication began in March 1997 and proceeded concurrently with the bridge substructure construction. The steel erection was complete in August 1998, and the concrete deck, parapets, and overlay were cast in the fall in time for traffic to cross the bridge in October 1998.

Project Team

Owner
West Virginia Department of Transportation

Designer
BRW/Hazelet & Erdal

Steel Fabricator
Stupp Bridge Company

Steel Detailer
Stupp Bridge Company

Steel Erector
Tri-State Steel Construction

General Contractor
National Engineering

48th Street Entrance Ramp to FDR Drive

New York, New York

The 48th Street entrance ramp to the northbound Franklin D. Roosevelt (FDR) Drive in New York City had been closed to traffic since 1987. In 1996, after nine years of extensive traffic congestion on Manhattan's east side, elected officials and the New York State Department of Transportation (NYSDOT) made a commitment to the community to reopen the 48th Street entrance ramp as quickly as possible.

Owner's Criteria

As part of the State's commitment to the community and to the traveling public, the following critical issues were addressed:

• Fast-track schedule that would permit the ramp to open quickly. NYSDOT estimated 15 months for final design and 18 months for construction;

• Technological improvements to the ramp design to improve safety, reduce maintenancence and be aesthetically compatible with the United Nations/East Side Manhattan neighborhood;

• Community participation program to ensure that neighborhood concerns were addressed. These provisions included functional aspects of the design, as well as noise concerns for residential areas and security concerns at the United Nations garage during construction.

• Construction staging to maintain three lanes of traffic on northbound and southbound FDR Drive during peak hours, and minimal closures of lanes at night.

Establishing a Fast-Track Schedule

NYSDOT's original schedule for reopening the ramp on a fast-track schedule called for a time frame of 15 months for final design and 18 months for construction, for a total of 33 months.

Cooperation between designers and NYSDOT accelerated the actual design work and produced final contract documents in twelve months, shaving three months off NYSDOT's design schedule.

In addition, the contract was bid in a cost-plus format that requires contractors to bid a contract amount for work items and to commit to a maximum construction duration. Detailed constructability analyses were performed during design, reducing NYSDOT's construction schedule by six months.

The contractor who was awarded the project was able to reconstruct the ramp and open it to traffic in seven months, which was five months ahead of our firm's schedule. A project that began with a 33 month schedule had been completed in 19 months.

Technological Improvements

The new ramp, one of the first composite box girders to be used in the New York metropolitan area, is a continuous four-span bridge, approximately 133 m in length, comprised of twin steel box girders. The ramp has a horizontal curvature of 90 degrees with a 50 m radius. The box girder design was selected because its configuration is particularly compatible with the client's criteria:

• The box girder design offers clear aesthetic advantages over I-beam construction. In response to its highly visible location, the new ramp design is a sleek four-span bridge with trapezoidal box girders. The new ramp's longer spans reduce the number of columns and promote a a clean appearance;

• Box girders are an efficient structural cross-section which resists the high torsional stresses caused by tight curvature; and

• Box girders reduce maintenance requirements as compared to I-beam construction. Because box girders do not have exposed lower flanges to collect debris, maintenance requirements are reduced.

NYSDOT's goal was to comprehensively address all technical issues related to the ramp design. The new entrance ramp at 48th Street had to alleviate the congestion along First Avenue while providing a safe access for the vehicular traffic. Our firm's design of the reconstructed ramp included geometric improvements that doubled the acceleration distance of the previous ramp, therefore allowing for a longer acceleration lane for entering vehicles to merge with the northbound mainline traffic. Major restriping and signage was also included to facilitate the merge between the ramp vehicles and the vehicles traveling on the northbound mainline FDR Drive.

Accommodating Community Concerns

A priority for NYSDOT in the design and construction of the ramp was to address the various concerns of Manhattan's east side community.

First, the community requested that the new ramp not preclude the potential for future pedestrian and bicyclist access to a future East River esplanade. As a result, the new ramp is located north of the previous ramp location to allow space for a future pedestrian and bicyclist ramp from First Avenue to a future esplanade.

Secondly, the project team met with the United Nations regularly during the design stage to discuss potential security issues. As a result, the contract documents include special notes and details to address these security concerns.

Thirdly, to alleviate concerns about construction noise during nighttime hours, noise-intensive operations were restricted at night. In addition, the contract documents included a contractor incentive for early completion of the pile-driving operations for the foundations.

Finally, to inform the community of the project's progress throughout the design stage and also to give the community the opportunity to voice their concerns, NYSDOT and our firm met with the community regularly during the twelve months of design to discuss the project progress. Task force meetings were held during construction to keep the interested parties informed about the project's progress and to discuss any concerns. A web page for the project kept the public informed during construction.

Cost

Design was completed under budget. The construction contract, bid at very competitive prices, was also completed within the budget and the contractor received the full incentive bonus.

Conclusion

The design of the 48th Street entrance ramp required a coordinated approach to integrate NYSDOT's criteria, the concerns of the community and a level of technological sophistication that improves vehicular safety and future maintenance.

Project Team

Owner
New York State DOT

Designer
TAMS Consultants, Inc.

Steel Fabricator
Tampa Steel Erecting Co.

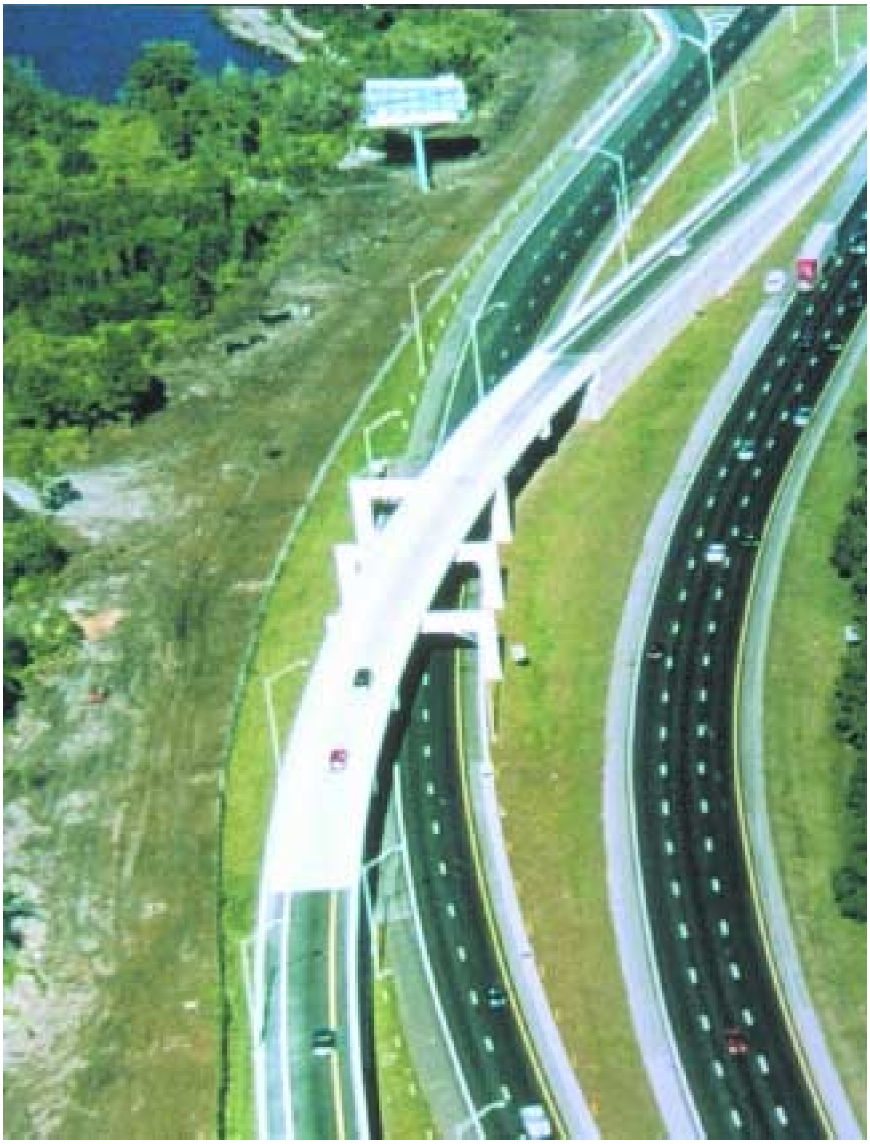
Steel Detailer
Tensor Engineering Co.

Steel Erector
Rice-Mohawk Construction Company

General Contractor
DeFoe Corp.

Ramp H over Westbound C/D Republic Drive/I-4 Interchange

Orange County, Florida



The Universal Boulevard (Republic Drive) /I-4 Interchange, provides direct access to a major theme park, Universal Studios, and eases traffic congestion on one of the busiest stretches of I-4 in Orlando, Florida. The new Ramp H over the westbound C/D Bridge is part of the Republic Drive / I-4 Interchange which carries one lane of traffic from westbound I-4 to Universal Studios and the surrounding community. The Ramp H bridge represents a unique, economical and yet aesthetically appealing solution to the complications imposed by crossing a braided ramp with severe skew. URS Greiner Woodward Clyde served as a subconsultant to Ivey Harris & Walls and was responsible for the design of all three grade separation structures planned for this interchange.

Bridge Description

The new bridge consists of seven equal spans, simply-supported, with 88' per span, making a total bridge length of 616'. The bridge alignment follows a mild 2.25 degree curve. The deck width is 30' and consists of an 8-inch-thick concrete deck slab supported by and composite with three lines of W36 × 245 rolled steel beams (Grade 50). The substructure piers are aligned radial to the baseline and consist of four hammerhead piers and three straddlebent piers located at the central portion of the bridge length. The piers are conventionally reinforced concrete supported on pile foundations.

Design Challenges

Although the bridge crosses over a two lane roadway only 46'-6" wide it includes travel lanes, shoulders and traffic barriers, the required minimum bridge length is in excess of 600". This is a result of severe 82.5 degree skew between the two roadway alignments. Additionally, to provide the required minimum vertical clearance of 16.5' for the lower roadway the structure depth was limited to a total of 7'. This is a result of two roadway geometric constraints on the vertical profiles: the lower roadway profile could not be dropped due to the high water table and its affect on the roadway subgrade and the bridge profile could not be raised due to the close proximity of an at grade intersection to the west and the I-4 exit ramp tie-in to the east.

Design Solutions

A common solution for relatively narrow structures with severe skews, such as the one found here, is a bridge structure with a continuous superstructure and single column piers along the bridge centerline. However, although this would minimize the main span length the resulting span length required would be in excess of 300', which was unacceptable given the structural depth constraints. During the bridge development phase of the project, two general bridge types utilizing short span lengths were evaluated: a single span structure with AASHTO beams framed transverse to the direction of traffic and supported with two long substructures running the length of the bridge on each side and a multi-span structure with beams framed parallel to traffic and supported with hammerhead piers where space permits, and straddle piers otherwise. Based on preliminary construction cost estimates, the transversely framed option was significantly more expensive (approximately 50%) and aesthetically undesirable. The longitudinally framed option was developed further to compare AASHTO type beams and rolled steel beams. For identical span arrangements, a direct cost comparison between the beam types showed them as being essentially equal in cost (within 6%). Rolled steel beams were selected based on aesthetic and lightweight considerations, and to provide consistency with the two other steel plate girder bridges within the interchange.

Design Economy

With a total structural depth limitation of 7' (including pier cap depth), a maximum rolled beam depth of 36" was available for structural optimization. A seven span arrangement with three girder lines using W36 × 245 rolled steel beams was found to be the most economical, resulting in approximately 25 lb. per square foot of structural steel deck area. A generous beam spacing of 10' with overhangs averaging 5' optimized the capacity of the beams and the 8" thick deck slab. The beams are simply-supported by piers with inverted "T" cap cross-sections. The use of shorter, simple spans benefited the overall bridge economy in several ways:

- Standard rolled beam shapes could be used that are easily shipped with no field splicing;
- The discontinuity at the beam ends allowed the structural section of the pier cap to extend into the superstructure and reduce the overall structural depth. This is achieved without the complications of an integral pier cap;
- The superstructure dead load reactions were minimized allowing for straddle piers designed using reasonable proportions.

Based on project bid tabulations and final quantities, the total construction cost for the bridge (excluding retaining walls) was $1,172,000, which equates to a unit cost of $63.43 psf of bridge.

Aesthetics

Although the substructure may be the predominant aesthetic feature of the bridge's overall appearance the relative proportions of the substructure and superstructure, and the variations in which they intersect, allow for the two to blend together as one form adapting to the site. The pier columns, which are in a sustained and direct view from the lower roadway traffic, utilize rusticated surfaces to soften the appearance of the large column faces. The bridge also has the unique feature of displaying its unique aesthetic appeal to those traveling under the bridge.

Project Team

Owner
Universal City Development Planners

Designer
URS Greiner Woodward Clyde

Steel Fabricator
Carolina Steel Corporation

Steel Detailer
ABS Structural Corporation

Steel Erector
V & M Erectors

General Contractor
Hubbard Construction Company

Kuparuk River Submersible Bridge

North Slope of Alaska

Jurors Comments

Bold application of steel...a structure that must endure extremely heavy vehicle loads and face one of nature's most hostile environments: arctic cold, large-scale ice flows and overtopping spring floods.

The Kuparuk River on the North Slope of Alaska is a typical northern stream with water flows of less than 5,000 cubic feet per second (cfs) for most of the year, but large spring break up floods that can exceed 140,000 cfs extending over a 2 mile wide flood plain. In addition to this tremendous amount of water, large 5' thick, fresh water ice floes also occur during spring floods. To support development of the new Kuparuk oil field, an access road was built across the Kuparuk River in the late 1970s at a location where the flood plain is approximately 10,000' wide. Economically bridging this flood plain for the spring break up flood has presented a design challenge since the original construction of this access road.

For nineteen years, the gravel road at the east and west channels of the Kuparuk River was breached annually and allowed to wash out during spring breakup, resulting in a six to eight week road closure interrupting access to the Kuparuk oil field. Historically, the cost of permanent bridges to provide access to the field were found to be cost prohibitive due to extreme environmental conditions, gross vehicle loads of up to 4,000,000 pounds and the river hydraulics in which large water flows must be passed during the spring floods. The innovative solution consists of submersible bridges in combination with paved roadway sections that are allowed to overtop during peak spring break-up floods.

The new Kuparuk River east (210' long) and west (150' feet long) channel submersible bridges, completed in 1999, reduce the closure period of this critical road link to a maximum of one week per year and eliminate the need to annually reconstruct the road. The cost savings of more than three million dollars per year in oil field operational and advanced material purchase costs will pay for the project cost in four years.

The crossings pass the peak spring breakup flows (typically more than seven times greater than summer flows) through and across the existing Spine Road by using a combination of welded steel submersible bridges and paved low water roadways. The short-span, stout, welded steel structures are elegant in their simplicity and are a practical, cost-effective answer to permanently crossing large, dynamic arctic coastal plain rivers.

Design and Construction

The bridges are designed to support any oil field vehicle currently in operation on Alaska's north slope. The largest of these vehicles weighs approximately 3.8 million pounds while others have maximum wheel loads that exceed 370 kips (185 tons). The entire load carrying capacity of the bridge is provided by the welded steel structure. The concrete deck was provided as a driving surface, for lateral buckling support of girders, and to ensure composite action for horizontal loads and lateral ice loads.

Environmental loads for the bridge consist of wind, seismic, river current, buoyant and river ice loading. For this design, wind, seismic, current and buoyant forces were insignificant when compared to the ice loading. Design ice thickness was 52" of hard structural ice (5' total nominal ice thickness) that is capable of imposing tremendous loads on the bridge deck and ice breakers.

The bridge substructure consists of large diameter, heavy wall and welded steel pipe piles—the only practical method to support the massive vehicle loads. Each pile bent, spaced at 30' consists of four vertical 36" diameter, 1" wall API 5LX-52 pipe piles driven to 80' penetration to support the heavy vehicle loads and provide lateral support for ice loads. Required vertical capacity (design load) of each pile was 750 kips (375 tons) which was easily achieved using a Delmag D-62 diesel impact hammer, rated at 165,000 foot-pounds of energy. Each in stream pile bent has a steel ice breaking pipe installed at 45 degrees on the upstream side. When impacted by an ice floe, this design will fail the ice sheet in bending, rather than crushing, substantially reducing the lateral force on a single ice breaker from approximately 750 kips to 320 kips. This unique design saved time and cost by reducing the ice loads to the structure, providing reasonable tolerances for field fit-up and utilizing a vertical pile in lieu of more expensive and impractical (for installation in hard permafrost) batter piles.

The pipe piles were slotted at cut off to receive the steel box pile cap. The slotted pile to pile cap connection provided both a full moment connection for lateral load resistance and the load transfer for vertical loads, eliminating the need for bearing stiffeners. Cost saving 1½" interior bearing stiffeners attached to the top flange of the pile cap also eliminated the need for bearing stiffeners in the girders.

The bridge abutment design utilizes open sheet pile cellular structures, a rugged and proven innovation utilized throughout the Pacific Northwest. These abutments are constructed in a circular arc in which the sheet pile cell remains unclosed beneath the roadway. As is found in closed cellular structures, hoop stresses are generated between the sheet piles, but with the open cell abutments the hoop stress is resisted solely by soil friction along at the tail ends of the structure. For these submerged structures, the tail ends of the central cell (tailwalls) were protected from scour by inclusion of short wingwalls on the upstream and downstream sides. Wingwalls were constructed in a circular pattern and behave in the same manner as the central sheet pile cell. This abutment type is not scour sensitive since sheet pile embedment at the streamside face is not required for the abutment stability.

The submersible bridge design utilizes 30' spans that allow an extremely shallow, high-capacity deck and girder system. The superstructure consists of eleven 22½" deep steel plate girders at 3' spacing encased in cast-in-place structural concrete. The girders were constructed using ASTM A572, Grade 50 material meeting Charpy V-notch impact criteria of 15/12 (avg./min.) foot-pounds at -50° F for cold weather performance.

The steel structure also served as formwork for the superstructure concrete by eliminating the need for falsework and minimizing on-site construction time and costs. A 26" diameter fabricated steel half-pipe deck nose is welded to the edge of the upstream girder to provide a round surface that further limits ice crushing loads on the deck. The deck nose is fitted with guardrail support pipes that are welded to the outside girders. A rolled plate welded to the downstream girder provided the concrete formwork on the other side of the bridge. Steel plate placed on the bottom flange of the plate girders and attached with intermittent fillet welds served as the underside concrete form for the bridge.

The bridge design required an easily removable guardrail for the crossing of oilfield vehicles up to 60' wide. Welded steel pipe sleeves at the edges of the deck provide support for the removable guardrails. The identical sections of guardrail, each fourteen feet long, are easily removed and replaced as the pipe legs slide into the pipe supports in the bridge deck. This system has received much praise for its ease of use, especially in extremely cold weather.

Fabrication

Fabrication of welded steel bridge components was a critical element to the success of this project. All of the components of the bridge were shop fabricated into sections that were easily transported to the site to minimize costs. Both the design engineer and general contractor worked carefully with the fabricator to assure that all fabricated pieces would be easily erected in the field. Careful match marking of each fabricated member and the fabricator's careful attention to detail allowed the structure to be erected in temperatures averaging -30° F and wind speeds of up to 20 mph without requiring field modifications.

Conclusion

By utilizing a combination of durable, submersible bridges and paved low water roadways an innovative solution was developed to provide reliable access to the Kuparuk oil field for 51 weeks out of the year. The unique design kept the cost of the project within reasonable limits for crossing two river channels in a flood plain over two miles wide. The project was designed and constructed on time with a tremendous cost savings over traditional, elevated bridge designs. This successful design promises to serve as a model for future expansion of the infrastructure on the North Slope of Alaska and in other climates around the world.

Project Team

Owner
Phillips Alaska, Inc.

Designer
Peratrovich, Nottingham, & Drage

Steel Fabricators
Jesse Engineering Company

General Contractor
Alaska Interstate Construction

Trunk Highway 47 under Saint Anthony Boulevard

Minneapolis, Minnesota

Jurors Comments

A beautiful bridge...elegant and shallow main span...interesting concept to counterweight the short back spans and hide them behind the abutments.

The bridge is a three span continuous welded plate girder with a 124' main span and 52' end spans. It has six girders with a 53" webs in the end spans, parabolic haunches at the piers and 32" webs in the main span. The bridge replaces a bridge with a haunched concrete slab main span flanked by deck girder end spans hidden by walled enclosures.

The aesthetics of the new bridge remind motorists that this is the northern gateway to Minneapolis. The girders were haunched to give a slender appearance to the main span. Enclosed end spans give the appearance of a walled abutment, retaining the style of the original bridge. The end span enclosures have a random stone surface finish, giving texture to the vertical faces. Aesthetic requirements called for an unobstructed view without a pier in the median of the highway below, and a shallow structure depth. This was accomplished by using three span continuous girders. A pier wall and side walls create a hollow enclosure for the end spans. Counterweights were used to shorten the end spans in order to maintain similar proportions to the original bridge while controlling uplift at the abutments. The end spans were not haunched at the pier for ease of fabrication and to allow more depth for the concrete counterweights at the abutments.

Project Team

Owner
Minnesota Department of Transportation

Designer
Minnesota Department of Transportation

Steel Fabricator
Egger Steel Company

Steel Detailer
Egger Steel Company

Steel Erector
High Five Erectors, Inc.

General Contractor
Lunda Construction Co.

Prize Bridge Award: Special Purpose

Old Plank Road Trail Bridge

Frankfort, Illinois

Jurors Comments

Unique use of skewed A-frame pylon to suspend a plate girder superstructure. A light, airy open design...a unique through-the-leg superstructure...Very interesting concept.

The Old Plank Road Trail (OPRT) Bridge in Frankfort, Illinois carries a bicycle path and pedestrian walkway along an old railway alignment across U.S. Route 45 at a skew of 43 degrees. A new bridge was required because of a major upgrade of U.S. 45 at this location, including a profile raise and widening to four lanes. The bridge was designed under the direction of the Illinois Department of Transportation (IDOT), and completed in 1999.

The defining structural feature of the bridge is an A-frame pylon with its legs straddling the highway at right angles (actually 2 degrees off a perfect right angle, to avoid an existing drainage structure). Thus, the main load carrying component, the pylon, spans the shortest distance across the highway. The skewed deck structure is suspended from the pylon by cables. There are no piers; from abutment to abutment the deck superstructure is supported only by the cables extending from the top of the pylon.

The abutments are set well back from the edges of the highway, yielding a total bridge length of 180' measured along the skewed deck. Four hanger cables from the top of the pylon, two on each side of the deck, divide the 180' length of the skewed superstructure into three 60' segments.

The basic dimensions of the bridge are indicated in its simplified plan and elevation. The pylon is 82' high and its legs are 114' apart at the base. The highway below is 73' wide overall (including four traffic lanes, shoulders and a median). The suspended structure is 180' long, at a skew of 43 degrees.

Details of Structure

The pylon legs are steel pipe sections of 30" outside diameter and 5/8" wall thickness. The material is of 36 ksi yield stress. The lower 12' of each leg is filled with concrete to improve resistance to traffic impact.

The suspended structure is framed in steel. The main longitudinal girders are W27 rolled beams, 12' apart. W14 floor beams at 12' centers span between the longitudinal girders and support a cast-in-place reinforced concrete deck. The girders and floor beams are of Grade 50 steel. Shear studs connect the steel framing to the concrete. The overall depth of the suspended structure, excluding the custom-designed railings, which are largely open and visually transparent, is only 27".

Four hangers support the suspended deck structure, each a 1½" diameter bridge strand, with standard open strand sockets at both ends.

The pylon is supported at the base of each leg by battered and vertical piles. An integral abutment design, with vertical piles at each abutment, is used for the deck structure. Internally reinforced earth walls are used for the abutments and wing walls.

The designers of the OPRT Bridge decided not to use plastic encasement or other heroic measures for protection of the hangers from corrosion. Instead, the hangers were made easily inspectable and replaceable. The bridge was designed to permit removal of one or all of the hangers with a single temporary support in the median of U.S. Route 45. This design feature, which required little additional strength in the structure, was also expected to be useful during erection of the bridge.

Design Criteria and Structure Behavior

Current AASHTO, *Guide Specifications for Design of Pedestrian Bridges*, were used for design of the bridge. The design live load was a distributed pedestrian load or a single H-10 truck. The design was based on complete three-dimensional analysis with finite elements representing the deck (this design did not differ significantly from a preliminary design based on a simple "back-of-an-envelope" analysis).

The calculated live load deflections (2.3' maximum) and the combination of natural frequency (1.0 hertz) and mass are well within the recommendations in the AASHTO, *Guide Specifications*.

Analysis of Cost

The OPRT Bridge was advertised, bid and contracted as part of a much larger project (with a total construction cost of about $10 million). The four bids received were within a 10% band, but the cost of bridge items in the bids ranged from about $422,000 to $857,000. This suggests an artificial breakdown of prices by the bidders and makes it difficult to reliably isolate the cost of the bridge from the overall bid prices. However, the bid prices support estimates prepared during design, which indicated that a conventional crossing with a pier in the median of U.S. 45 would have cost about the same as the design that was adopted. The striking appearance and the elimination of the center pier and the related safety benefits were achieved at little or no extra cost.

Other Potential Applications

The diagonal-pylon concept developed for the OPRT Bridge is applicable to a wide range of crossings for roadways and walkways over land or water and shows a design that was proposed recently for a 40' wide roadway crossing over a rail yard in Chicago—a solution abandoned for urban-planning reasons in favor of a tunnel.

Though the full benefit of the diagonal-pylon concept will not be realized in bridges that are not skewed the concept may prove to be a viable alternative to conventional designs even for certain non-skewed crossings.

Highlights of OPRT Bridge Design

Though the bridge is skewed, the main load carrying component, the pylon, spans the shortest distance across the highway below.

The clear span under the bridge is between the legs of the pylon, rather than on each side of it as in conventional cable-stayed bridges.

The large angle between the plane of the pylon and the deck structure, the skew, allows the deck to restrain or "brace" the pylon in the out-of-plane direction. Thus, the overall structural concept is one in which the pylon supports the deck vertically while the deck supports the pylon laterally.

The challenge presented by the extreme skew of the crossing was turned into an advantage through this unique structural design.

The cost is comparable to that of a conventional bridge with an additional pier at the center of the crossing.

The structural concept developed for this bridge is applicable to a wide range of skewed crossings for roadways and walkways over land or water.

Project Team

Owner
Illinois Department of Transportation

Designer
Teng & Associates, Inc.

Steel Fabricator
Industrial Steel Construction, Inc.

Steel Detailer
B & D Detailing Inc.

Steel Erector
Angus Contractors Inc.

General Contractor
K-Five Construction Corp.

Consulting Firm
Herlihy Mid-Continent Co.

Prize Bridge Award: Moveable Span

Casco Bay Bridge

Portland, Maine

Jurors Comments

Innovative...unique trunnion strut, graceful lines and aesthetic pier shape...excellent presentation to make a moveable bridge aesthetically appealing.

The Fore River is an important navigable waterway serving both commercial shipping and recreational boating activities of the Portland-South Portland area. The old movable bridge spanning the navigation channel was a two leaf Sherzer rolling bascule type providing a channel clearance of only 98' horizontally and less than 24' above mean high water vertically when the bridge was closed. The draw span provided a narrow entryway with less than 5' side clearances, at times, for large tankers and cargo ships to delivering oil and cargo to the terminals located in the upper Fore River. The bridge is also an integral part of the area's transportation network with over 30,000 vehicles per day traveling between the two cities.

Public debate about replacing the old bridge started as far back as 1951. Numerous studies were conducted to evaluate the deteriorating structural condition of the old bridge and to determine the feasibility of rebuilding or replacing it, including the possibility of a tunnel crossing. Other studies focused on navigational needs and potential navigation improvements that would be provided by a bridge replacement.

It was not until 1987 that a plan to replace the old bridge was accepted by local, state and federal officials, clearing the way for the design and construction of the Casco Bay Bridge.

The Casco Bay Bridge is the Maine Department of Transportation's largest bridge construction project to date. The 4,748' long structure includes a mid-level movable bascule span over the navigational channel of the Fore River that flows into Casco Bay. The span is one of the largest of its type in North America and it is a trunnion bascule with a center-to-center trunnion distance of 285.5'. The new span has a horizontal channel clearance width of 60 m (196.85'), over 100' wider than the old movable span, making the passage through the bridge safer for navigation. The new span is also higher providing 65' of vertical clearance at the center of the channel, with the bridge in the closed position, thus decreasing the number of openings of the span and reducing delays to bridge users.

Bascule Span Design

The design of the bascule span incorporates the state-of-the art in bridge design and construction for structural, mechanical and electrical systems and conforms to both AASHTO's, *Standard Specifications for Movable Highway Bridges*, and *Standard Specifications for Highway Bridges*, 15th Edition, using a design live load of HS25 and alternate military loading. The specifications are supplemented by the latest industry standards applicable to each individual discipline.

ASTM A709, Grade 36 and Grade 50 painted structural steel, was used for the bascule superstructure. Due to the size of the bascule leaves and the need for counterbalancing, it was beneficial to provide an efficient structure which minimizes the weight of the leaves where feasible to achieve an economical design. The reduced mass of the leaves also results in cost-effective design of the support system, balance system and drive system. Still, for the bascule leaves strength design is not always the controlling factor. Live load deflection of the cantilevered leaves at mid-span had to be controlled to minimize any potential problems with the span locks. Parabolic-shaped steel I-girders were chosen to conform to the moment envelope of the cantilevered leaves for efficient distribution of materials and ease of fabrication. Similarly, the full-depth floor beams were configured as trusses with readily available rolled shape members designed to have adequate load carrying capacity as well as to provide torsional rigidity for the entire movable leaf during span operation. The floor beams support the galvanized stringers, open grid decking, steel barriers and steel sidewalks.

Unique Features

Each bascule leaf is counterweighted with a concrete-filled steel box at the heel end between the pair of I-girders. The box is 16' × 19' × 30' and is formed with 3/4" stiffened steel plates. Due to the size of the counterweight, and the 78 degree angle of opening needed for the bascule leaf, a sizable clear space had to be provided between the support columns to allow for the movement of the counterweight. The conventional bascule bridge pivot consists of a trunnion shaft through the girder web with support bearings on each side of the web. This arrangement was not feasible for this structure. An innovative concept was advanced to solve this problem and was

accomplished by the use of the trunnion strut. A stiff space truss (referred to as the trunnion strut) spans between each pair of support girders. At each end of the strut a trunnion shaft penetrates the main girder web to engage the strut in order to transfer the load of the bascule leaf to the supporting trunnion bearing. The single bearing at each girder is supported by an exterior column. This arrangement opened up an uninterrupted space between supports for the movement of the counterweight. A large percentage of the steel used for the strut is distributed to the corners for efficient use of material to provide a very stiff element with constant section property in any orientation. The required stiffness is used to control the deflection in order that camber and load distribution will not be a problem, thus controlling the alignment of the bearings.

The sizeable 1500 ton dead load per bascule leaf required support bearings capable of supporting very heavy loads while limiting the size of the trunnion bearings. Special maintenance free spherical plain bearings with sliding contact surface combination of steel and special bronze was specified. The sliding layer is composed of discs of bronze material inserted in recesses milled into the inner steel spherical convex surface. The special bearings, specifically manufactured in the United States for this project, are capable of supporting very heavy radial loads and axial loads. These may be the only bearings of this type used for bridge application in this country.

Foundation and Substructure

Although alternate 7' diameter drilled shafts and H-pile foundations were designed for this bridge, the contractor selected the later for construction. High bending capability required for the H-pile foundation resulted in the specification of A572 high strength HP14 × 117 steel piles, reinforced with cover plates near the tops of the piles. A total of 231 piles were utilized for each bascule pier. A critical length of embedment of the H-piles was required to develop sufficient anchorage of the piles against lateral loads. Difficult pile driving conditions were anticipated in the glacial till material, based on available geotechnical information, but did not present any significant problems during construction.

A pair of unique, reinforced concrete piers were designed to emphasize the entrance to the harbor. The fully

screened and enclosed piers were desirable due to their ability to protect the bridge's operating machinery from the weather, as well as keeping out birds. The shape of the pier tops is more or less defined by the arc of travel of the counterweight within when the leaves open or close. The reduced width of the lower portion of the mid-level bridge piers also resulted in a savings of material.

Pier Protection

A pier protection system consisting of four cellular sheet pile dolphin and fenders demarcating the boundaries of the channel was designed to prevent, or at least minimize, any damage to the bridge piers due to vessel impact.

Concrete from the old bridge was recycled by processing the demolished concrete into a consistent gradation and used as granular fill for the cellular sheet-pile dolphins.

Clusters of 36” diameter fusion-bonded epoxy coated steel pipe piles and wales consisting of W24 × 117 rolled beams form the protective fender system along each edge of the channel. The wales were faced with ultra high molecular weight (UHMW) polyethylene rubbing strips for decrease vessel impact force due to the very low coefficient of friction. The UHMW material was also selected for its durability and resistance to deterioration.

Efficient energy absorbing kinematic rubber fenders were introduced at the pier locations to provide the minimum offset of the fender, and maximize the channel width opening to satisfy the navigational clearance requirements of the U.S. Coast Guard.

Electrical/Mechanical

The state-of-the-art electrical system includes automatic control which is performed by the programmable logic controller (PLC) for sequencing of the various operating steps required by the movable span. Solid state speed controls are also used to provide a higher degree of accuracy in bridge movement.

The bridge drive machinery uses a single enclosed drive arrangement for each leaf to enhance reliability and minimize maintenance. The main motors and motor brakes, including the auxiliary drive system, were pre-assembled on the drive unit in the manufacturer's facility in an attempt to provide more accurate alignment of the various components.

Unique “wet” type disc brakes were specified for the bridge machinery. These compact brakes provide an efficient braking system and also have excellent corrosion resistance.

Aesthetics

Special consideration was given to the visual impact of the bridge on the landscape of Portland Harbor. An aesthetic committee was established to provide input and guidance to finding a design that would complement its environment and serve as a new landmark for Portland Harbor. By taking advantage of the long curvilinear alignment of the new structure the design team endeavored to achieve the concept of a continuously flowing ribbon in space, punctuated only at the bascule span.

The treatment of the large bascule piers commanded the attention of two nationally renowned bridge architects. The upper section of each bascule pier above the shaft is shaped to conform to the enclosed space required to accommodate the movement of the counterweight as the span opens and closes. It also provides a protective enclosure for the trunnion bearings and the machinery which operates the span. The bascule span is viewed as an accent to the desired ribbon effect.

A special red color was selected for the paint on the structural steel girders to enhance their appearance and blend in with the red brick seen on many of Portland's waterfront buildings.

Project Team

Owner
State of Maine Department of Transportation

Designer
Modjeski and Masters, Inc.

Steel Fabricator
Tampa Steel Erecting Company

Steel Detailer
Tensor Engineering Co.

Steel Erector
Cianbro Corporation

General Contractors
Cianbro Corporation

Consulting Firm
T.Y. Lin International

Damen Avenue Arch Bridge

Chicago, Illinois

Jurors Comments

The use of bent, steel pipes for the arches without lateral bracing is innovative...aesthetically pleasing

The bridge, located six kilometers northwest of downtown Chicago, is part of a $12.6-million improvement project along a section of North Damen Avenue. The mixed-use properties surrounding the site are rapidly transitioning from factories to mini-malls and condominiums. In view of this redevelopment, the city of Chicago proposed to build a signature bridge at this site to act as the focal point for the overall public and private revitalization of the area.

Among the project's innovations are the arch ribs, which are freestanding and constructed without lateral bracing. Additionally, the arch is not tied. Tied arches represented potential durability and safety concerns for both the Federal Highway Administration and the city of Chicago, concerns which were avoided by eliminating the tie.

Bridge Description

The new structure spans 94 m over the river and carries two lanes of traffic, with sidewalks along each side, in each direction. The two ribs are fabricated from 1.2 m-diameter steel pipe that is formed into a compound circular curve using induction heat bending. Each rib lies in a vertical plane and is located between the roadway and sidewalks. The ribs have a constant wall thickness of 25 mm throughout their length, and is filled with concrete over a distance of 8 m at each end in order to resist the higher thrust and moment near the spring points.

The superstructure is comprised of a longitudinally post-tensioned, cast-in-place concrete deck and stiffening girders that are supported by transverse steel box beams. The transverse beams act compositely with the deck. The beams are supported from the ribs by structural strand hangers anchored at the bottom flange and attached to the ribs using steel gusset plates and an open socket. The gusset plates penetrate the rib and are welded to stiffener plates and bolted to angles to transfer the hanger forces into the rib.

The semi-integral abutments and rib thrust blocks are founded on a common reinforced concrete cap. Each cap is supported by six 2.1 m-diameter drilled shafts that extend to bedrock.

Innovations

The structure is a unique blend of materials and components that are designed to result in a rapid speed of construction, an aesthetically pleasing appearance and excellent long-term durability. The concrete deck is post-tensioned and overlaid with a latex modified concrete wearing surface to improve the rideability and durability of the bridge deck system. The longitudinal concrete stiffening girders are connected to the transverse steel floor beams using continuous post-tensioning clamping the two components together to achieve structural continuity. This innovative method of connecting the steel floor beams to the concrete stiffening girders greatly simplified the fabrication and construction of the floor system and allowed each material to be used where it is most effective.

The ribs are freestanding and constructed without lateral bracing. This eliminates the traditional cross bracing associated with the design of conventional arch bridges, which detracts from the clean appearance and elegance of a soaring arch rib, increases the construction cost and represents a maintenance and performance problem to the owner.

The ribs are unique in that they were fabricated from 1.2 m-diameter pipe instead of a traditional box section that is fabricated using welded plates. Use of a pipe section resulted in a significant reduction in wind pressure on the ribs and resulted in improved aesthetics.

The ribs were fabricated using an induction heat bending process. Induction heat bending is commonly used to fabricate large diameter utility pipes but is not typically used to fabricate structural bridge steel. After investigating several concepts for fabrication of the ribs, it was concluded that induction heat bending should be specified as the preferred method.

Induction bending utilizes an induction-heating coil to create a narrow, circumferential heated band around the material to be bent. Once the heated band has attained the desired temperature the material is moved through the coil at a predetermined speed. A radial arm that rotates about a central pivot point, and is clamped to the leading edge of the pipe, applies the bending moment.

After the material passes through the coil, an air or water spray quenches it.

Social and Economical Considerations

The project was driven by the owner's desire to build an aesthetically pleasing structure that added value to the surrounding community. The bridge has become a catalyst for the overall public and private revitalization of the area and stands as an identifier or signature of the community as a whole.

This crossing of the Chicago River provided an important access point to the river, as well as to the city's riverwalk development program, which is a long term project ment to provide a continuous linear parkway and bike trail system along both sides of the river. The bridge span was adjusted to provide for the riverwalk along both banks.

The existing bridge represented a functional traffic problem to the city, due to the importance of Damen Avenue as a transportation arterial. The existing bridge was in such poor structural condition that traffic was restricted from four to two lanes until it was replaced. A new bridge was needed, and was needed soon, as residential and retail developers were advancing new projects in the area. The design and detailing of the bridge were tailored to maximize the opportunity for off-site construction and large component erection in order to minimize construction time. This allowed the contractor to complete the construction and reopen the bridge to traffic in just eight months.

The new bridge provides the public with a safe and reliable structure that at the same time livens up their journey with its dramatic appearance.

Design Problems and Solutions

The owner's goal of designing an arch bridge that could be opened to traffic within eight months created a complex design and construction challenge.

Arch structures generally take longer to build than conventional bridges because of the long lead-time required to procure and fabricate the steel ribs. Therefore, in an effort to speed the construction process, the bridge configuration was optimized to minimize falsework requirements and strive to make the bridge self-supporting during each stage of construction. This resulted in the completion of rib erection, hanger and beam erection, superstructure casting and post-tensioning, approach slab placement and traffic control installations in approximately one-and-a-half months. This is a remarkable construction scheduling and engineering achievement on behalf of the contractor that, in our opinion, was facilitated by the configuration and details of the structure.

Arches are exceptionally sensitive to placement of unsymmetrical loads during construction. The deck placement procedure was developed in such a way as to maximize the contractor's options for deck placement, and minimize the potential for overstressing the ribs during the deck pour. The contractor ultimately elected to utilize dual finishing machines and pumps working symmetrically from the center of the bridge outward, as originally conceived by the team.

The bridge foundations were complicated considerably by the presence of existing underground structures, including a maze of timber piles supporting the existing retaining walls. The new foundations had to be designed to account for the difficulties of working around these existing piles. Drilled shafts with sufficient diameter were selected to deal with interference with the existing piles.

Although the owner's goals created a complex design and construction challenge in the optimization of the structure and meeting the project schedule, the final design resulted in a simple form that utilizes conventional methods of construction.

Aesthetic Considerations

A successful design is one that maintains a careful balance between technological and aesthetic considerations. The ultimate goal must be to achieve harmony with the surroundings with simple forms and minimal current, as well as future resources. When this goal is achieved bridges can be a vital part of the community. Vital not only from the standpoint of commerce, safety and mobility, but also as a landmark or tribute to the creativity, fortitude and technological proficiency of the people who design, build, and use them. The city of Chicago recognizes this principle and uses bridges and other public works beautification projects as a tool to stimulate commerce and revitalization of a community or area. Therefore, the visual and functional friendliness of the site received considerable attention from the design team.

All architectural features were designed to enhance or compliment the natural elegance of the arch form. The ribs are painted red and are highlighted at night with underlighting located in the deck. Precast abutment towers with carved granite caps are located at opposite corners of the bridge. Belvederes are located at the other two corners to provide a location for pedestrians to stop and look out over the river. A staircase was constructed at the northwest corner of the bridge to allow access to the future riverwalk below. Ornamental handrails are located along both sides of the sidewalks and will be painted red to match the color of the ribs.

Careful attention was given to the specifications regarding finish and color of the precast and cast-in-place concrete on the bridge and approaches to ensure consistent or complimentary textures and colors. The color of an existing retaining wall was integrated into the overall structure using a concrete stain. The contractor was required to construct mock-ups for approval of all critical concrete elements prior to starting production.

Meeting Client Needs

The Damen Avenue Arch Bridge represents the successful integration of all of the clients project goals relating to aesthetics, speed of construction, constructability, durability and cost. The final contract documents were delivered to the client on schedule.

The design facilitated the contractor meeting the owner's schedule of opening the bridge to traffic within eight months. The bridge has also received numerous awards and a very favorable architectural critique by the Chicago Tribune.

Project Team

Owner
City of Chicago Department of Transportation

Designer
J. Muller International

Steel Erector
Steppo Construction

General Contractor
Walsh Construction Company of Illinois

Engineering & Erection Procedures
Danny's Construction Co.

Consulting Firm
TranSystems Corp.

Prize Bridge Award: Long Span

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