Construction History of the Blue Water Bridges

Day in and day out motorists cross bridges of many lengths and kinds without a thought to their design and construction. Yet bridges serve a critical purpose linking an otherwise fragmented road system. The desire to get to the other side of a natural or man-made obstacle has challenged people throughout history. The building of monumental bridges in particular raises many questions about how its builders met that challenge. The stories behind these bridges reveal how we tackle engineering problems.

At 6,535 feet long, construction of the Blue Water Bridge spanning the St. Clair River between Port Huron, United States and Point Edward, Canada posed its own challenges during the 1930s. Nearly sixty years later, construction of a second bridge just south of the historic Blue Water Bridge offers a unique chance to compare past and present stories behind these two monumental structures.

Private interests mounted the first serious effort to build a bridge spanning the St. Clair River between Port Huron, U.S. and Sarnia, Canada. During the early 1920s planning for the Ambassador Bridge between Detroit, U.S. and Windsor, Canada inspired others to pursue a second international crossing. Although Detroit had far more traffic than Port Huron, the latter city also served as an international cross-roads with a rail tunnel and busy ferry services shuttling people and goods across the river. With the explosive popularity of the automobile, Port Huron investors recognized the economic potential of a toll bridge and wanted to vie with Detroit for business. During the late 1920s competing plans for a new bridge sprung up and the race began to win the necessary government approvals and obtain financing for the project.

The behind-the-scenes promotion of monumental bridge projects plays as an important a role as the engineering. Many great bridges resulted from the partnership of a promoter and an engineer. Successful bridge engineers recognized the importance of marketing a design and promoters recognized the importance of working with an engineer capable of creating an economical, beautiful bridge. Sometimes, the bridge designer also served as its promoter.

The St. Clair River project had no lack of promoters. Four competing proposals emerged: one from Lyle Harrington, a leading bridge engineer from Kansas, another from local businessman Maynard D. Smith, a third from the Port Huron-Sarnia Ferry Company and a fourth from a Toledo, Ohio investment company joining forces with a group of Sarnia attorneys. These proposals faced many hurdles. First, the international nature of the project complicated matters, dictating support and approval from two governments to build the bridge. Secondly, the United States Army Corps of Engineers regulated some aspects of the design and still ensure that the St. Clair River remains navigable for commercial and military vessels. The Corps required the bridge to clear the water by 150 feet and also insisted that construction not interfere with channel activity. The bridge could not be built with floating platforms or falsework in the water.

Project promoters got off to a bad start when selecting a location for the new bridge. All four proposals called for the bridge to extend between downtown Sarnia and downtown Port Huron. Politics heavily influenced this decision. After all a privately sponsored bridge would need to attract investors. Not only did these proposals call for a lengthy structure spanning the St. Clair River and Sarnia Bay, but by attempting to direct traffic into downtown Port Huron, at least one of the proposed designs had an awkward, almost laughable appearance. (See photo montage in the sidebar).

The more practical location for the bridge lay to the north between the small community of Point Edward and the former Village of Fort Gratiot, annexed by Port Huron in 1893. This location required a shorter bridge and had better soils. The Fort Gratiot neighborhood supported a Grand Trunk Railroad facility and a surrounding residential area. Purchasing real estate for a bridge in downtown Port Huron versus the Fort Gratiot neighborhood added considerable cost. Both Sarnia and Port Huron feared that locating the bridge far away from the central business district would hurt their communities.

Local businessman Maynard Smith hired the well-known Pennsylvania firm of Modjeski and Masters in 1928 to tackle the bridge's design. Frank Masters first designed a suspension bridge and later turned to a cantilever through-truss design similar to that eventually used for the Blue Water Bridge. In the meantime, Smith received the endorsements of Port Huron and Sarnia to proceed. He also convinced the U.S. Congress and Canadian officials to support his project and obtained the necessary permits to begin construction. Owners of the ferry service between Port Huron and Sarnia tried to stall his progress and he had difficulty finding financing. The Great Depression forced him to abandon the bridge, but he had succeeded in giving it momentum. The dream of crossing the St. Clair River evolved from a private venture into a government sponsored undertaking.

Congressional representatives acquired extensions for the construction permits and also passed a bill granting a state bridge commission the power to build and run a bridge as well as buy out the competition - the Port Huron-Sarnia Ferry Company. The state of Michigan had created a bridge commission in 1935 that could issue bonds to finance the design and erection of the bridge. Revenue from bridge tolls would repay the bonds.

The commission agreed the bridge should be located at its northern site, connecting Port Huron with Point Edward. They based the decision on the lesser cost of construction at this narrowest segment of the river. The bridge would also connect with the proposed Montreal-Chicago international highway. Murray D. Van Wagoner, State Highway Commissioner eagerly promoted the project through state channels. During these preparations, Modjeski and Masters continued to work on the design of the bridge. They had limited choices of bridge types given the length of the crossing and the U.S. Army Corps of Engineers height and construction requirements. They explored a suspension bridge, like the Ambassador bridge and a cantilevered through-truss. The site conditions favored a cantilevered through-truss. Suspension bridges require tall towers with massive cable anchorages on land. The flat nature of the crossing would make such a bridge appear disproportionate. Modjeski and Masters also had problems making the suspension bridge high enough to meet the 150' vertical clearance requirement for shipping. They decided to pursue the cantilevered through-truss.

Modjeski and Masters hired Monsarrat and Pratley, a Canadian design firm to help negotiate the Canadian bureaucracy, however, the Canadian firm apparently had little input into the design of the main span. Monsarrat and Pratley designed the Canadian approach spans under a separate contract. Because of the international nature of the job, officials approached the main span of the bridge as a joint venture, while work for the approach spans fell to their respective owners under separate contracts. Having conquered questions of financing and location promoters could move on to the details of designing and implementing construction of the new bridge

Fifty years after the first promoters began pursuing the St. Clair River crossing, the questions of sponsor, financing and location arose again for the second bridge. The politically sensitive issue of where to locate the second bridge preceded final decisions about who would build and pay for it. However, by the late 1970s when Canadian and American officials initiated the St. Clair River Crossing Study, established bureaucracies spearheaded efforts for a second bridge. In Michigan, the Department of Transportation had responsibility for the Blue Water Bridge as well as the highway system feeding into it and in Canada the Blue Water Bridge Authority had ownership and control of Canadian bridge operations. Planners at the Michigan Department of Transportation toyed with the idea of having a private firm finance, construct and operate their part of the bridge but in the end returned to the form of financing used on the original bridge by selling bonds to pay for the project with future toll reveunes repaying the bonds.

Increasing traffic on the Blue Water Bridge prompted the Ontario Ministry of Transportation and Communications and the Michigan Department of Transportation to find a location for a second bridge. They assembled an international team of engineers, transportation planners and environmental planners to direct the study. Much thought went into the location of the second bridge. The team selected three locations to examine: one adjacent to the existing bridge, another to the south, between Marysville and Sarnia and yet another even further south between Marine City and Sombra, Canada. The study team wanted to know if a new bridge at any of these three locations would divert enough traffic from the Blue Water Bridge to significantly extend its life. The study also looked at a tunnel option.

The tunnel did not fare well in the analysis. Building a tunnel would cost three to four times more than a bridge. Likewise, new bridges at the two southern locations would cost two times more than a bridge next to the existing. New access roads and toll/customs facilities drove up the price of these options. More importantly, the existing highway systems in both countries led to the Blue Water Bridge site and a new bridge to the south would not divert enough traffic to benefit the old one.

The study also established a maximum capacity for the Blue Water Bridge. When the traffic

volumes reached 1,500 vehicles per hour, then construction of a second bridge should be planned and implemented. It also made several short-term suggestions for improvements including re-striping the pavement markings on the bridge to provide for a truck-climbing lane and expanding the Michigan bridge plaza. After holding public meetings and studying several alternative locations for a second bridge, the team members recommended that a second bridge be constructed just to the south of the existing bridge.
The Canadian Blue Water Bridge Authority had already purchased right-of-way on the south side of the bridge. A new bridge to the south of the existing one would require less displacement of property and homes than one to the north. The southern location would also accommodate the expansion of the bridge plazas on both the U.S. and Canadian sides of the bridge.

With the location of a new bridge established, the Michigan Department of Transportation began planning a new toll and customs plaza. The plaza acted as a bottleneck, causing traffic to sit on the bridge rather than flow across it. This placed undue stress on the materials making up the bridge, especially when heavy trucks backed up in a row. If traffic could be kept moving, then the bridge would stay healthier over the long-run. Plans for the new plaza progressed and the Michigan Department of Transportation completed it in 1997.

In 1981 planners hoped that a new bridge would not be needed until the year 2000. However, traffic increased dramatically during the 1980s. Both countries completed major freeways leading to the bridge. I-69 in Michigan and Highway 402 in Canada provided an attractive low-traffic alternative to the Detroit-Windsor route. Ironically the original Blue Water Bridge Commission planned for the bridge to serve the Montreal to Chicago International route, but the descendent of this route did not become a freeway reality until the 1990s. Consequently by 1991 the bridge had reached capacity when 6,100,000 vehicles traversed it, representing 29% of all Michigan/Ontario traffic using the international bridges and tunnels between the United States and Canada. Total traffic on the bridge had doubled in 10 years. In contrast the bridge carried 310,000 vehicles in 1939. The time had come to make the second bridge a reality.

Past and present ways of deciding what type of bridge to build across the St. Clair River vary mainly because contemporary environmental laws have greater influence in both Canada and the United States. These laws require increased public input as well as a public record of the decision-making process. Experts from both Canada and the United States joined the team responsible for analyzing designs for the new bridge. Given the long length of the bridge, they had limited choices. They selected five main bridge types for detailed analysis: a cable-stayed bridge, a duplicate of the Blue Water bridge, a parallel chord truss bridge, a continuous tied arch bridge, and a single-span tied arch bridge. They did not consider a suspension bridge design like that use for the Mackinac Bridge because the crossing is not long enough to make this type of bridge economically feasible. Suspension bridges require "massive concrete anchorages to transfer cable forces to the ground. The weak soil conditions on both sides of the river would make cable anchorages difficult and expensive to construct." The team evaluated the remaining designs according to the following criteria:

maintainability, durability, constructability, cost and aesthetics.

At this point, historic preservation interests also influenced the analysis. The National Park Service declared the Blue Water Bridge eligible for listing on the National Register of Historic Places in 1983. Consequently, MDOT requested the comment of the Michigan State Historic Preservation Office on the design selection process. The SHPO challenged the evaluation team to consider "how the bridge alternatives may affect the value of the existing bridge as an historic resource by including consideration of such aspects as changes to traditional views of the Blue Water Bridge and preserving or enhancing the uniqueness of the existing bridge." As a consequence the sixth evaluation criteria of "Heritage" was added to the analysis.

The study team used a scoring method to evaluate the designs. A three-part rating system included scores from the Bridge Engineering Team, the Environmental Team and the public. Visually unappealing, the Parallel Chord Truss Bridge and the Single Span Tied Arch Bridge fell out of favor immediately. The debate over the three remaining designs heated up, with the study teams having differing perspectives on the best design.

The Engineering Team preferred the cable-stayed design because of its superior performance in the durability, maintainability and cost categories. They also felt that this design had superior aesthetic appeal. Cable-stay bridges have increasingly replaced suspension bridges for long crossings. First becoming popular during the 1950s, they have a dramatic appearance and appeal to engineers because of their high structural redundancy. Multiple cables connect the roadway of the bridge with the supporting towers. If a cable should break, there are many redundant cables to compensate for its loss. Although safe, truss designs do not have the same level of redundancy, often having critical members whose failure could result in the bridge falling down. In the continuous tied arch for example, the tie-girder or the large box of steel running the horizontal length of the bridge at the roadway level, is a critical member. Should it fail, the bridge might collapse.

The Environmental Team felt the continuous tied arch design complemented the historic Blue Water Bridge. Citing federal historic preservation standards, the Michigan State Historic Preservation Office noted the continuous tied arch "is clearly differentiated from the historic bridge, yet it is compatible with it. The design retains the through-arch and curvilinear character of the existing bridge yet does not duplicate overpower it... The reduced structural members allow the visual qualities of the historic bridge to remain prominent. The height of the tied arch bridge is also compatible with the existing bridge and the character of the surrounding area, allowing the historic bridge and its new partner to remain the tallest structures in the immediate vicinity. Construction of a duplicate bridge would be historically confusing since it would "lead to a false sense of historical development for the pair of bridges." Each historic property is a physical record of its time, place and use.

To put this into perspective, if there were no historic bridge at this location, current design philosophy as well as construction techniques and materials would lead engineers to consider a contemporary design rather than duplicate a historic design. The new bridge should not bring a sense of false history to the St. Clair River crossing. The cable-stayed bridge used materials, size, scale, proportions and massing that did not complement the old bridge. As a stand-alone bridge, the cable-stayed design had a high visual impact, but the strong vertical statement made by the towers competed with the arches of the existing bridge.

Finally, public opinion strongly favored the construction of a duplicate bridge. The Blue Water Bridge represents a dominant aspect of the local landscape. It has become a symbol of local identity appearing on stationary for the tourist/visitors agency in Port Huron as well as on patches for Police and fire department representatives. Residents of both Canadian and U.S. cities have strong emotional ties to the bridge and felt only a duplicate structure would suffice. The public found the cable-stayed design the least acceptable of the three alternatives.

Like many great debates, this one ended with a compromise. The team recommend construction of a continuous tied arch bridge. To please the engineers, the tied-arch design would undergo modifications to make the bridge more durable and easier to maintain. The tied arch represented a contemporary treatment of the historic bridge design. At first the decision caused controversy with the public, but as the new bridge took shape the controversy faded. This may largely be due to the attention paid to design details attempting to blend the new bridge with the old.

Once the designers have settled on a bridge type, they need to make critical decisions about its appearance. In the case of both the old and new bridges the visual concerns included the look of the main span crossing the river as well as the relationship of the main span to the approach spans. The treatment of the piers supporting the bridge also provides an opportunity to change its overall look. The engineer has the tricky task of designing a bridge with complementary piers, approach, and main spans while keeping costs to a minimum. They typically investigate different material types and quantities to control costs.

Critics of cantilevered arch bridges completed prior to the Blue Water bridge complained about their awkward appearance. The firm of Modjeski and Masters recognized the challenge of designing a beautiful bridge and struggled with this aspect of the project. They consulted with the firm of Paul Cret, a well-known Philadelphia architect who had collaborated with Modjeski and Masters on other bridge projects. Modjeski and Masters drafted two designs for the piers. The first called for stone or concrete supports at the river's edge under the main span and its flanking anchor spans. According to an engineer with Modjeski and Masters "the main span looked good but the large anchor piers appeared bulky, the eye insisting on returning to this focal spot rather than contemplating the entire effect." This design failed to make the transition between the approach spans, anchor span and main spans visually appealing. The second and successful design called for the construction of a concrete pier right at the water's edge with a steel tower supporting the anchor span. This gave the tower a less massive appearance, easing the difficult transition between the approach, anchor and main spans by using steel rather than concrete.

At the request of the State Highway Department, Modjeski and Masters also modified the length of the approach spans, incorporating suggestions from Cret's firm to use longer trusses than originally proposed. This decision saved on material costs by reducing the number of supporting piers and improved the look of the lengthy approach spans. The architect also commented on such details as the arrangement of the structural steel and the use of steel lacing connecting various members of the bridge.

Modjeski and Masters also successfully tackled the problem of making the main span attractive, but economical by settling on an innovative low arch design that merges the traffic deck with the bottom structural supporting steel for the portion of the bridge suspended over the water. This eliminated the need for expensive bracing and contributes to the graceful appearance of the structure. An engineer from the firm exclaimed that "we may congratulate ourselves that we have created a happy marriage out of necessity and discover that this bond is a happy, long lasting union."

Nearly 60 years later, Modjeski and Masters returned to the drafting table to work out the details of the new bridge. This time the firm of Buckland & Taylor Ltd. served as their Canadian partner contributing equally to the design of the main span as well as the approaches. All work involving the shared main span was seen as a joint venture while decisions and costs associated with the approach spans were largely left up to the owner. The designers worked with both nations to ensure a uniform overall appearance.

When delving into the design details of the new bridge, these design firms faced many of the same visual issues as the earlier designers, with the added challenge of making the new bridge compatible with the old one. In tackling the main span, they discovered the arch on the new bridge would be higher than the arch on the old bridge. They chose a higher main pier to support the arch near the water's edge. This flattened the arch on the new bridge so that it would match the old. This decision forced the designers to re-think their design for the main piers. Originally, they wanted to recreate the look of the main pier on the old bridge. However, a taller pier with the same design characteristics as the old one would have a bulky look. Instead they decided to keep the basic form of the old pier, yet give it a simple, contemporary look more in keeping with the new bridge.

For the anchor and approach span piers the engineers selected concrete hammer-head piers rather than steel. Based on cost considerations, this decision also gives the new bridge a simpler look, making it easier to distinguish the old bridge from the new one. Steel piers would have cluttered the view of the old bridge. Likewise, the designers used three box girder spans on either side of the main span rather than constructing deck trusses similar to the ones flanking the old bridge. This decision contributes to the clean lines of the new bridge and leaves the view of the old bridge's deck trusses uncluttered.

The Americans and Canadians took different paths when constructing the approach spans for the original Blue Water Bridge. The largest difference occurs in the composition of the steel beams. Canadian steel mills could not roll beams of sufficient size to meet the span length requirements, so they used built up sections of steel rather than the single beams used on the American approach. Each country made use of available materials and familiar technologies to build the approaches. The same scenario occurred with construction of the new bridge. This time the Americans used large pre-cast concrete beams to build their approach and the Canadians used concrete pre-cast box girders.

In Canada, engineers had used the box girders on other bridges while the Americans lacked familiarity with this design. From the side view of the bridge, the differing approach spans are the same depth and appear identical. The difference becomes apparent beneath the spans. The Americans used six beams for their approach spans while the Canadians used three box girders.

Other noteworthy differences between past and present design and construction practices exist. The original Blue Water Bridge used more steel than the new design. In order to keep the weight of the bridge within acceptable limits, much of the steel in the old bridge consists of open lacing. This gave strength, but not weight to the bridge. Affectionately referred to as "bird's nests" by those who maintain the old bridge, these open steel members tend to trap salt and debris in addition to being difficult to inspect, clean and paint. The new bridge uses less steel and it is all enclosed. Built mainly of steel boxes, the smaller box sections are sealed, while the larger box girders have access doorways and interior lighting to allow for inspection and maintenance.

Because the new bridge has less steel, large towers supported construction activities suspended over the water. Without the towers, the steel would bend as it stretched out over the water. Cables extended from the towers to the truss in order to hold it up until both sections could be connected in the middle. Construction of the old bridge did not require these towers. The truss itself had a substantial amount of metal, making it self-supporting as it suspended over the water.

Construction workers used different connecting techniques on the two bridges. They connected the steel in the old bridge with rivets using air-driven riveting machines. The rivet consisted of a metal pin with a head on one end. The worker passed the pin through a hole in the steel and used the riveting machine to hammer down the plain end into a head, locking it in place. Bolts have replaced rivets in bridge building. Workers need fewer bolts than rivets to connect the steel because bolts are stronger. Bolts therefore cost less and have the advantage of being easily replaced.

All bridges must have footings holding up the piers. Construction techniques for the main piers on the old and new bridges differed significantly. In the case of the Blue Water Bridge two round concrete caissons, measuring 24-26' in diameter support each main piers. At the bottom of these circular concrete caissons are steel cutting edges. Workers sank the caissons 100 feet beneath the ground to bedrock to provide a good foundation for the bridge. As each caisson sank workers added concrete sections on top. Cranes scooped dirt and debris from the caisson's hollow core to help lower it. Work on the Canadian side went smoothly, however, the Americans encountered 20,000 year old logs buried by the glaciers 45-90 feet beneath the surface and then hit a 25' deep layer of heavy clay bogging down the caissons descent. Divers had to work with pneumatic chisels inside the caisson to clear the debris. This messy, difficult work delayed the job about one month.

The engineers planning the second span of the Blue Water Bridge decided to use piles to support the main piers of the bridge. Steel beams or piles were driven into the bedrock from the surface of the ground. Although noisy, the pile driving did not require the messy excavations associated with the caissons. The Americans did encountered difficulty when they hit the concrete foundation of the former Peerless Cement factory. The massive concrete plant has long since been demolished, yet the foundations remained. Again, workers took special care to remove this debris so that the pile driving could continue.

Workers completed the original Blue Water Bridge in a mere 16 months (need cost). Completion of the second bridge took 24 months and cost 70 million dollars. Both projects had exceptional safety records. One construction-related fatality occurred on the original bridge while none have occurred on the new bridge. Given that safety measures have increased in the intervening years to control work-related injuries, the original project remarkably had few problems. The manner in which officials implemented both projects testifies to a strong commitment to getting the job done in a quick and efficient fashion.

To conclude, the major ingredients needed to successfully complete both the historic and new bridges across the St. Clair River included: forceful and persistent sponsors, reliable financing, the right location, proper design and effective implementation. In the case of the historic Blue Water Bridge, completed in 1938 and the second span opened in July, 1997, the course of planning, design and construction for both bridges may have changed slightly during the intervening 60 years, the process of building monumental bridges remained remarkably unchanged.