The METALLURGICAL HISTORY *of* MONTREAL BRIDGES

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PART 2
THE VICTORIA TRUSS BRIDGE (1898) — STEEL, HOT RIVETED

The Victoria Truss Bridge (1898) — steel, hot riveted

Abstract

In 1898, the Victoria Truss Bridge[1] that crossed the St. Lawrence River at Montreal was designed as a double-tracked steel truss. This new bridge replaced the original single-track box-girder and was constructed on the same piers as the original bridge, which had been built half a century earlier. In the time between construction of the first and the second bridges, large-scale steel production had replaced wrought iron production because of the cost and strength advantages of steel. This transition in Canada and its impact on bridge construction are discussed. The essential role that rivets played in bridge construction at this time is also described, with a focus on limited rolling capability and lack of dependable welding. Then, the addition of roadways on the outer sides of the bridge trusses are explored — these provided the first badly needed crossing for carriages and automobiles. Finally, the addition of a spur and lift spans across the Seaway are described.

Introduction

The single-track Victoria Tubular Bridge was a great success by 1890, carrying up to 100 trains per day of much heavier engines and carriages than those used in its construction era (Ball, 1987; McQueen, 1992, 2008a; Triggs, Young, Graham, & Lauzon, 1992; Szeliski, 1987; *Victoria Jubilee Bridge,* 1898; Wilson, 1999). This original box-girder bridge had good prospects for longevity, as was confirmed by the long lifespan of the similarly designed Britannia Bridge, which was comprised of twin tubes. It was not until 1970 that the Britannia Bridge was damaged by fire in its heavily tarred wooden roof that protected it from salt spray (McQueen, 1992, 2008a; *Pantydd Menai,* 1980; Rosenberg & Vincent, 1978).

Despite its good prospects for longevity, technological advances spurred plans for the construction (by 1898) of a new bridge in the place of the Victoria Tubular Bridge. Duplicating the use of iron was not a sound engineering choice because wrought iron had become more costly than Bessemer steel, which was about 50 per cent stronger. Rolling was much more advanced and could produce a plate and angle size and thickness greater than those of the original bridge. Developments in bridge design from extensive railroad experience indicated that for construction to be completed in 1898, a Pratt truss design would be more effective; this design would enable double-tracking and the addition of roadways (Fig. 1; Szeliski, 1987; *Victoria Jubilee Bridge,* 1898).

Before examining the design of the Victoria Truss Bridge on the original piers (Fig. 2; McQueen, 1992; Szeliski, 1987;

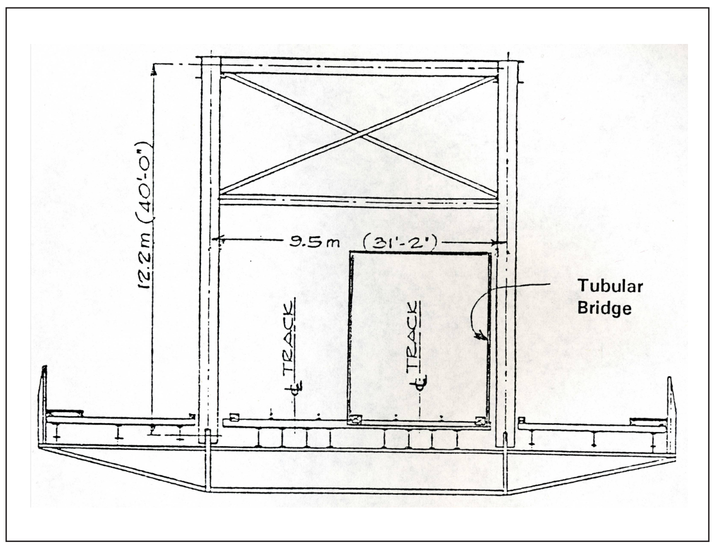


Fig. 1. The cross-section of the double-track truss is shown in reference to the single-track tube cross-section that was replaced. The truss had twice the lineal weight, but could carry close to four times the load in increased train weights and added road traffic (after Szeliski, 1987).

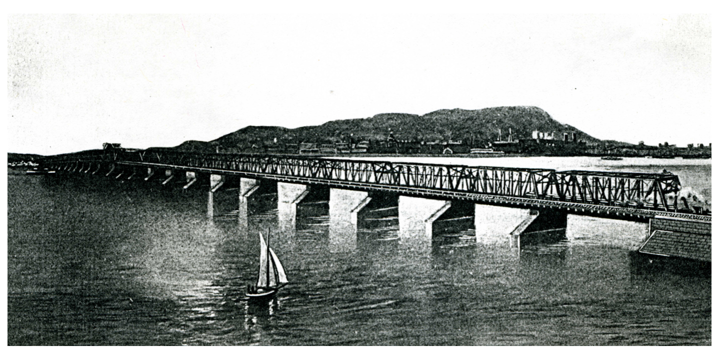


Fig. 2. A view of the Victoria Truss Bridge from the south-west, showing Mount Royal and Montreal in the background (taller centre span outlined against sky; Victoria Jubilee Bridge, 1898). The piers had been widened above the prows and the abutments simplified.

[1] Originally called the Victoria Bridge. It was rebuilt as a truss bridge and renamed the Victoria Jubilee Bridge on the occasion of Queen Victoria's 60th birthday.

Triggs et al., 1992; *Victoria Jubilee Bridge,* 1898), the development of bridge technology, along with the critical role of rivets, are considered. In addition, advances in steel technology are described, along with the gradual transition from wrought iron to steel in various areas of construction and transport. The clever construction method that made it possible to put the new bridge in place without ever halting traffic for more than a few hours is recounted. Consideration is given to the impact of the bridge on railroad expansion, as well as on road traffic; the Victoria Truss Bridge was the first to allow road traffic across the St. Lawrence River. Finally, there is a brief description of the modification of the bridge near its south end, which occurred about 100 years after its initial construction; this was carried out in order to permit passage of large ships on the St. Lawrence Seaway.

Bridge Evolution: Hot Driven Rivets

In the early 19th century in North America, timber truss bridges became common to obtain a greater height of structure and, hence, a longer span. Many of these structures were covered with a roof and side walls to protect the load-bearing timbers from the elements; a number of such road bridges remain today (Harrington & Harrington, 1976). The design of these trusses depended mainly on the experience of the builder; some were patented after experimental trials. They generally relied on wrought iron bolts to hold them together and, sometimes, long iron rods were used for additional strengthening. Instead of using masonry viaducts as had been employed in Europe, timber trestles were successfully constructed in wide, mainly dry valleys. With the advent of heavier rail traffic, sturdier timber bridges were attempted. However, the heavy vibrating loads tended to enlarge the bolt holes and the uneven loading could splinter the timber; there were several collapses and many more emergency repairs (Watson, 1975). There were many experiments to combine cast iron compression components with wrought iron tension rods, but these did not prove satisfactory (Steinman & Watson, 1957). It became clear that it would be necessary to fabricate compression members from wrought iron plates and angles, which were commonly employed for boiler and ship construction; sound rivet technology was essential at a time when screw fasteners or welding had not yet been developed. Three wrought iron truss bridges were built and served without incident; these included one bridge on the Inter-Colonial Railroad at Trois Pistoles, Quebec (built in 1870), one bridge over the Miramichi (built in 1872; Ball, 1987) and one bridge on the CPR line at LaSalle, near Montreal (Wilson, 1999).

The box-girder bridges in England and Canada were the first applications of riveting in bridge technology (McQueen, 2008a; Rosenberg & Vincent, 1978). Rivets had been used since the early ages of metals. Typically one to three rivets were used to join one piece of metal (cast and wrought, bronze or copper) to another, to itself for forming a hoop (barrel) or to a wooden handle. In iron ship hull technology, plates were cut and shaped, and angles formed from slit plate were bent to make the needed contours. Along the length of lap seams or attachment to ribs, at least two rows of rivets were essential. Moreover, the ship hulls had to be watertight, which could have been achieved by caulking as had been done with wooden ships, but caulking proved unnecessary with the use of hot driven rivets.

Driving red-hot rivets is much easier than driving them cold because the strain hardening of cold rivets makes it harder and harder to reach the desired tightness. Red-hot iron rivets near 900 degrees Celsius are in the ferritic condition, where they have good ductility and develop a strengthening substructure as they are pounded tight. As they cool, they shrink by approximately 0.9 per cent, clinching the two pieces of metal together; the stresses in the rivet shank attain the yield stress as the temperature descends. More closely spaced rivets and more rows raise the average pressure (Fig. 3; Duggan, 1918; Fisher & Struik, 1974; Lemieux & Morentz, 1968). Because the rivet holes are stress raisers, the spacing between rivets should be four times the diameter of one rivet to diminish this effect. However, riveted joints with a metallic discontinuity are very good crack arrestors, especially compared to welded joints made of continuous metal; moreover, welds may have defects, such as cavities or shrinkage cracks, that initiate cracking (Smith, 1964).

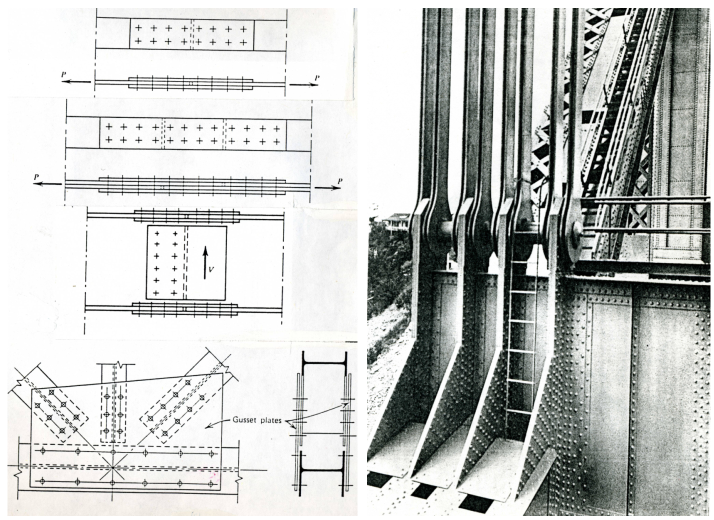


Fig. 3. Examples of riveted joints: (a) variety of types in trusses: longitudinal splices in plates, flange and web splices, connections of horizontal and vertical beams (Fisher & Struik, 1974); (b) assembly of plates and angles of a transverse floor beam at the connections to the lower chord girders and to tension eye-bars with pins (from the *Quebec Bridge;* Duggan, 1918; McQueen, 2008b).

Rivets tend to be 2.5 to 5 centimetres in diameter and are generally made from hot-rolled bar by cold heading. They must be heated in a portable forge until they become cherry red (900 to 1,000 degrees Celsius); too excessive a temperature (above 1,400 degrees Celsius) or too long a time can cause oxidation or melting at the grain boundaries. The hot rivet is placed in a hole towards the most accessible side and is held by a maul with a head cup or a 12-pound hammer (Fisher & Struik, 1964; McQueen, 2008b). On the other side, the rivet is struck repeatedly by two-hand riveters wielding nine-pound hammers or, alternatively, by a pneumatic gun with a suitable cup. In the factory, riveting is frequently done by C-shaped hydraulic rams. Beforehand, the plates, angles, I beams or H beams must have holes that are the correct diameter for shank clearance and that are punched or drilled in the designed locations, so that all parts are exactly aligned (Fig. 3; Duggan, 1918). At the time of the construction of the Victoria Truss Bridge, organization of the bridge members, the shape of each steel part and the order of fabrication had to be designed in such a way that the necessary rivets could be driven. This meant that fabricated components were shipped to the construction site with all the necessary holes and the exact dimensions already in place (Duggan, 1918).

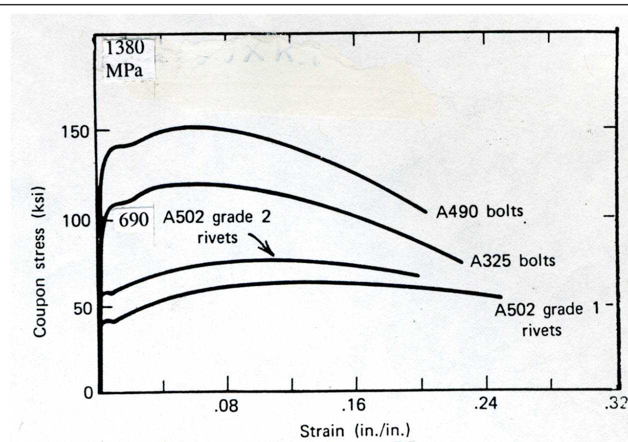
Steel rivets are likely heated into the austenite range, so they suffer an expansion on reverting to ferrite. However, this occurs from contact with the plates and the holding and hammering tools. The transformation to ferrite and to pearlite occurs before driving is complete, so the steel rivets exert a similar clinching effect as do iron rivets, but with higher stress because of higher yield stress (Fisher & Struik, 1974). There are two grades of rivets, as shown in Figure 4; the stronger one is comprised of approximately 0.25 per cent carbon and 1.5 per cent manganese, compared to 0.19 per cent carbon and 0.5 per cent manganese in the standard rivet.

While rivets served very well for almost two centuries, high tensile bolts have replaced them, particularly in the field, because bolts require no portable forge (Fisher & Struik, 1974; Smith, 1964). By means of wrenches with measurable torque, it is also possible to obtain a more uniform clinching force. In a properly designed joint, the total clinching force should exceed the permissible design strength of the steel, so that the joint remains rigid and causes the parts to act as if they were a continuous piece.

Transition from Iron to Steel

Shortly after the construction of the original 1859 bridge, the age of steel began to dawn. There were now large-scale productions after centuries of difficult small methods, such as cementation of solid wrought iron by charcoal or crucible melting with suitable slag, alloying and charcoal. Steel was stronger and harder than wrought iron, but less tough, as the C (Fe_3C) content rose and crucible steel was slag-free and isotropic. Steel could be greatly hardened by quenching and then toughened by tempering. Circa 1865, two methods were developed for de-carbonizing pig iron and keeping the steel liquid (Fisher, 1963; Habashi, 1994; Tylecote, 1992; *Making, Shaping and Treating of Steel,* 1957). In an extension of the puddling process, the Siemens-Martin open-hearth (used in Britain and France) developed high enough temperatures by means of regenerative pre-heating and was associated with clean burning fuel, such as town gas. The Bessemer-Kelly converter (used in Britain and the United States) blew air through the molten blast furnace pig and slag; it was effective for low phosphorous ore. Truly functional quality needed the addition of an iron-manganese-carbon-alloy (developed by R.F. Mushet) and a method to stop blowing at correct carbon content (developed by G.F. Coronson). Finally at about 1875, basic slag (and suitable refractories) was developed for high phosphorous ore by S.G. Thomas and P. Gilchrist. Because of its 50 per cent superior strength, it had been used in the construction of many merchant ships by 1865; consequently, thickness specifications were reduced by 20 per cent, which allowed for increased cargo capacity. Nevertheless, the British Admiralty tried to show that it was brittle. Bessemer himself countered with visual proofs of its high ductility in upsetting, tension, twisting, bending and cupping tests, both hot and cold (Bessemer, 1989). The brittleness had been induced by workers experienced in wrought iron, who had overheated the steel until low melting impurities liquefied at the grain boundaries.

Steel production by the Bessemer process often was introduced into iron works equipped with forging and rolling equipment. While ingot casting practice had yet to be developed, the product was nevertheless as large as bundles created from many forged and rolled wrought iron muck bars. In the austenitic state, steels of even high carbon content (up to 1 per cent) were as soft and ductile as wrought iron; eutectoid steel rails (containing 0.8 carbon) could be rolled down to 720 degrees Celsius, whereas wrought iron had to be shaped above 900 degrees Celsius (Fisher, 1963; *Making, Shaping and Treating of Steel,* 1957). All primary hot working technology could be transferred from iron to steel. Rolling technology was advanced rapidly with innovations conceived, plant-tested, brought to effectiveness and transferred with improvements to other works. Rolling mills of the 2-high, 3-high for reverse passage, 4-high, reversing and continuous type were developed (Fisher, 1963; *Making, Shaping and Treating of Steel,* 1957). American industry followed the British, with the gap being closed rapidly by about 1900; often the Americans optimized conditions so that productivity exceeded that of the originators (Fisher, 1963). Commencing at about 1868,



	Grade 1		Grade 2	
	Min.	Max.	Min.	Max.
Rockwell B	55	72	76	85
Brinell, 500-kg load, 10-mm ball	103	126	137	163

Fig. 4. The properties of two grades of rivets are shown: (a) in stress-strain curves in comparison with high-strength bolts (not available before 1950); and (b) in a table of hardnesses (grade 1: 0.19 carbon and 0.5 manganese; grade 2: 0.25 carbon and 1.5 manganese (Fisher & Struik, 1974).

Montreal Rolling Mills produced sheet for nails, skelp for tube and rod for conversion to wire and fasteners. Although the purchased feed stock was initially wrought iron (mainly from England) by 1990 conversion to steel billets (mainly from the United States) had been carried out smoothly (Kilbourn, 1960). A rolling mill in Hamilton to re-roll worn, deformed iron rails originally from England operated from 1864 until 1872, when long-life steel rails were introduced. After 1879, Ontario Rolling Mills adapted the mill to steel products for hardware manufacturing (Kilbourn, 1960).

The rate of introduction of steel was slower in applications where the properties of wrought iron gave satisfactory results (Table 1). While in shipbuilding the conversion to steel was complete by 1890, the railroad axles transition only took place between 1890 and 1910, and the cast charcoal-iron wheels conversion took place between 1900 and 1910 (Fisher, 1963; Habashi, 1994; Tylecote, 1992; *Making, Shaping and Treating of Steel,* 1957). In rails, where wear resistance from steel was increased over iron by a factor of 18, steel had replaced all rails in service by 1890. In the first 12-storey skyscraper with a structural skeleton, Bessemer steel was substituted after six floors of wrought iron and the weight saving permitted the addition of two more floors. Nevertheless, in 1889, wrought iron was used throughout the Eiffel Tower. In bridges (although the American Society of Civil Engineers recommended against it because of brittleness in a frost), steel was utilized for highly stressed members. In the first bridge across the Mississippi (1874, St. Louis), Eads Bridge utilized steel only for the tubular arches (3 by156 metres), inspired by steel arch members built in 1868 crossing the Rhine in Holland; Fisher, 1963). C.C. Schneider specified steel for the main chords in a cantilever bridge across the Niagara gorge to replace the suspension one in 1883 (Plowden, 1974). The first all-steel bridge in North America was a cantilever one across the Mississippi River at Glasgow, built by S. Smith in 1878. As a first for Canada in 1884, an all-steel cantilever (from Britain) was erected by C.C. Schneider across Siska Creek on the CPR Fraser Gorge line (Plowden, 1974). In 1889, the great Forth Bridge, built by J. Fowler and B. Baker, had two spans and was the second longest cantilever in the world; this bridge utilized plate and rib technology (as in the Victoria Tubular Bridge) to create the principal members as circular tubes (Smith, 1964).

Across the world, annual steel production rose rapidly, from 60 kilotons in 1850 to 0.5 million tons in 1870 and to 28 million tons in 1900 (Britain accounted for 4.9 million tons), while puddled iron production fell from 3 to 0.5 million tons (Table 2; Fisher, 1963; Habashi, 1994). The American industry went through significant growth, from 22 kilotons in 1870 to 11 million tons in 1900. In Nova Scotia, the Londonderry Iron Works, founded in 1855, changed to a coke blast furnace (which had

Table 1. Applications transfer from wrought iron to steel (Habashi, 1994; Tylecote, 1992)

	Rails	Axles	Wheels	Ships	Bridges	Buildings
Steel begins	1865* 1878**	1890	1900	1860	1870	1888
Wrought iron ends	1890	1910	1910	1890	1890	1900***

* Pearlitic, steel 18 times the life of iron
** Bessemer North America
*** 1889 Eiffel Tower 300 metres

Table 2. World production of iron and steel (Habashi, 1994; Tylecote, 1992)

	1850	1870	1880	1890	1900	1918
Pig iron	4.8 Mt*	(70%)***		(5%)***	39 Mt	
(blast furnace, coke)						
Britain	2.4 Mt				10 Mt	
Germany	2.4 Mt				10 Mt	
USA					13 Mt	
Charcoal (Canada)	5 kt**	10 kt	4 kt (1885)		18 kt	0 kt
Coke (Canada)		0 kt	20 kt (1885)		80 kt	3 Mt
Puddled iron						
Britain	3 Mt				0.5 Mt	
Canada	0.5 kt					
Steel					28 Mt	87 Mt
Britain	60 kt	0.5 Mt	0.65 Mt (1873)		4.9 Mt	11 Mt
Germany	12 kt				8.0 Mt	
USA	0.2 kt	22 kt	0.2 Mt (1873)		11 Mt	50 Mt
Canada†					0.1 Mt	1.9 Mt

* Mt = million metric tons (mega tons)
** kt = thousand metric tons (kilo tons)
*** Percentage that went to the puddling process
† Canada: ~0.5 Mt (1910), ~1.2 Mt (1938), 2.9 Mt (1945), 5 Mt (1960), 11 Mt (1970)

produced 12,000 tons per year) in 1877 and tried to make steel in a Siemens style furnace, but without success; it ceased iron production in 1911 (Andreae, 1989). From 1890 to 1902, Ferrona operated a coke blast furnace and supplied a foundry in New Glasgow, Nova Scotia, that produced open-hearth steel for railroad castings from 1892-1902 (Andreae, 1989; Inwood, 1989). In about 1901, steel mills were just being set up in Sydney, Nova Scotia, and in Sault Ste. Marie, Ontario (Inwood, 1989; Williams, 1989). Consequently, at the time of reconstruction of the Victoria Bridge, the production of steel in Canada was almost nil (Duggan, 1918; Kilbourn, 1960); the steel for the bridge had to be imported from the United States and was most probably produced in Bessemer converters.

Victoria Truss Bridge: Construction, Evolution

In association with doubling the track, it was decided that the new bridge would be able to carry three trains pulled by two engines in each direction, in contrast to carrying only one train at a time (as was the case with the original Victoria Tubular Bridge). In addition, carriageways and sidewalks were planned for outside the truss, for a total width of 20.1 metres (or 66 feet) (Fig. 1; McQueen, 1992; Szeliski, 1987). For such upgrading, the tube was to be replaced with truss spans that were 12 metres (or 40 feet) high at the extremities and 18 metres (or 60 feet) high in the middle (Fig. 5); this new bridge could accommodate a double track of 9.7 metres (or 32 feet) in width. A Pratt type truss (Plowden, 1974; Smith, 1964; Steinman & Watson, 1957) was chosen because steel was now available with much greater strength and in longer sections than was wrought iron. The weight of the new bridge, which had four times the load capacity, was only 20 million kilograms (or 22,000 tons; *Ponts du Québec,* 1975; Szeliski, 1987; *Victoria Jubilee Bridge,* 1992; Wilson, 1999). The cost for the superstructure was \$2 million, compared with the \$7 million that had been spent to construct the original tubular bridge and piers. The tops of the original piers were widened without any change to the prows or foundations. These piers have been in satisfactory service for 140 years, having been strengthened by grouting in 1940.

Because of high traffic demands, the construction of the new bridge, under the supervision of chief engineer J. Hobson, took place without any traffic stoppage that exceeded two hours. A framework was designed that could be rolled out over the tube and positioned on two adjacent piers (*Ponts du Québec,* 1975; Szeliski, 1987; *Victoria Jubilee Bridge,* 1992; Wilson, 1999). The new truss was constructed on the outside of this framework without disturbing the tube in operation (Fig. 6). When the truss was completed and supported on the piers, the frame was moved forward to the next span. The renovation was started from both shores and the two frameworks were finally pinned together to provide support for the longer central span. Nineteen spans of the bridge were fabricated and erected by Detroit Bridge and Ironworks, and six spans were built by Dominion Bridge of Montreal. The steel was supplied from the United States because no Canadian steel mill was yet in operation and no suitable plates would be produced in Canada for several decades to come (Kilbourn, 1960). The open structure of the truss (Fig. 2) provided passengers with the opportunity to view Montreal and its river and mountain setting, inspiring eloquence:

"The view from the train crossing the Victoria Jubilee [Truss], as seen while approaching Montreal from the South Shore, is one of much grandeur: the St. Lawrence River, sweeping under this massive structure, with hundreds of steamboats, sailing vessels and steam tugs, scurrying hither and thither on its waters opposite the harbor, and the city of Mount Royal as a background, form one of those beautiful pictures which delight the eye of the artist. The massive stone warehouses that line the harbor for miles, the extensive manufactories, from whose tall chimneys belch forth columns of smoke, (on the shores of the river as far as the eye can reach), tend to show that Montreal is the commercial metropolis of the Dominion of Canada" (Victoria Jubilee Bridge, 1898).

The new carriageways were extremely popular, even with the toll of \$0.05 per pedestrian and \$0.15 per vehicle. However, in 1908, one carriageway was replaced by double tramcar tracks. In 1940, the other carriageway was widened to provide passage in two directions for automobiles, with no pedestrian walkway. In 1955, the tramcar tracks were replaced by a two-lane roadway (*Ponts du Québec,* 1975; Wilson, 1999). In 1919, the Quebec Bridge was built, which provided road and rail crossings 180 miles downstream (Duggan, 1918; McQueen, 2008b; *Ponts du Québec,* 1975). The Victoria Truss Bridge remained the only

Fig. 5. Close-up view of the truss structure fabricated by riveting from narrow sheared plates, bars and angles; vertical laced girders are in compression, diagonal bars in tension. The transverse beams, attached below the truss, support the twin tracks and extended roadways.

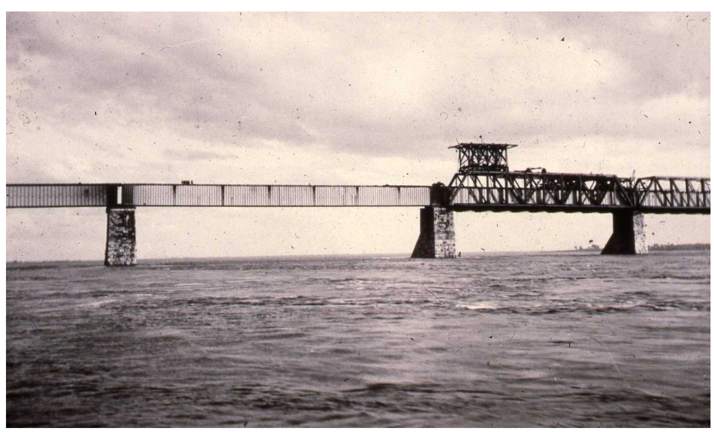


Fig. 6. Construction of the truss span around the tube was supported by a wider construction frame directly resting on the piers; however, it could be rolled forward span by span, being supported on the tube (Triggs et al., 1992).

road link across the river near Montreal until the construction, in 1929, of the high cantilever Jacques Cartier Bridge over the port. In time, additional road links were provided to the west by the Mercier Bridge in 1938 and the Champlain Bridge in 1960 (*Ponts du Québec,* 1975; Wilson, 1999). In 1967, the Concorde Bridge was completed across the main channel of the St. Lawrence to Île Ste-Hélène. It originally carried a double track for passenger trains for Expo 67, a boardwalk and two lanes of road traffic; it is now four lanes with sidewalks. Interestingly, the Concorde Bridge is of orthotropic (box-girder) construction and the roadway is similar in structure to that of the original Victoria Tubular Bridge, except that the Concorde's traffic is on top instead of inside.

Spur and Twin Lift Spans at the Seaway

At about 1958, the St. Lawrence Seaway was routed along the south shore of the river to replace the old Lachine Canal, which had not proved a direct obstacle to the Victoria Bridge on the Montreal side. The Seaway Authority proposed that the CNR build a new, higher bridge that would not obstruct ships. The CNR refused and argued that traffic could not be disrupted by a bridge that opened frequently. The dispute was resolved as follows: because the canal passed between the first pier and the abutment, that span of the bridge was replaced by a vertical lift span. Excavation proceeded in successive narrow trenches so that reinforcing walls could be built to prevent the bridge supports from sliding into the hole. At the opposite western end of the first seaway lock, a second lift span was constructed; this required the construction of a spur in the bridge, as well as one on land (Fig. 7; McQueen, 1992; Szeliski, 1987). One lift span would be down at all times so that trains could be switched to it.

The spur was constructed on the riverside of the canal by adding five new piers and six truss spans (Fig. 8) of much simpler construction than the original ones (McQueen, 1992; Szeliski, 1987). The members were comprised of rolled wide-flange beams that were joined by welding. The necessary switching arrangement and turnout required removal of two of the old truss spans and replacement of each by four large I beams underneath the tracks; these were supported by two additional piers. To avoid halting rail traffic, the primary track was supported by a temporary I beam placed above and between the existing tracks. After the existing crossbeams were bolted to the I beam at their midpoints, the other halves that supported the second track were cut away to leave space for installation of two other I beams below track level (Szeliski, 1987). Once rails were laid, the primary track and supporting crossbeams were removed to permit positioning of the new I beams, which were to form the permanent span. In order to avoid conflicts with vehicular traffic, the roadway on one side was raised in a fly-over above the spur (Figs. 7 and 8). The automobile traffic did not follow the land spur, but was routed through one or the other of the lift spans by roads on the banks of the seaway. The design was carried out by CN's engineering department, under the direction of R.O. Stewart. The turnout and spur spans (i.e. trusses welded from rolled structurals) were erected by the Bridge and Tank Company. The lift spans were designed and constructed by Dominion Bridge.

Conclusions

The Victoria Tubular Bridge that provided the first railroad crossing was rebuilt as a steel truss of twice the weight, but four times the capacity, carrying a double track and the first road crossing of the St. Lawrence River. Based firmly on the original piers, the Victoria Truss Bridge has served the railroad well for almost a century and a half, and the motoring public for more than half that time. In its original wrought iron tubular form and in its later steel truss construction, this bridge reflected the most up-to-date materials and designs for the periods in question. In both cases, relatively small hot-rolled plates were spliced into unified bridge components by the clinching stresses from shrinkage of the rivets, after being driven while red hot. Moreover, in neither case was the metallurgical industry sufficiently advanced to provide the ferrous structural materials; however, a Canadian bridge company participated in the reconstruction. Initially outstanding for its length, it is now remarkable for containing a spur that allows for switching traffic to one or the other operating lift spans crossing the St. Lawrence Seaway. The new spans of the bridge were considerably lighter, rolled structurals with welded fabrication; at the switch, two truss spans were replaced by girders under the tracks.

Fig. 7. Photograph (circa 1980) of the Victoria Bridge from the northwest shows the trusses rising to the higher centre span and the new spur going to the west lift-span (outlined against sky) over the seaway.

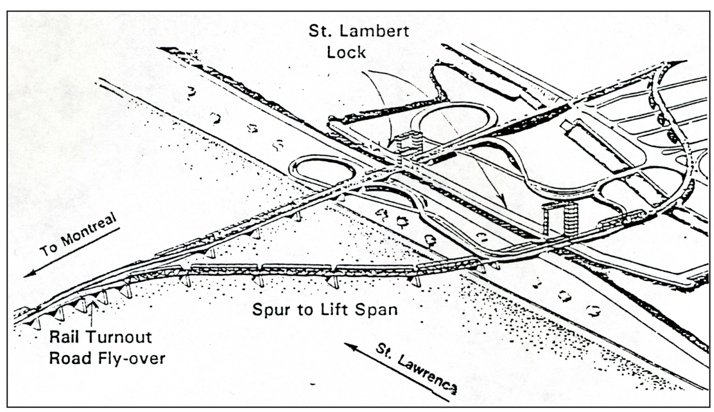


Fig. 8. Diagram of the track diversion required by the introduction of twin lift-spans at the seaway. The turnout (lower right) required replacement of two original spans by below-track girders and construction of a spur with six new spans on piers in line (of water flow) with the old ones (after Szeliski, 1987).

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