A Second High-Level Blue Water Bridge

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Planning, design, construction, and maintenance issues are presented for the proposed second high-level Blue Water Bridge, which crosses the St. Clair River between Port Huron, Michigan, and Point Edward, Ontario, Canada. The bridge design meets the requirements of AASHTO load resistance factor design specifications as well as the *Ontario Highway Bridge Design Code*. The construction plans are prepared in metric (SI) units. Main spans are a continuous tied arch bridge. The fracture-critical tie girder is fully bolted (no welding is allowed) to improve redundancy. The empirical design method is used to design the reinforced concrete deck. Approach spans are predominantly prestressed concrete I- or box beams with a reinforced concrete bridge deck.

This paper presents issues related to the planning, design, construction, and maintenance of the proposed second high-level Blue Water Bridge, which will span the St. Clair River between Port Huron, Michigan, and Point Edward, Ontario, Canada. The new bridge will be constructed adjacent to the existing Blue Water Bridge and will provide an additional link between Interstate highways 94 and 69 in the United States and Highway 402 in Ontario. The proposed high-level bridge (a continuous steel tied arch) will provide a navigational clearance of 155 ft. (47.2 m) and have a center span of about 870 ft. (265.2 m). The total length of the bridge, including approach spans, is about 6,600 ft. (2001.7 m). The approach spans will be steel and prestressed concrete beam spans with reinforced concrete decks. When the new bridge is completed, it will carry eastbound traffic to Canada; the existing bridge will carry westbound traffic to the United States. The estimated cost of the new bridge is about $70 million, and it is expected to be opened to traffic in spring 1997. Figure 1 shows the proposed bridge, with the existing bridge in the background.

This international bridge is designed using AASHTO's new load resistance factor design (LRFD) specifications for highway bridges (*1*); it also meets the requirements of the *Ontario Highway Bridge Design Code* (*2*). The plans of the proposed bridge are prepared in the metric (SI) units.

The new and existing toll bridges are owned and operated by the Michigan Department of Transportation (MDOT) and the Blue Water Bridge Authority (BWBA), Canada. Both agencies will share the cost of the new project and provide equal design effort, labor, and materials for construction.

Planning

Traffic

Planning for the proposed structure took several years. The traffic studies indicated substantial growth in 1980 through 1991, from 3.5 million to 6.1 million vehicles a year. By 2031 the traffic is estimated to be 15.5 million vehicles a year. Currently the bidirectional annual truck traffic is estimated to be 1 million trucks. Recent

FIGURE 1 Proposed second high-level Blue Water Bridge; existing bridge in background.

passage of the North American Free Trade Agreement, or NAFTA, will generate more commercial traffic at this crossing. Truck traffic is forecasted to increase by 100 percent in the next 10 years. The existing bridge, which provides one lane of traffic each way, is not able to handle traffic growth. The proposed bridge will have three traffic lanes, shoulders, and a pedestrian sidewalk. It will carry eastbound traffic to Canada, and the existing bridge will carry westbound traffic to the United States. The toll plazas on the both sides will be upgraded for handling increased traffic.

Funding

The second Blue Water Bridge will be a toll crossing, so the costs of construction of $70 million will be repaid using the toll revenues.

Environmental Report

An environmental impact study was conducted in order that final approvals could be received from the regulating agencies. The impact categories analyzed as a part of this study are as follows:

1. Natural environment: air quality, climate, geology, soils, vegetation, wildlife, aquatic environment, and special habits;
2. Social environment;
3. Cultural environment;
4. Local economics;
5. Archaeological resources;
6. Noise environment;
7. Built heritage resources; and
8. Traffic and transportation.

The study recommends mitigation for these impact categories. In particular, barges will not be allowed on the St. Clair River for construction and erection of the main span. This prohibition will require a construction method for the steel tied arch that uses a cantilevered erection of steel from the main piers on the river banks.

Selection of Structure Type

For spanning the St. Clair River the following bridge alternatives were considered:

- Cable-stayed (steel and concrete),
- Duplicate truss,
- Parallel-chord truss,
- Continuous tied arch, and
- Single-Span tied arch.

These alternatives were evaluated using the criteria of initial cost, life-cycle cost, construction disruption, maintenance/inspection, durability, redundancy or robustness, aesthetics, and engineering evaluation. The numerical results of these alternatives are presented in Table 1.

The evaluation indicated that cable-stayed (concrete and steel), duplicate truss, and continuous tied arch bridges were top choices. The public was given an opportunity to express its opinions on the three choices. The following is a summary of selected public input:

- Of those expressing an opinion, 63 percent preferred the duplicate existing alternative.
- By comparison, 19 percent preferred the continuous tied arch, and 16 percent the cable-stayed alternative.
- Bridge aesthetics was rated the most important evaluation factor in Port Huron, Michigan, and public health and safety was rated the highest in Point Edward, Canada.

Even though the public favored the duplicate truss bridge, the historical commission ruled in favor of the continuous tied arch bridge in order to preserve the historical uniqueness of the existing bridge. The commission also pointed out that the continuous steel tied arch bridge is aesthetically pleasing and blends with the existing bridge and the surrounding area.

Thus, the final selection was a continuous tied arch bridge for the river crossing. The adjacent three spans on each side of the arch bridge were selected to be of steel box girder spans for aesthetic reasons. The remaining approach spans, averaging lengths of about 25 to 35 m, are prestressed concrete I- or box beams. The structural and architectural features of the graceful con-

TABLE 1 Evaluation Matrix

Criteria	Weight	Cable-Stayed Steel Bridge	Cable-Stayed Concrete Bridge	Duplicate Truss Bridge	Parallel Chord Truss Bridge	Continuous Tied Arch Bridge	Simple Tied Arch Bridge
Initial Cost	3	85	85	85	100	85	85
Life Cycle Cost	1	85	90	60	90	75	100
Construction Disruption	1	100	100	90	90	85	80
Maintenance/Inspection	1	90	100	70	85	85	90
Durability	1	85	85	100	100	85	100
Robustness	3	100	100	90	85	80	75
Engineering Aesthetics	3	100	100	100	50	100	50
Engineer's Evaluation (Points)		1,215	1,230	1,145	1,070	1,125	1,000
Normalized Value		99	100	93	87	91	81

tinuous steel tied arch provide a pleasing view of the new bridge while preserving the uniqueness of the existing bridge, which has been an area landmark for a half century.

The bridge deck is reinforced concrete for the approach spans as well as for the tied arch span. The major steel tied arch bridges in North America have steel orthotopic decks with thin asphalt overlays. After considering winter conditions and the possibility of total deck replacement in the future, it was decided to not use steel orthotopic deck. The main span design will account for deck replacement in the future, using part-width construction to maintain one traffic lane.

Design/Build or Design/Tender Bid

Design/build was considered as an option for completing the project on time and within budget. From the owner's perspective, design/build offered the following important advantages:

- *Establishes single source of responsibility.* When both the design and construction functions are with a designer/contractor, this single entity has greater responsibility to the owner's concerns; this option also lowers the number of formal change orders.
- *Shifts risk.* The design/build team is responsible for errors and omissions in the design plans as well as defects in the construction.
- *Reduces project delivery time.* This option can reduce total project delivery time as construction of some phases can begin while later phases are still in the design stages.
- *Lowers cost.* Reducing project delivery time can provide an opportunity to reduce construction overhead and financing costs.

Disadvantages from the owner's perspective for design/build are as follows:

- *Lengthens review process.* The owner needs to define the scope of the project in great detail. Prequalification of design/build teams, request for proposal, review, selection, and award of the contract take considerable time, especially in the public agencies.
- *Decreases flexibility.* Any change in the predefined work is expensive.
- *Shifts control.* As more responsibility and control are placed with the design/build team, the owner loses a similar degree of control. Loss of control can result in a reduction of quality of materials and workmanship. Extensive specification and quality contract documentation is necessary to maintain some checks and balances.

After considering the preceding information, MDOT and BWBA decided to adopt the conventional design/tender bid method to complete this project. The selected design consulting team will be maintained for construction engineering of the project, and a second consulting team will be hired to perform an independent review of plans and quality assurance functions for the owner (MDOT).

Selection of Consultant

The joint partnership between MDOT and BWBA required that the design consulting team be made up of consultants from the United States and Canada. In addition, the consultant team must have experience in designing long-span structures, in the LRFD highway bridge design specifications adopted by AASHTO, in the *Ontario Highway Bridge Design Code*, and in metrication of contract plans. The consulting team needs to include local subconsultants for surveys and geotechnical investigations. The consultants must show qualifications of the staff who will be assigned to complete the project.

Design Criteria

The bridge must be designed to meet the requirements of the LRFD specifications for highway bridges adopted by AASHTO (*1*) as well as those of the *Ontario Highway Bridge Design Code* (*2*). Measures must be taken to improve redundancy of the tie box girder of the continuous tied arch. The design live loading conditions must reflect operational situations on the bridge: namely, traffic tie-ups resulting in slow-moving but closely spaced commercial trucks, at least in one lane. It is possible that the concrete bridge deck will be replaced using part-width construction while maintaining one lane of traffic on the bridge. The contract plans must be prepared in metric units.

Engineering Issues

The following engineering issues were considered in the design phase:

- Geotechnical investigations. To provide complete data, at least one soil boring was taken at each substructure location; the borings were taken to rock depth. For main piers of the continuous tied arch, the borings were taken at least 10 ft (3.048 m) into the rock. The soil profile indicates layers of sand, gravel, and soft clay to an average depth of 100 ft (30.48 m). The hard shale rock layer is approximately 100 ft (30.48 m) below the natural ground.

  Foundations for main piers and approach span piers will be supported on steel H-piles driven to bedrock. Because of the proximity of the existing bridge, care will be taken to minimize vibrations due to the pile driving operation. Two pile load tests, one on each side of the river bank, were conducted to determine design pile capacity. Test piles were subjected to a 400-kip ultimate load; the design capacity of the piles is limited to 200 kips for the main piers.
- Hydraulics/scour protection. Since the St. Clair River flows from Lake Huron to Lake St. Clair in a well-defined channel, only minor river bank erosion control is required. The water level in the river does not vary much as it is controlled by the water levels in the Huron and St. Clair lakes. The main span piers are on the banks and out of the main river channel.
- Life-cycle/cost analysis. The analysis indicated that for the approach spans, using prestressed concrete beams is better because they eliminate the need for coating, as required for steel beams. Epoxy-coated steel will be used in the reinforced concrete deck and areas of splash zone of highway runoff containing deicing salts used during winter.
- Constructability. The plans will show a feasible scheme for erecting the continuous tied arch using a cantilevered construction from main river piers, thus avoiding use of barges in the St. Clair River.
- Maintainability. Ongoing maintenance will be a key to the durability of the bridge. To facilitate traffic and maintenance operations, the following provisions are made: (a) inspection walkways, (b) deck drainage system to drain into a pond, (c) lights, (d) waterline to fight emergency fires, (e) hazardous waste recovery system in case of truck spills, (f) crossover bridge between the new and existing bridges to divert traffic in case of repair or emergency on one of the bridges, and (g) use of slag material instead of salt for maintaining the riding deck surface during winter.
- Reinforced concrete deck design. The empirical method will be used to design the bridge deck with isotropic steel reinforcement. This method uses less steel reinforcement than does the traditional design. Epoxy-coated steel reinforcement will be provided in addition to a thin asphalt overlay with waterproofing membrane as corrosion protection.
- Bridge railings. Crash-tested railings with some modifications will be used for this bridge.

Construction

Construction of the bridge will begin in March 1995, and it is expected that the bridge will be opened to traffic in spring 1997. The project will be divided into three major contracts. One contract will be for the continuous tied arch and adjacent three spans on each side, and the other two contracts will cover approach span construction of both the U.S. and Canadian sides. Approximately 24 months of construction time will provide many challenges and opportunities for coordination and innovative construction methods. At this time, there is no plan to instrument this bridge for monitoring its long-term performance. However, during the construction phase the alignment and elevations and construction loads will be monitored.

SUMMARY

In summary, this will be the first major international bridge between the United States and Canada designed using the AASHTO and Ontario specifications, plans prepared in metric (SI) units, and featuring a deck design using isotropic steel reinforcement.

REFERENCES

1. *LRFD Bridge Design Specifications.* AASHTO, Washington, D.C., 1994.
2. *Ontario Highway Bridge Design Code.* Ministry of Transportation and Communications, Ontario, Canada, 1991.