The Failure and Reconstruction of the Quebec Bridge

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ABSTRACT: At the time of its construction, the 1800 ft span cantilever bridge across the St. Lawrence River in Quebec, Canada was going to be the longest cantilever bridge in the world. However, on August 29, 1907, during its erection, the bridge collapsed killing 75 workers. A commission of prominent international engineers was formed by the Canadian Government to investigate the collapse of the Quebec Bridge. It was decided to build a new, but much heavier and stronger, cantilever bridge adjacent to the old failed bridge. On September 11, 1916, after the center span was raised successfully 12 to 15 feet, it suddenly fell into the St. Lawrence River killing eleven workers and injuring six. The St. Lawrence Bridge Company, which was erecting it, took full responsibility for the collapse of the second bridge and placed orders for the new steel. The new center span was successfully hoisted for the third time and put in place on September 18, 1917 using the same lifting procedure that was used in 1916. The new bridge was opened to traffic 100 years ago, on December 3, 1917. This paper provides the details of the old and new bridges, and the people connected with them.

1 INTRODUCTION

When a survey among bridge engineers in Europe, Canada, and the U.S. was made by Major Charles Bebe Stewart in 1846, only four engineers believed that it was possible to build a bridge across the Niagara Gorge, and they were John Roebling, Charles Ellett, Jr., Samuel Keefer, and Edward Serrell, (Gandhi 2006). Serrell was retained by the Corporation of the City of Quebec in Canada in 1851 to ascertain the feasibility of “throwing” a bridge over the St. Lawrence River. He made an examination and reported that a suspension bridge across that river was perfectly practical from a “scientific” point of view at about 6 miles above Quebec. The span would have been 1600 ft and the roadway would have been 100 ft above the water (Scientific American 1851).

Figure 1 from Middleton (2001) shows seven possible bridge locations investigated in the 19th century. The location selected by Serrell was at the St. Lawrence River’s confluence with the Claudiere River (Location 1), the same location decided about 50 years later to build a bridge.

In 1887, the Quebec Bridge Company was incorporated by an Act of Parliament to build and operate a railway and highway bridge across the St. Lawrence River. Further Acts of Parliament extended the time for the construction of the bridge in 1891, 1897, and 1900. In 1903, the name was changed to the Quebec Bridge and Railway Co. and the government undertook to guarantee the bonds of the company up to $6,678,000 against conveyance of the property. The time for completion was fixed to July 1910.

In 1887, the government engineers of the Province of Quebec produced a design for a bridge where the river was about 2400 ft wide but was too deep for piers in the center. The design consisted of two granite piers to be built at a distance of 500 ft and 240 ft from the shores in about 40 ft of water with the cantilever ironwork to be built on them. The dimensions of the bridge were as follows (Railroad Gazette 1887):
Length of center (cantilever) span: 1442 ft
Length of shore spans: 487 ft
Total length of bridge and approaches: 3460 ft
Height from high water mark to bottom of bridge: 150 ft
Extreme height of top of cantilever above high water: 408 ft

In this design, the center span was 270 ft shorter than the 1710 ft single cantilever span of the Forth Bridge near Edinburgh, Scotland, the world’s longest at the time.

To avoid founding the two piers supporting the cantilever span in deep water, numerous borings were made which indicated that while solid rock was beyond a depth feasible to reach, suitable material for foundation could be found well within the practicable limits of pneumatic work by locating the main piers near the shores. In 1900, Theodore Cooper, the Consulting Engineer to the Quebec Bridge Co., increased the length of the cantilever span to 1800 ft which would make the Quebec Bridge the longest cantilever span in the world when completed. He approved the stress sheets for the suspended and anchor spans in 1904. One-half elevation of the Quebec Bridge symmetrical about the centerline is shown in Figure 2 after the revisions made by Cooper.

The contract for the superstructure of the bridge was awarded to Phoenix Bridge Co. of Phoenixville, PA. and had an estimated weight of about 40,000 tons. The bridge was designed to carry two railroad tracks, two trolley tracks, and two roadways between the trusses on the single deck, and two sidewalks cantilevered outside the trusses. The trusses were placed 67 ft apart center to center. Mr. E.A. Hoare was Chief Engineer of the Quebec Bridge Co.

Figure 1. Location 1 to build the Quebec Bridge, oriented in the north-south direction.

Figure 2. Half diagram of the Quebec cantilever bridge.
2 SUBSTRUCTURE WORK

Work on the Quebec Bridge was formally inaugurated on October 2, 1900 when Sir Wilfred Lawrence laid the cornerstone of the first abutment pier (Engineering News 1900b). The contract for the substructure was awarded to Mr. M.P. Davis of Ottawa. Mr. Davis estimated the quantity of masonry at 50,000 cubic yards (CY).

Besides the two abutments, one on the Quebec (north) and the other on the Levis (south) side, there were two anchor piers and two river piers, the latter supporting a span of 1800 ft. From each abutment to its neighboring pier the distance was 214 ft and the anchor spans were 500 ft each. The total length of the bridge from abutment to abutment was 3228 ft.

Mr. Davis planned to use 5000 CY of masonry before closing his operation for winter on November 15, 1900. He had until October 1902 in which to get the substructure built. In May of 1901 he planned to start work on one of the inner piers. During the winter of 1900 to 1901, he planned to build pneumatic caissons 168 ft (L) x 50 ft (W) x 50 ft (H) to be launched when required.

The abutments were U-shaped in plan and measured 80 ft at right angles to the bridge. Each of the two wing walls were 40 ft long. The wing walls were founded on solid rock, and together contained about 4,000 CY of masonry. Details of the south anchor pier and wooden caissons supporting the south main pier are excellently covered in Engineering News (1903). Figure 3 shows the plan and elevation of the Contractor’s plant for south shore abutment and piers. (Engineering News 1903).

The north caisson was launched on June 20, 1901 and the south caisson on May 26, 1902. The sinking of the south caisson was begun on June 7, 1902 and finished on October 17, 1902 thus requiring 131 days to sink 59 ft, or at an average sinking of 5.4 inches per day, varying from a minimum of 2 inches to a maximum of 10 inches. The number of men employed at the bridge site varied from 500 to 600. The construction plant for the north shore abutment and piers was in its general features a duplicate of that for the south shore work. In fact, the machinery and materials of the north shore plant were largely used in constructing the south shore plant.

3 SUPERSTRUCTURE

The superstructure consisted of pin connected members. In general, the eyebars were 15 and 16 inches in width and, for a few special members, 18 inches in width. The pins were 12 inches in
diameter and the main lower pin at shoe was 24 inches in diameter. The main chords were 54 inches in depth and 68 inches in width by 4 ft deep. The main intermediate posts were from 40 to 48 inches in width and the main plate floor beams were 10 ft deep. The suspended span was 675 ft long and 130 ft deep at the center. Figure 4 shows a view of pedestals and shoes with main post and diagonals connected (Engineering News 1905).

Figure 4. View of pedestals and shoes with main post and diagonals connected.

Figure 5. South cantilever arm of the St. Lawrence Bridge at Quebec.
Figure 5 shows the south arm of the cantilever bridge on August 28, 1907, the day before its fall (Engineering News 1907).

4 FALL OF THE PARTIALLY COMPLETED BRIDGE

On Thursday, August 29, 1907 at about 5:30 PM, 15 minutes before quitting time, there was a loud noise and without warning the river end of the south side of the cantilever slowly began to sink. When it was nearly down to the water’s edge, the main traveler tower became unstable, broke its anchorage, and revolved towards the north shore. The 315 ft vertical posts over the main pier collapsed and the whole superstructure went down along with 86 men on the structures, 75 of whom were killed (Skinner 1907).

The trusses fell almost vertically and were terribly wrecked and mangled. The anchor span moved, longitudinally about 100 ft towards the river with its top chord almost intact, and except one eyebar which was sheared off, few of the eyebars suffered bending and twisting. The principal failures of the compression members were at the bottom chord splices and where latticing had yielded.

The substructure remained absolutely intact and uninjured except for small scars on the coping and where it had been chipped by the sharp corners of the steel members.

The collapse of the superstructure was due to the movement of the anchor arm trusses in their own plane about 100 ft towards the river, the vertical way they fell, and the fact that the buckled condition of the two lower chord panels, which had been reported buckled three days earlier, established the possibility of their failure.

The coroner’s jury examined some witnesses and rendered a verdict which failed to fix the responsibility or cause of the disaster and left it to be investigated by a government commission.

5 REPORT OF THE ROYAL COMMISSION ON THE QUEBEC BRIDGE FAILURE

The Royal Commission was formed in 1907 and was composed of:

1. Mr. Henry Holgate, Civil Engineer, Montreal, Canada,
2. Mr. John G.G. Kerry, Civil Engineer, Toronto, Canada, and
3. Professor John Galbraith, Toronto, Canada.

The Royal Commission submitted its report to the Canadian Parliament on March 9, 1908. The single most important finding of the Commission was that “the bridge fell because the latticing of the lower floors near the main pier was too weak to carry the stresses to which it was subjected.” The Commission further concluded that “although the lower chords 9-L and 9-R anchor arm, which in our judgement were the first to fail, failed from weakness of latticing, the stresses that caused the failure were to some extent due to the weak end details of the chords and to the looseness, or absence of, the splice plates arising partly from the necessities of the method of erection adopted and partly from a failure to appreciate the delicacy of the joints and the care with which they should be handled and watched during erection.” The Royal Commission reported fifteen other conclusions that are given in Engineering – Contracting (1908).

The appendices to the report included information of interest to engineers. Appendix 13 contained a “Summary of Tests of Large Columns” (Engineering News, 1908a). The results of 176 tests were plotted and 10 conclusions were drawn. The last conclusion stated that “no tests have been made on columns of the form of the Quebec lower chords nor on any having more than about 1/25th of the cross-section of these chords.”

Appendix 15 of the Quebec Bridge Commission’s report described the tests of two compression chord models. One of the two test members was an exact model of chord 9 of the anchor arm which failed and the other was similar, differing only in having been strengthened at those points where the main weakness o the Quebec Bridge chord was thought to have been located. While the first test chord failed at a load just above that which caused the failure of the Quebec Bridge chords, the second test member failed at a load 38% higher than the first member (Engineering News, 1908b).
Commenting on Theodore Cooper who was the Consulting Engineer for the Quebec Bridge, Middleton (2000, p. 102) writes, “It was a role he was, in many ways, ill-equipped to fill. Poorly paid for his consulting duties, he could not afford the staff he needed to assist him. In ill health, he never once visited the bridge site after erection of the structure had commenced, and he was forced to rely upon letters, sketches, and photographs to understand the problems and questions that were presented to him for decision. Separated from the site of the work by almost 600 miles and subject to the vagaries of wire and postal communication of the time, Cooper was ill situated to provide the prompt and decisive action that the crisis of late August demanded.” Cooper’s illustrious career came to an abrupt and sad end because of the Quebec Bridge disaster.

6 REPORT OF SCHNEIDER ON THE DESIGN FOR THE QUEBEC BRIDGE

While the Royal Commission was conducting its investigation, the Government retained the services of Charles Conrad Schneider, a past president of the American Society of Civil Engineers (ASCE) and a well-known bridge engineer, to determine the sufficiency of the design for the original Quebec Bridge. The findings by Schneider are summarized below (Engineering News 1908):

1. The floor system and bracing are of sufficient strength to safely carry the traffic for which they were intended.
2. The trusses, as shown in the design submitted to the writer, do not conform to the requirements of the approved specifications, and are inadequate to carry the traffic or loads specified.
3. The latticing of many of the compression members is not in proportion to the sections of the members which they connect.
4. The trusses of the bridge, even if they had been designed in accordance with the approved specifications, would not be sufficient strength in all their parts to safely sustain the loads provided for in the specifications.
5. It is impracticable to use the fabricated material now on hand in the reconstruction of the bridge.
6. The present design is not well adapted to a structure of the magnitude of the Quebec Bridge and should, therefore, be discarded and a different design adopted for the new bridge, retaining only the length of the spans in order to use the present piers.
7. The writer considers the present piers strong enough to carry a heavier structure, assuming that the bearing capacity of the foundations is sufficient to sustain the increased pressure.

7 THE NEW BEGINNING

Exercising its rights under the 1903 legislation, the Canadian government took over the Quebec Bridge and Railway Co. and in August 1908 appointed a Board of Engineers to oversee the construction of the new bridge. The three international board members were:

1. Henri Etienne Vautelet, Chairman and Chief Engineer, Canada
2. Ralph Modjeski, Member, USA
3. Maurice Fitzmaurice, Member, England

The board checked the feasibility of a suspension bridge to occupy the place of the cantilever bridge that had collapsed. The board members had differences of opinion as to the form, shape, and location of the new bridge. It was agreed to replace the old bridge with a new cantilever bridge. As the new bridge was going to be 21 ft wider and weigh almost twice as much as the old bridge, it was evident that little or none of the existing substructure could be utilized.

In June 1910, Fitzmaurice resigned from the Board. He was replaced by Charles MacDonald, a well-established and well-known bridge engineer and former President of the ASCE. He was born in Canada, but moved to the United States at an early age.

In order to reduce the dead loads of the main members, the Board initiated tests on nickel-steel which permitted higher stresses compared to the mild steel (Engineering News, 1911b). The first
series of tests covered a large number of riveted splices, both lap and butt, with different thicknesses of plate packing, for comparison with prior tests of mild steel rivets. These tests were conducted at the University of Illinois at Urbana. The second series of tests were made of models of the principal compression members designed for the bridge. These models were tested at Phoenix Iron Co. in Phoenixville, PA.

The results of the first series of tests indicated that the ultimate strength of the rivets proved to be remarkably constant and the values ranged from 55,200 to 60,250 lbs per square inch (psi) in shear area. The results of a very large number of repetitions or reversals of stress proved conclusively that stress reversals produced very marked movements in the joints possibly due to altered stress distribution. The results of the second series of tests on models showed that the elastic limits of the columns ranged from 37,000 to 45,600 psi. The ultimate strength ranged from 48,800 to 64,000 psi. The columns failed at loads slightly below the elastic limit of the tensile tests.

The removal of the superstructure weighing about 17,000 tons was undertaken to clear the channel for the construction of the new bridge. Oxy-acetylene torches were used to cut the large members into smaller ones for ease in handling and the rivets were cut out to separate different members. The scrap was sold in Montreal for about $12 per ton. The Quebec Bridge loss was estimated at $6,854,987 taking into account the value of unused steel at $300,000 (Railway Age Gazette 1911).

8 THE RECONSTRUCTION OF THE QUEBEC BRIDGE

The Board of Engineers prepared one design which is shown in Figure 6. The Board’s design was for a cantilever bridge with anchor arms and cantilever arms of the same length and suspended spans to be erected by cantilevering out. Five modifications of this design were also prepared by the Board. A tender on any of the six propositions was going to be considered a tender on the Board’s design. Two of these schemes were based on erecting the suspended span by cantilevering out while the remaining four were based on erecting the suspended span at an adjacent site and floating it into position. The design had a cantilever span of 1758 ft versus the 1800 ft span of the old bridge. Bids on this design and its modifications and alternate designs were invited from contractors in the USA, Canada, and Europe (Engineering Record 1910).

Figure 7 shows locations of the old and new main piers based on the design proposed by the Board of Engineers. On April 8, 1911, the contract for the Quebec Bridge was awarded to the St. Lawrence Bridge Company of Montreal for about $8,650,000. It was a combination of two Canadian firms, Dominion Bridge Co. of Lachine, Quebec and Canadian Bridge Co. of Walkerville, Ontario. In addition to the St. Lawrence Bridge Co., three other firms submitted bids:

1. Maschinen Augsburg-Nürnberg AG of Gustavburg, Germany,
2. British Empire Bridge Company of Montreal, and
3. Pennsylvania Steel Co. of Steelton, PA.

Figure 6. Board of Engineers’ design for suspended span bridge erected by cantilever method.
Three of the four firms submitted their own designs besides bidding on the Board’s design. The St. Lawrence Bridge Co. submitted seven different designs with their respective bids. The German firm submitted bids on three of the designs of the Board and also bid on its own design. The British Empire Bridge Co. submitted six bids on the Board’s six designs only. The Pennsylvania Steel Co. submitted ten bids on the Board’s six designs using different erection schemes and a bid on an eyebar suspension span designed by Gustav Lindenthal.

Six of the designs submitted by the three competing firms along with the Board’s design are shown in Figure 8 (Modjeski 1913). The design that was approved by a majority of the Board and additional experts appointed by the Government due to its ease in erection is shown at the bottom. The old main piers were to be demolished to the mud-line and the granite blocks to be reused in the new piers.

The new bridge would be designed to accommodate two railway tracks and sidewalks for foot passengers. The government had decided not to support highway traffic on the bridge.

9 CHANGES IN THE BOARD OF ENGINEERS

On October 1, 1910 bids or tenders for the reconstruction of the Quebec Bridge were received and opened by the government. Vautelet had a difference of opinion with his original fellow board members Modjeski and MacDonald regarding the evaluation of multiple bids submitted by the four firms and selection of the winner. To resolve this matter, on January 20, 1911 the Government appointed two additional engineers, H.W. Hodge, a New York bridge engineer, and M.J. Butler, Vice President and General Manager of the Dominion Steel Corporation. On February 8, 1911, when the votes were taken, Vautelet selected the designs and bids submitted by the British Empire Co., whereas the other four members agreed that the design submitted by the St. Lawrence Co. was the best considering its constructability. The British Empire Co. had submitted six bids on the original design and five of its variations were prepared by the Board under Vautelet.
Figure 8. Outline diagrams of accepted design and six competing designs for the new Quebec Bridge.
Vautelet submitted his resignation on February 28, 1911 which was accepted by the government (Engineering News, 1911). The remaining members changed the cantilever span of 1,758 ft selected by Vautelet back to 1800 ft. Both Hodge and Butler resigned from the Board as they confirmed the superiority of the design submitted by the St. Lawrence Bridge Co. over the Board’s design and on April 4, 1911 the construction contract was signed by the government with the St. Lawrence Bridge Co.

In Vautelet’s absence, MacDonald worked as Acting Chairman and Chief Engineer. When MacDonald joined the Board, it was with the understanding that soon after the award of the construction contract, he would retire. With his resignation, there were two vacancies in the Board. On May 6, 1911, Lt. Colonel Charles N. Monsarrat was appointed as the Chairman and Chief Engineer of the board and on May 15, 1911, Charles Schneider was appointed as a Board member. Following his death, his position was filled on January 8, 1916 by H.P. Borden who, up to then, had been working as Assistant to the Chief Engineer. The new and the final Board was as follows:

1. Charles Monserrat, Chairman and Chief Engineer, Canada
2. Ralph Modjeski, Member, USA
3. H.P. Borden, Member, Canada

10 CONSTRUCTION OF THE SUBSTRUCTURE

Work on the substructure continued over a four-year period from 1909 to 1913. At the end of the 1913 season, all that remained was finishing the bridge seats and minor details. The amount of masonry used in the four piers was 106,090 CY.

11 DESIGN OF THE SUPERSTRUCTURE

The bridge was designed for 5000 lb per lineal foot covering both entire tracks with two E60 engines. The engine and train loads were placed to give the maximum loading condition.

Wind load was assumed at 30 lb/ft² of exposed surface of the two trusses and 1.5 times the elevation of the floor and 300 lb per lineal ft as a moving load on the exposed surface of the train. A wind load of 30 lb/ft² parallel with the bridge was also assumed acting on one half of the area assumed for normal wind pressure.

12 SPECIAL SHOPWORK ON THE HEAVY MEMBERS OF THE NEW BRIDGE

Unprecedented steel fabrication was involved in the construction of the new Quebec Bridge. Among the factors were metal thickness of over 9 inches, 1-1/8-inch diameter rivets, mixing of nickel and carbon steels, the great weight of parts and completed members, drilling from solid metal for nearly all rivet holes, planed faces up to 10 ft x 20 ft, 45-inch pin-holes, and assembling in the shops. Engineering News (1914b) provides details and photos of the fabricated members and the fabrication shop.

All plates riveted together in the shop were given one coat of iron oxide and were allowed to dry before they were assembled. The shop coat was pure red lead to which 4 oz of lampblack was added for every 30 lb and mixed with pure linseed oil to the proper consistency. Each member was weighed individually and the weight was painted on in plain figures before being stored. The following conditions were assumed for temperature stresses (Engineering News 1914):

1. Variation of 150˚ F on the uniform temperature of the entire structure
2. A difference of 50˚ F between the temperature of steel and masonry
3. A difference of 25˚ F between the temperature of a shaded chord and the average temperature of a chord exposed to the sun
4. A difference of 25˚ F between the outer webs exposed to the sun and the inner webs of compression members
The superstructure of the bridge was partly constructed of carbon steel and partly of nickel steel. The floor throughout was made of carbon steel. The truss members of the suspended span were all nickel steel to reduce the dead load. Practically all members of the anchor arms were made of carbon steel except for a few members where it was necessary to use nickel steel in order to keep the grip of rivets down to practical limits.

The sizes of the rivets varied from 7/8-inch to 1-1/8 inch. All rivets were carbon steel. When the grip of the rivet exceeded four diameters, the allowable unit stress of the rivet was reduced by 1% for each 1/16 inch of additional grip. This did not apply to compression members having butt joints. All rivets over 5 inches long had a taper of 1/32 inch in 12 inches. The size under the head was 1/32 inch smaller than the diameter of the hole.

No material less than 1/2 inches in thickness was allowed in main members. Material 3/8-inch in thickness was allowed in details such as lattice bars and the tie-plates of the lateral and sway bracing, provided the requirements of the specification as to unsupported length were fulfilled.

13 HOISTING AND COLLAPSE OF THE SUSPENDED SPAN

At the end of July 1916, both the north and south cantilever arms of the new Quebec Bridge were completed, and the details for hoisting of the suspended span were finalized. Figure 9 shows the general scheme for hoisting the suspended span (Engineering News 1916). The suspended span was 640 ft long and 88 ft wide. The depth at the end was 70 ft and at the middle 110 ft.

The vertical distance through which the span was to be hoisted depended upon the water level in the St. Lawrence River, but was estimated to be about 145 ft. Each operation of the jacks hoisted the span 2 ft, and each jacking cycle took about 15 minutes to complete. There were approximately 73 separate lifting operations and the time it took from the moment of coupling up to the hanger lifting chains to the driving of the last pins connecting the two portions of the permanent eyebar suspenders was estimated at 20 hours barring unforeseen delays.

The center span fell into the St. Lawrence River at 10:50 AM on Monday, September 11, 1916 after it had been hung to the cantilever arms by the erection hanger chains and had been hoisted successfully 12 to 15 ft. Eleven lives were lost in the disaster and six men were injured.

By the process of elimination, the place of initial failure was narrowed down to where the truss rested on the girders which hung from the bottom of the lifting chains. A steel casting by which the weight of the southwest corner of the suspended span was transferred to the lifting girder broke in such a manner that the girder kicked back from under it. This corner of the span dropped into the water starting a chain reaction causing the entire span to fall in the St. Lawrence within a few seconds. Figures 10 through 12 show the sequence of events that took place in those few seconds (Engineering News 1916b).

Figure 9. General scheme for hoisting the Quebec Bridge suspended span.
SUCCESSFUL HOISTING OF THE SUSPENDED SPAN

Immediately after the collapse of the suspended span, the St. Lawrence Bridge Co. took full responsibility, announcing they would bear the cost of replacing the fallen span and had placed orders for the new steel. Raising and reusing the fallen span, which was in water about 200 ft deep and possibly broken and twisted, was ruled out. Even though there was a scarcity of steel due to World War I, the carbon and nickel-alloy steel were made available to rebuild the Quebec Bridge.

Unlike the first attempt to raise the center span in September 1916, which the St. Lawrence Bridge Co. had planned to do in one day, in September 1917, they scheduled the hoisting of the suspended span over three to four days and there was no night work planned. The same lifting procedure that was used in 1916 was also used in 1917.

On Monday September 17, 1917, the four chairs under the ends of the spans were attached to the eyebar lifting-chains, and at 9:30 AM the jacking began, thereby raising the span 2 ft at each
stroke. By 4:40 PM, twelve 2-ft lifts were made. The span was anchored against wind, and the work was stopped for the night.

On Tuesday September 18, 1917 22 more lifts were made. The work was not hurried, and it was interrupted to remove the freed links of the lifting chains. On the following day, 26 lifts were made, making 60 lifts over a three-day period. By noon on Thursday, September 20, 1917, seven lifts were already made and only eight more lifts were needed to raise the suspended span to its final position.

The 74th lift was taken very slowly (from 2:10 to 3:10 PM), as some of the wooden working platforms were taken down, the clearances inspected, and the eyebars guided into proper position. The 75th lift followed quickly and locomotive cranes were run out to all four corners with pin-driving cages and pins. At the end of the stroke, at 3:25 PM, the first of the eight pins were driven. The clearances were perfect and each long pin slipped through its eyebars with a few taps from a short rail swung by about ten men. At 4:10 PM the final pin was driven, and all restraint among the workers and onlookers was lost.

The river boats passed the signal to the City of Quebec and by the Mayor’s proclamation, every whistle and bell and automobile horn was turned loose and flags and buntings were thrown to the breeze as Quebec’s dream of thirty years had come true.

On Saturday September 22, 1917, the dismantling of the hoisting equipment started. The span floor system had yet to be erected, the footwalks laid, and some lateral bracing connections had to be riveted. It was expected trains would operate on the bridge in six to eight weeks. Although the official bridge opening ceremony was performed by the Prince of Wales (the future Edward VIII) on Aug. 22, 1919, trains started using the bridge almost 100 years ago on December 3, 1917.

15 PERSEVERANCE AND TRIUMPH OF CANADIAN ENGINEERING

It was not easy to live under the shadow of a highly-developed neighbor like the United States and claim credit for building the biggest cantilever bridge in the world because of the two previous failed attempts. The Government and engineers connected with this bridge in Canada were determined to make the third attempt the final and successful one. During the 1916 collapse, one end of the span was 2 ft higher than the other. Care was taken this time to lift the two ends of the span at the same time and at the same speed.

Every man was trained to perform duties of two positions which were of a different nature, and one not involving such nervous strain as the other. For example, the north central control operator and the north “end engineer” were interchangeable, both knowing each other’s duties. Similarly, the assistant end engineer in charge of, say, the northwest corner was interchangeable with the assistant valve operator in charge of the northwest corner, and those two men were made to know each other’s duties. It was made obligatory that the men in more serious positions were relieved at least every two hours.

There were consulting engineers and bridge company officials on both cantilevers carefully watching and closely monitoring every stage of the operation. Also, expert electricians, hydraulic engineers, and skilled mechanics were on hand ready to deal with any emergency.

The individuals deserving credit for the successful completion of this mammoth project were:

1. **Board of Engineers**
   
   Henri E. Vautelet Changman and Chief Engineer (1908-1911)
   Charles N. Monsarrat Chairman and Chief Engineer (1911-1917)
   Ralph Modjeski Board Member (1908-1917)
   Charles C. Schneider Board Member (1911-1916)
   Charles MacDonald Board Member (1910-1911)
   Maurice Fitzmaurice Board Member (1908-1910)
   H.P. Borden Board member (1916-1917)
   Joseph Mayer Principal Assistant Engineer
   Archibald J. Meyers Chief Draftsman
2. **St. Lawrence Bridge Company**

- Phelphs Johnson: President and General Manager
- George H. Duggan: Chief Engineer
- George F. Porter: Engineer of Construction
- J.D. Wilkens: Resident Engineer (1909-1915)
- John Rankin: Resident Engineer (1915-1917)
- E.H. Pacy: Assistant Engineer
- H.E. Bates: Assistant Engineer for Shop & Field work
- W.P. Copp: Chief Inspector of Erection
- S.P. Mitchell: Consulting Engineer of Erection
- Francois C. McMath: Consulting Engineer
- Herbert W. McMillan: Chief Shop Inspector
- C.J. Yarrell: Chief Mill Inspector
- Walter P. Ladd: Superintendent of Manufacture
- W.B. Fortune: Superintendent of Erection

16 **CONCLUSIONS**

The Ultimate success of this gigantic bridge was built on the ruins of the prior two collapses and painstaking analysis of what went wrong validated by laboratory tests on large compression members and tension bars. The effects of distortion in trusses were explored further than before, and means were devised for dealing with such effects. Much knowledge was added on the assembly of heavy members, and new standards were set as to the degree of precision and finish in shopwork. There was a quantum jump in our knowledge about planning and training for the erection of very large bridges.

According to the Engineering News Record (1917), “the great value of the achievement lies in the inspiration emanating from the courage of the men who have erected on the failure of 1907 and the loss of 1916 this greatest of bridges and in so doing not only have erected a monument to themselves and their courage and ability, but have vindicated the profession before a doubting world.”

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**REFERENCES**

*Canadian Engineer* 1917. Editorial: 33, 266.


*Engineering News* 1900a. The Quebec Bridge over the St. Lawrence River: 44(12) 189.

*Engineering News* 1900b. Work on the Quebec Bridge: 44(15), 241.

*Engineering News* 1903. The Substructure for the 1,800 ft Cantilever Bridge at Canada: 49(5), 92-97.

*Engineering News* 1905. The 1,800 ft span Cantilever Bridge across the St. Lawrence River at Quebec: 54(11) 272-274.


*Engineering News* 1910. Caissons for the Main Piers of the New Quebec Bridge; Launch of the North Pier Caisson 64(10) 262-263.
Engineering News 1911a. Resignation of Mr. H.E. Vautelet from the Board of Engineers for the Quebec Bridge: 65(9) 271-272.
Engineering News 1911b. Tests of Nickel-Steel Details for the Board of Engineers, Quebec Bridge: 65(18) 526-531.
Engineering News 1914a. Design of the Superstructure of the New Quebec Bridge: 71(18) 942-945.
Engineering News 1916. Fig 3. General Scheme for Hoisting the Quebec Bridge Suspended Span: 76(9) 422.
Modjeski, Ralph 1913. Design of Large Bridges with Special Reference to the Quebec Bridge. Journal of the Franklin Institute: 176(3), 239-282.
Railway Age Gazette 1911. Quebec Bridge Loss $7,154,987: 50(5) 249.
Railroad Gazette 1887. Proposed Bridge at Quebec: 19(20), 341.
Scientific American 1851. Suspension Bridge over the St. Lawrence: 7(14), 106.