Engineering Ethics for New York Engineers: The Quebec Bridge That Collapsed Twice

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Engineering Ethics: The Quebec Bridge That Collapsed Twice

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Spanning the St. Lawrence River near Quebec City, the massive Quebec Bridge has a history of triumph and tragedy. Completed in 1917 at the cost of more than $22 million, it is the longest cantilever bridge in the world, stretching more than 1,800 feet between its main piers. For years, the bridge has been viewed as an engineering marvel, but few people know the full story behind its construction and the two disasters that claimed the lives of 89 workers. The bridge will forever be remembered as one of the worst engineering disasters in Canadian history. (Whalen, 2000)

The fateful story of the Quebec Bridge began in 1887 when a number of entrepreneurs, businessmen and political leaders from Quebec City decided that there was a need to increase business traffic in the area. They subsequently formed the Quebec Bridge Committee, which was later incorporated as the Quebec Bridge Company.

The desire to bridge the St. Lawrence River was fueled by Quebec's need to be competitive in trade. The St. Lawrence River was the main channel of trade for Quebec during the summer months. However, during the winter, it filled with ice, and trade was completely cut off until the river iced over, and travel was possible again across a dangerous ice bridge. Moreover, Montreal already had the Grand Trunk railway system, which passes through it from the west connecting it to Toronto. Quebec was left even farther behind when Montreal began, in 1854, construction of the Victoria Bridge, which was completed in 1859, thereby connecting Montreal to western ports. This development quickly established Montreal as Canada's leading eastern port.

Quebec's businessmen and political leaders formed the Quebec Bridge Company and obtained a charter of incorporation to erect a bridge over the river, a few miles upstream from the historic city near the mouth of the Chaudiere River. The newly-formed company now faced the problem of financing the great bridge project. Government funding was requested; however, no money would be awarded for the project until a bridge site was

selected. With some financial help from the local Quebec legislature, preliminary surveys were made. In 1898, after years of debate, the Chaudiere site was selected from the three recommended sites to be the location of the Quebec Bridge. With a site selected, bridge design proposals poured in. (Middleton, 2001)

But before that, back on June 16, 1897, the chief engineer of the Quebec Bridge Company wrote to a friend, who was also the president of the Phoenix Bridge Company. In response, the Phoenix Bridge Company sent its chief engineer, John Deans, to meet with the Quebec Bridge Company's chief engineer, Edward Hoare, at an American Society of Civil Engineers (ASCE) meeting in Quebec in 1897. The Phoenix Bridge Company offered to prepare plans for the bridge free of charge. In return, the Quebec Bridge Company would then be obligated to accept the Phoenix Bridge Company's proposal for the bridge construction. Theodore Cooper, who learned of the Quebec Bridge project at the ASCE meeting, offered his consulting services to the Quebec Bridge Company.

Due to lack of funds, the Quebec Bridge building project did not commence until 1900 when the company finally received financial assistance from the federal, provincial, and municipal governments, and the Quebec Bridge Company contracted with the Phoenix Bridge Company of Phoenixville, PA, to build the structure. With the support of the Canadian government, which wanted to establish a National Transcontinental Railway from Moncton to Winnipeg, the bridge project moved forward.

The Phoenix Bridge Company's design called for a cantilever bridge of 150 feet in height above the high-water mark. It was also decided that the structure would have a cantilever attached to piers on each side of the river by anchor arms of 500 feet each and linked together by a center span initially projected at 1,600 feet. Besides being a transportation link for trains, the bridge would also serve as a crossing point for vehicles and pedestrians. (UNCC.edu)

The First Bleak Signs

On the afternoon of August 29, 1907, a bridge worker named Beauvais was driving rivets into the southern span of the bridge when he noticed that one of the rivets, driven in only an hour before, had split into two. Beauvais called out an alarm to alert his foreman, but just then, a large cantilever fell from under him and crashed into the river with a resounding boom.

Ten kilometers away in Quebec, people heard the noise and thought they were experiencing an earthquake. Beauvais plummeted into the water with the debris but managed to wrestle himself free. The timekeeper, who was just about to signify the end of the day, had to run from the bridge toward solid ground and reached it only as the girder shattered behind him. A locomotive plunged into the river, but the engineer was pulled from the wreckage by a rescue boat. Others were not so fortunate: Of the 86 workers on the bridge that day, 75 died—many of them local Caughnawaga, who were famous for their high steelwork. Some of the dead had been crushed by the twisted steel, others by the fall. Still, others drowned before the rescue boats could reach them. (Marsh, 2013)

What Went Wrong?

How did this ambitious project, staffed by some of the world's most brilliant engineering minds and builders, result in such tragedy?

To begin answering that question, we need to go back to the American Society of Civil Engineers (ASCE) meeting in Quebec in 1897, which was attended by engineer Theodore Cooper, who, following the meeting, offered his consulting services to the Quebec Bridge Company. Hoping to retain an engineer considered to the best in the field, the Quebec Bridge Company ultimately hired Cooper, an American bridge designer famous for his prestigious projects, including the Second Avenue Bridge in New York City. The choice seemed ideal because when it came to professional construction designers, Cooper had few equals on the continent. But Cooper had a reputation for both brilliance and arrogance. Cooper endorsed the design of Peter L. Szlapka of the Phoenix Bridge Company as the "best and the cheapest," and later decided to lengthen the center span from 1,600 to 1,800 feet. (Marsh, 2013)

Despite Cooper's impressive past accomplishments, the word "cheapest" would later come back to haunt him.

Before the parts for the bridge's superstructure were manufactured, Szlapka, estimated the weight of the completed work. The Canadian government had hoped to hire its own engineer to review the weight calculations, but Cooper objected, saying that it would "put him in the position of subordinate," which he was not willing to accept. Cooper had strong qualifications for this project: In his long career, Cooper had written an award-winning paper pioneering the use of steel for railway bridges and had prepared general specifications for iron and steel bridges. His method of accounting for railroad loads on bridge structures had become widely used. So, again, Cooper seemed to be the most imminently-qualified person for the job, and, as such, and given that the Canadian government didn't want to lose him, Cooper's plans were accepted without alteration and without review by an independent engineer.

At the age of 60, and suffering from health issues, Cooper did not want to supervise the on-site work. He did not make visits to the site during the erection of the superstructure. Instead, he directed the project from his New York City office and entrusted supervisory tasks to Szlapka, who was little more than a desk engineer. (Marsh, 2013)

On-site work was supervised by Edward Hoare, the chief engineer for the Quebec Bridge Company (who had never before worked on a bridge longer than about 300 feet), and a young engineer by the name of Norman McLure, the inspecting engineer for the Quebec Bridge Company, neither of whom had experience in such a massive engineering undertaking.

The Quebec Bridge was the longest cantilever structure ever to be attempted in its day. It would bridge the St Lawrence River approximately nine miles north of Quebec, connecting into the Grand Trunk rail line. The cantilever arms would reach a distance of 562.5 ft. They were to support a suspended span with a length of 675 ft that would stand 150 ft above the river. The initial design length for the clear span was 1,600 ft; however, in May 1900, Cooper decided to increase its length to 1,800 ft He justified the increase in length by saying that it would eliminate the uncertainty of constructing piers in such deep

water, lessen the effects of ice, and shorten the time of construction of the piers. (Middleton, 2001)

Construction of the bridge officially began on October 2, 1900. The completed piers, made of huge granite facing stones with concrete backing, would stand approximately 26.5 ft above the highest water level. The top of each pier was made of solid granite. The piers were tapered one in twelve (one inch per foot) until they reached the dimensions of 30 ft by 133 ft at the top. Each pier rested on a concrete-filled caisson that was 49 ft wide, 25 ft high, and 150 ft long, weighing 1,600 tons.

The main vertical posts of the Quebec Bridge, once complete, would stand 315 ft tall and would weigh approximately 350 tons. The anchor pier towers would withstand a load of 3,500 tons. The tension eyebars were designed to withstand a maximum stress of 108.5 MPa (15,730 psi) and were about 42 ft long. The floor system was designed to carry a live load of well over 280 tons. (UNCC.edu)

Under a separ ny, the Phoenix Bridge Company began the c nd completed them in 1903. Erection of the s begin until July 22, 1905. The Phoenix Bridge Co ted by the last day of the year in 1908. Otherwis required to pay $5,000 per month to the Quebe pleted. (Middleton, 2001)

A Series of Poor Decisio

In February 1906, C ned when he examined the detailed drawings of the Phoenix Bridge Company and found that the actual weight of the manufactured steel parts far exceeded the weight estimated by Szlapka prior to manufacturing. These facts beg the questions: Did Szlapka know about the weight discrepancies and had chosen not to reveal them to Cooper? Or had he not known but should have?

Cooper decided to forge ahead and not introduce any changes. Construction continued because Cooper became convinced that the increase in stresses would be safe. (UNCC.edu)