Historic Structures

significant structures of the past

The Quebec Bridge

Part 1

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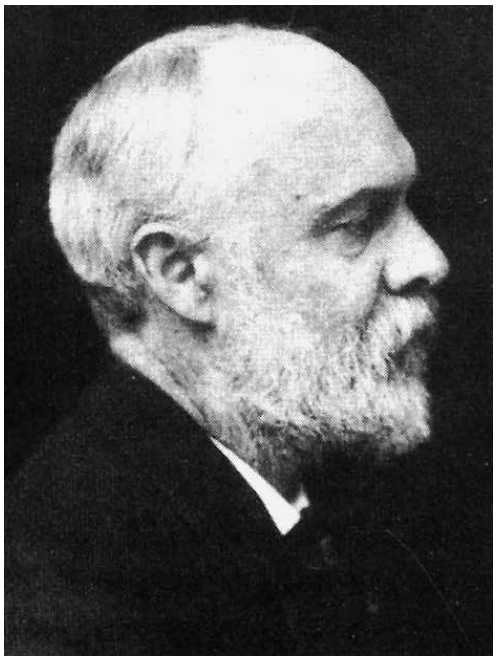
The first in a three part series on the Quebec Bridge.

In the middle of the 19th Century, the St. Lawrence River had not been bridged. In early 1852, the City Council of Quebec City requested Edward W. Serrell to make a study of the problem and make recommendations for a bridge. His major bridge at this time was the suspension bridge he built across the Niagara River connecting Lewiston and Queenstown. At the time of its construction (1851), it was the longest suspension bridge in the country. Serrell's report to the City Council recommended a bridge site about six miles above the city where the Chaudiere River intersects the south bank of the St. Lawrence River. His suspension bridge had a central span of 1,610 feet, and the bridge would carry a single track and a roadway. He concluded his report to the Board with, "Gentlemen of Quebec, you must either build a bridge or a New City."

The Acts of Confederation signed in 1867 included the creation of the Intercolonial Railroad connecting the Provinces of Nova Scotia, New Brunswick, and Prince Edward Island (indirectly) to the south bank of the St. Lawrence River at River Du Loup. The Quebec, Montreal and Occidental Railroad running southwesterly along the northern shore of the St. Lawrence connected Quebec City to Montreal and was seeking its own outlet to the south and the United States, particularly a route to Portland, Maine, so that the railroad could provide transportation to the Atlantic Ocean during the winter months when the river was impassable due to ice.

In 1887, the Quebec Bridge Company was incorporated with Edward Hoare, a well-known Canadian Engineer, retained to survey the various sites and make another recommendation as to the best site for a bridge. In 1891, with activity at a standstill, the charter was re-enacted "with the provision that work start in three years and be completed by July, 1897." Nothing happened until 1897, when the charter was renewed again with the bridge now scheduled to be completed in five years. In June 1897, the American Society of Civil Engineers (ASCE) held their annual meeting in Quebec. In attendance were John Sterling Deans, Chief Engineer of the Phoenix Bridge Company and Theodore Cooper. The Phoenix Bridge Company was one of the leading designers of iron bridges in the country. Theodore Cooper graduated from Rensselaer Polytechnic Institute in 1858. Over the next forty years, he became one of the leading bridge engineers in the country.

Hoare wrote to Deans asking if he intended on attending the convention and, if he was, would

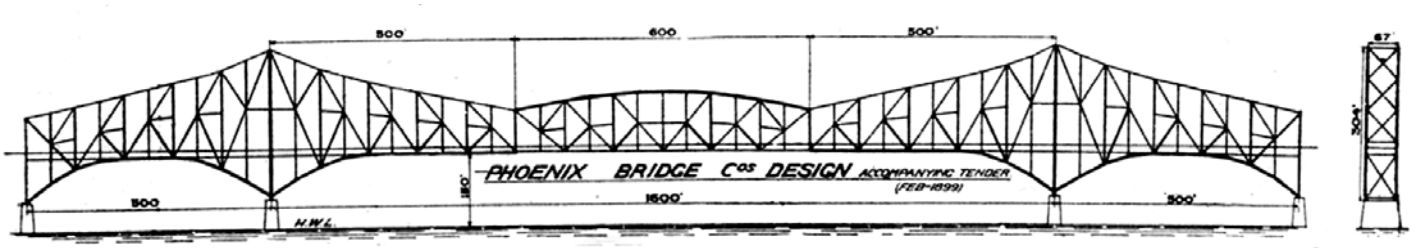


Theodore Cooper.

he "call to see him" about the Quebec Bridge. Hoare told Deans that if he was "interested in the bridge project, I shall be glad to send you a profile of the crossing at the proposed site and other necessary information so that you may, if you wish, be prepared to bid, if the project is carried out." After the meeting, Deans returned to Phoenixville. When the profiles were received, the company took the calculated risk of preparing a preliminary plan for a 1,600-foot span cantilever bridge to span the St. Lawrence. The first plan was submitted on November 30, 1897 or only five months after the ASCE Convention. The bridge company approved of the plan and called for "tenders" on the project. They used the Phoenix Bridge design as a base plan, but indicated that they would entertain other designs. Hoare's specifications went along with the request for tenders, as well as the same profile information he had sent to the Phoenix Bridge Company earlier.

Proposals (tenders) were submitted by the Phoenix Bridge Company, the Dominion Bridge Company, the Keystone Bridge Company and the Union Bridge Company, each of which had several proposals. The bridge company now needed someone with an international reputation to review the proposals and make a recommendation as to which design best met its guidelines. They asked Cooper to review the plans and he agreed, reporting on the competitive plans on June 30, 1899. He reviewed all of the tenders and selected that of the Phoenix Bridge Company for a cantilever.

He wrote that the Phoenix plan was slightly lower in estimated cost and it was, "an exceedingly creditable plan from the point of view of its general proportions, outlines and its



Phoenix Bridge Company – cantilever.

constructive features." He "recommended it as the 'best and cheapest' plan and proposal of those submitted to me..." Cooper, still acting in a consulting role, was asked to follow up on the suggestion made many years ago by Walter Shanley that an 1,800-foot span might be more economical given the better foundation sites that would be associated with a span of this length. He reported on May 1, 1900, "after a careful consideration of all the conditions by your chief engineer, Mr. E.A. Hoare, and myself, it was decided that an 1,800-foot channel span was most desirable if the expense was not too great." Back at Phoenixville, Deans told Peter Szlapka to prepare a preliminary design for a 1,800-foot central span. Szlapka prepared all the plans that Phoenix submitted to the Quebec people to date and would now be the designer of the largest cantilever bridge in the world, as well as the longest span bridge in the world.

During the period of mid-1900 to mid-1903, some work continued on the design and details of the anchor and cantilever spans. The Quebec Bridge Company did contract with William Davis & Sons to build the substructure on August 22, 1899. Work started shortly afterwards and was completed late in 1902.

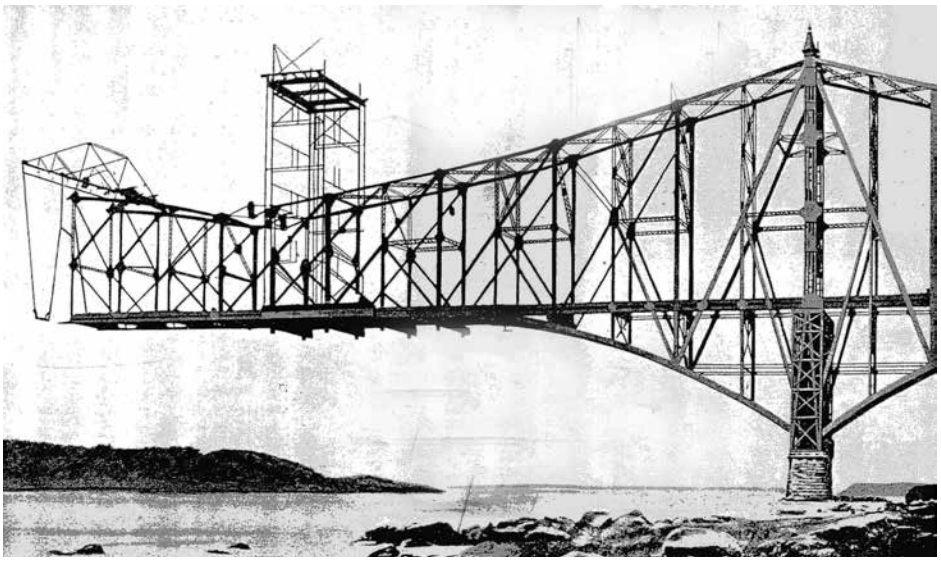
With the financial support of the government in 1903, the project moved ahead with more speed than at any time since 1899. Cooper then sent in his "Proposed Specifications of June 30, 1903." The main changes were a reduction in wind load, an increase in rolling loads, an increase in the allowable working stresses in the members to 20,000 pounds per square inch under a Cooper E-30 loading and 24,000 pounds per square inch under a Cooper E-50 loading over the entire length of the bridge. Deans testified later, "the changes in unit stresses for compression members carried them out of the field of past experience in bridge construction and detailing, and did not follow usual practice."

It wasn't until late 1903 that funding for the superstructure was finally approved and a contract signed with Phoenix Bridge. Erection of the anchor span on falsework began in July 1905 and it, along with the south cantilever arm, was completed in 1906. While designing the south cantilever span and the suspended span, Szlapka discovered that the bridge was coming in heavier than he had assumed. He brought this fact to the attention of Cooper. He now determined that the weight "exceeded the original estimated weight. There was no means of changing or correcting this work. I made an estimate of the increased strains due to this increased weight and found it to be about 7 per cent... Realizing that there was no remedy and that this 7 per cent was not a fatal increase, I did say to Mr. Szlapka, in effect, that we would have to submit to it." When Szlapka had designed the bridge for the 1,800-foot span, he used his earlier estimate for dead weight of the structure he had determined for a 1,600-foot span.

In August 1907, the heavy main traveler was being removed as it was to be moved to the north side of the river. A smaller traveler was at work extending the suspended span outward from the cantilever arm. Work proceeded to the fourth panel point outward from the end of the cantilever arm. At this time, early August, the splice in the lower chord 7-8 L of the anchor span showed additional signs of distress. Cooper later stated that he began to get "uneasy" about the lower chord members on August 8 when he got McLure's report on apparent bending of the web plates. The design of this member consisted of a series of four web members stiffened by angle irons, with the top and bottom spaced using solid plates near the panel points and lattice angles between these areas. The cross sectional area of the plates was 781 square inches. All compressive load was to be transferred through the carefully planed end surfaces of the web plates. Almost immediately after the beginning of construction of the suspended span in July, problems with member 8L started, setting into motion one of the most bizarre set of miscalculations, miscommunications and plain incompetence in the history of bridge building.

Cooper had not visited the bridge site since the beginning of steel erection due to failing health, so he had to rely exclusively on the reports of McLure who did not have a great deal of practical experience. Cooper's staff in New York was small, so it did not have the resources to do all that Cooper had almost insisted on doing for a very small fee.

Between August 7 and August 27, a flurry of letters and telegrams were sent between McLure and Cooper and Deans discussing the distress of the lower chord member. On August 9, for instance, Cooper wrote to McClure suggesting a way to bring the bends back into "proper line by use of 15 to 20 1-inch bolts, threaded through both ends for nuts, passing through the two webs..." "If necessary, after getting the bent webs in line to hold them, spacers and possibly some through bolts may be used." Cooper wrote to Deans describing his solution stating, "It is



Quebec Bridge August 27, 1907 south cantilever. Small traveler on left and large traveler at end of cantilever arm.

Quebec Bridge August 29, 1907.

a mystery to me how both these webs have to be bent at one point and why it was not discovered sooner?" On August 13, Cooper wrote to Deans saying that he was getting conflicting information from Deans and McLure, and that he "can take no action on the matter until the exact facts are presented…Without going into it carefully, I think that there will be more compression at these points with more of the suspended span in place. Please report promptly regarding joint 7 and 8-L with the facts." On August 21, Cooper wrote to Deans discussing his theory that the chord had been hit during erection and indicating that "I still believe that the bend can be partly removed by use of long bolts... I cannot consent to let it go without further action, as the rivets in the cover plates would not satisfy the requirements of my mind."

In the meantime, the people at the bridge site had been showing a great deal more concern than Cooper or the people in Phoenixville were. Norman McLure sent a letter to Cooper on the 27th with his sketches and the statement that "the erection will not proceed until we hear from you and from Phoenixville." It also contained the comment that "although a number of the chords originally had ribs more or less wavy, as I have reported to you from time to time, it is only very recently that these have been in this condition, and their present shape is undoubtedly due to the stress they are now receiving. Only a little over a week ago, I measured one rib of the 9-L chord of anchor arm here shown, and it was only ¾-inch out of line. Now it is 2¼ inches." McLure arrived at Cooper's office in New York City on the morning of the 29th. Cooper later testified:

> *"After carefully reading and considering the letter, I called Mr. McLure into my office and cross-examined him to find out whether the facts given were actual or whether he had been scared, and satisfying myself that the data there were from actual measurement and actual observation, I said: 'It is very serious.' I immediately telegraphed them to add no more load to the bridge till after due consideration of facts. I then said to Mr. McLure; 'You must go to Phoenixville immediately and tell the Phoenix Bridge Company that I do not want any delay such as that involved in the discussion that we have had heretofore on similar occasions, but I want immediate action to strengthen that chord and to protect the bridge.'…"*

Cooper sent McLure to Phoenixville. He also thought that McLure would wire Kinloch at the bridge to stop work, but McLure did not do so. Work continued throughout the day at the bridge site as neither Hoare, Cooper, McLure, Deans nor Szlapka had told them otherwise. McLure met with the Phoenix Bridge people, who had received Cooper's telegram telling them effectively to stop work and add no more load to the bridge. They decided to do nothing until the morning, awaiting A. H. Birks' information. That decision was made shortly after McLure had arrived around 5:30.

The shift was to end at 5:45 with 86 men working on the bridge. There were three riveting crews and one hoisting crew working on the anchor arm, and six riveting crews working on the cantilever arm. A locomotive had just delivered an eight-ton load of steel to the end of the bridge and was returning with another load of the same size. It was located at just about the end of the cantilever arm near the large traveler when witnesses reported a loud explosion. In no more than 20 seconds, probably less, the massive 17,000-ton structure just settled downward into the St. Lawrence River.

A total of 75 men were killed instantly, with 11 escaping with their lives. The *Philadelphia Ledger* summed it up very nicely when it stated: "The world's confidence in the skill and judgment of the engineering profession will be seriously shaken unless it can be shown that the accident was the consequence of unforeseen and unavoidable contingencies." Part II of the series discusses the investigation into the failure and the redesign.▪