the VICTORIA bridge

[THE EIGHTH WONDER OF THE MODERN WORLD]

CONTENTS OF THE VIRTUAL EXHIBIT

THE VICTORIA BRIDGE: THE 8TH WONDER OF THE WORLD

Page 0. Introduction : A work of gigantic proportions

There was a time, in bygone days, when the Victoria Bridge was considered the eighth wonder of the world. While its connection with the city is different today, it still continues to fascinate. Why was it such a wonder for people at the time?

In the mid-19th century, the Grand Trunk Railway and its engineers embarked upon a bold enterprise that was also a first: the construction of a railway bridge that would span the broad and raging St. Lawrence River. Inaugurated in 1860, the Victoria Bridge was thus a tangible sign of progress, an undeniable proof that the impossible could become a reality. It symbolized the power of the change that drove the century and shaped peoples' lives. The psychological effect was considerable, and extended not only to the period's engineers but also to the citizens who celebrated their achievement.

A new era comes into view.

Page 1. Theme 1. A vital means of transportation

The development of the railroad was directly related to a recent phenomenon: industrialization, which made mastery over the material world possible. One of its manifestations, the steam-powered engine, would revolutionize the means of transportation in the first half of the 19th century, particularly in the domain of land transportation, which underwent rapid expansion thanks to the railroad. By 1860, the year in which the Victoria Bridge was inaugurated, the main railway lines were either already built or under construction throughout Europe and the United States. Canada was somewhat slow to get in step, embarking on a systematic approach in 1850. Meanwhile, the capacity of passenger and freight cars continued to grow everywhere.

Page 1.1 / Sub-Theme 1.1 The age of coal and steam

Page 1.1.1 / Chapter 1.1.1 The conquest of the material world

The 19th century saw the rise of new values tied to production, speed, efficiency and change in every area. As technical and technological innovations multiplied, industry expanded in Europe and, particularly, in North America, where it made a spectacular leap forward. It had a considerable impact on Western, European and North American society through urbanization and modernization. This period of rapid growth was characterized by, among other things, enthusiasm for progress and inventions, whose material benefits would soon be felt in all spheres of society.

Page 1.1.2 / Chapter 1.1.2 Steam: A revolutionary form of energy

The first wave of industrialization (1760-1830) took place during the era of coal and oil, with the first steam-driven engines. The first of these were used in the textile industry of Great Britain, where the industrial revolution was born in the 18th century. During the first half of the 19th century, this form of energy led to the development of a host of machines that would radically transform human labour by mechanizing it. Means of transportation would, in turn, greatly benefit from these inventions.

The steamship, the first of which was built by the American Robert Fulton (1806), reduced the cost of overseas transportation to a quarter of what it had been since late Middle Ages. And thanks to the efforts of the Englishman George Stephenson, the railroad in 1825 embarked upon what would become the greatest revolution in land transportation of the 19th century. In the space of a half century, the costs of moving freight and people came to represent only one sixth of what they were during the age of the stagecoach.

The repercussions were tremendous: industrialists could transport more merchandise for less money, travellers could go farther more conveniently, and families had the option of emigrating in the hope of a better life.

Page 1.1.3 / Chapter 1.1.3 The transition to the modern world

Industrialization, made possible by technical progress in the 19th century, transformed social reality. The machine was to have a very tangible and direct impact on the material aspects of human life, as well as on work organization and social relations. The introduction of automated machine tools (1840), the invention of the absorption refrigerator (1850) and the harvester (1851), the mass production of watches in Great Britain (1853), the appearance of the Otis hydraulic elevator (1854) and the household sewing machine (1858) – all these resulted from a series of innovations that promoted durable progress first in the lifestyles of individuals and then in society as a whole.

The first wave of industrialization was characterized by an enormous increase in the number of factory workers. A rural exodus began, to the greater benefit of cities where development continued apace and where labour became more concentrated in response to ever-increasing demand. This first wave followed in the wake of the Enlightenment, which saw the machine as the uncontested source of improved standards of living, the instrument that would liberate human beings and humanize them. Yet, as industrialization and mechanization progressed, the working conditions of the working class deteriorated.

Page 1.2. Sub-Theme 2.2 Significant innovations

Page 1.2.1 / Chapter 1.2.1 New structures

The demand for iron for use in the manufacture of textile machines, steam engines, ships, rails, train cars, etc. paved the way for modern metallurgy. The use of coke, known in Great Britain since the 18th century, became more widespread, while “puddling” made it possible to transform cast iron into steel (late 19th century). Steel could be moulded, was fireproof and easy to use, possessed a better load-bearing capacity over greater distances, and was generally less expensive. Engineers soon turned to it when building their works. Brunel, a naval architect and one of the most celebrated architects of the Victorian era, saw his influence grow as a result of being the first to apply the technique of self-bearing structures in the shipbuilding industry.

Iron was also used in ambitious architectural products, such as the Crystal Palace of London in 1851 and the Crystal Palace of Montreal in 1860; so much so that people of the period had the impression that it was engineers and not architects who were shaping the emerging cities. Like the Victoria Bridge built in 1860, these architectural wonders compelled admiration, for this was the first time that steel and glass were brought together to make a transparent structure resembling a greenhouse.

Then the discovery of the procedure for making steel, which occurred while the Victoria Bridge was under construction, would revolutionize building methods. Starting in the 1870s, steel made it possible to support loads much greater than might have been possible with iron or masonry. The Brooklyn Bridge (1883) and the Eiffel Tower (1887-1889) are eloquent examples of the new technology.

Page 1.2.2 / Chapter 1.2.2 The railway: A decisive stimulus

With the expansion of the railway, engineers were induced to design structures that made it possible to overcome natural obstacles that had previously remained unconquered. In 1845-1850, the construction of the Britannia Bridge over the Menai Straits in England represented one of the key chapters in the history of contemporary civil engineering. Designed by Robert Stephenson (the son of George Stephenson) and Francis Thompson, the bridge, with its tubular structure, borrowed the assembly technique perfected by Brunel. The principle, which is rather simple, consists in having the trains move through a rectangular tube composing a hollow beam extending between two towers.

In 1850, there were only 35 000 kilometres of railway lines in the world; by 1914 there were already a million. During the same period, shipping capacity rose from 5 to 50 million tons: for the first time in the history of humanity, heavy cargoes (grains and industrial raw materials) could be sent by sea.

Page 1.2.3 / Chapter 1.2.3 A new invention: The telegraph

The telegraph, another revolutionary invention, was perfected after 1832 by the painter Samuel Finley Breese Morse. Keenly interested in electrical phenomena, Morse managed to convince the United States Congress to fund his efforts. On May 24, 1844 he transmitted a first message along a test line running from Washington to Baltimore.

On January 14, 1848, a first telegraph service was made available by the Montreal Telegraph Company, which connected Toronto and Quebec City via Montreal, generally by following the railway lines. A telegraph wire was installed on the Victoria Bridge as soon as it was opened. This invention made communication possible between cities separated by enormous distances. The telegraph very quickly became a tool essential to rail traffic.

Page 1.3 / Sub-Theme 1.3 Railway fever

Page 1.3.1 / Chapter 1.3.1 A sprawling network

Although the first railway lines were laid in Lower Canada, they spread more quickly in Upper Canada in the late 1840s and early 1850s. Railway line construction was made possible mainly through government aid, which became more generous with the creation of the Grand Trunk Railway in 1853. This aid took the form of land subsidies and capital guarantees. The government also developed labour and business legislation, and oversaw investment in share capital.

The Grand Trunk soon became the main railway company and proceeded to buy up various fledgling companies like St. Lawrence and Atlantic. Financed largely by British capital, it had a twofold mandate: to build one line between Montreal and Toronto along the St. Lawrence and Lake Ontario, and another connecting Toronto to Sarnia. The first stretch joined Montreal's south shore with Portland in the United States, giving it year-round access to the sea. But the lines very soon came up against the St. Lawrence River, a natural obstacle that had to be overcome if year-round access to the sea was to be had directly from Montreal. One solution seemed particularly promising.

Page 1.3.2 / Chapter 1.3.2 Montreal at the hub

Rail transportation enabled Montreal industries and businesses to open up to new and previously inaccessible markets, and contributed to the settling of the Canadian West. Montreal soon became the hub of this network, a position that was consolidated with the opening of the Victoria Bridge. This situation fostered transportation by rail and ship to both domestic and foreign markets, and particularly to those of the British Empire. Indeed, beginning in 1853, the Montreal Ocean Steamship Company provided regular steamship service between Montreal and Great Britain, although the river could not accommodate most of the larger cargo ships.

The arrival of the railway represented a major technological advance: for the first time human beings had devised a rapid means of land transportation. Likewise, the reduction in the time it took to move people and goods constituted a considerable advance, making it possible to increase the frequency and scale of trade and other forms of exchange.

Page 1.4 / Sub-Theme 1.4 A mentality in the making

Page 1.4.1 / Chapter 1.4.1 Industrialization in Montreal

In Montreal, the refurbishing of the Lachine Canal, which was completed in 1848, facilitated the establishment of factories and the use of considerable quantities of hydraulic energy. The southwest of Montreal soon became the industrial centre of Quebec, with mainly four sectors: flour production, iron and iron products, wood and wood products, and shoe-making. Then, starting in the 1860s, the textile industry underwent unprecedented growth, constituting a major share of manufacturing in Quebec.

Industrialization and the urbanization that accompanied it led to a significant modification of demographic behaviour. This transition, already noticeable in the pre-industrial era, signalled the conditions that would prevail in the industrial age to come, as well as the changes that would characterize the social structure, ways of thinking and population distribution as people migrated to cities.

In Lower Canada, industrial growth and projects like the construction of the Victoria Bridge led to rapid increases in urban population growth, which went from 14.9 % in 1851 to 16.6 % in 1861, and then to 19.9 % in 1871. In Montreal alone, the population rose from 57 715 in 1851 to more than 90 000 in 1861, an increase explained by the establishment of industries along the Lachine Canal during the 1850s.

Page 1.4.2 / Chapter 1.4.2 Urbanisation: An implacable trend

Until the mid-19th century, Montreal was essentially a business and services centre oriented toward both international and domestic markets. Between 1850 and 1870, the city became industrialized and gradually took on a different look. The work force became concentrated around factories, and took part in the creation of a new working class composed of unskilled workers and day labourers, while craftsmen gave up their traditional roles to become wage earners. To supply industry with the manpower it needed, numerous immigrants were brought in from Great Britain, particularly from Ireland, while rural francophones were encouraged to settle in the city. The same period saw the rise of a business class that derived its wealth from industry, consolidating Montreal’s position as the economic heart of the country.

The expanding railway system formed the backbone of trade and passenger transportation, and urban and regional development radiated out from it. The construction of the Victoria Bridge sped up this process, while contributing to the growth of the railway industry in Montreal. The Grand Trunk set up shop in Point St. Charles, where it maintained and repaired rolling stock, and built train cars and barracks for its office workers and those employed in the manufacture of various materials. This new area would bear the name of Victoriatown; its street names – Stephenson, Conway, Britannia, Menai – referred to people or places associated with the world of the railroad.

Page 1.4.3 / Chapter 1.4.3 A diversity of manpower

Between 1 500 and 3 000 men worked on the construction of the Victoria Bridge, either in workshops or offices. Most of the workers were hired in Canada, and came directly from Great Britain. However, the English company of Peto, Brassey and Pets, contracted to build the bridge and the Grand Trunk system, arrived in Montreal complete with several teams of masons, quarrymen, riveters, steam engine mechanics, crane operators, metal workers and carpenters. The salaries offered to this skilled labour were high, and the jobs were guaranteed for a period of five years.

Many Irish workers were hired on to build the Victoria Bridge. The manpower recruited in Canada came from various backgrounds – English, French, Irish, Scottish – and was made up of unskilled labourers, tradesmen, tinplate workers, carters, carpenters, secondary engineers and subcontractors. Workers hired in Great Britain had to pay a considerable sum for their passage to Canada. The company advanced this amount to each worker, who had to pay it back out of his salary at the rate of one shilling per day.

Not far from the barracks of the bridge crews, a cemetery holds the remains of some 6 000 mostly Irish immigrants, who died of typhus between 1846 and 1847. As work on the bridge drew to a close, the workers suggested that a monument be set up in memory of the deceased. The stone, a moraine raised from the riverbed, was unveiled in 1860.

Page 2. Theme 2. Belief in the idea of progress

Successive technological innovations, as well as the urban and social upheavals experienced by countries in the full swing of industrial revolution, helped to change people's ways of thinking. The period was fascinated by the idea of progress, which, it was believed, would foster the "advancement of civilization" and enable people to move beyond current social and artistic values.

Progress does not exclude the possibility of error, for only in this way is evolution possible. The construction of railway bridges reflects this tolerance precisely with regard to the experiments carried out from 1840 to 1870, before a cohesive theory of bridge building was formulated. The idea of change, this "effect of a beneficent necessity," pervaded the modern mentality.

Page 2.1/ Sub-Theme 2.1 Dominion over nature

Page 2.1.1 / Chapter 2.1.1 New needs

In the 1850s, railway companies used stream engines designed to haul freight cars or even whole trains. This was the case with the Princess Victoria which, starting in 1863, ran along the St. Lawrence River between La Prairie and Montreal. In 1853, the first ferry crossed the river with a locomotive and three cars operated by the Montreal and New York Railway Company.

But these means of transportation were soon no longer suitable for an era in which freight had to be moved more quickly. The slowdown in transportation caused by the transfer of freight cars even became an obstacle to the commercial and economic growth of Montreal, which had to deal with stiff competition. Moreover, the city's importance as a railway terminus led to increased pressure in favour of the construction of a bridge across the St. Lawrence River, in order to facilitate transportation and make it viable year round.

Page 2.1.2 / Chapter 2.1.2 The control of nature
The prime function of bridges is to master an obstacle by means of a fixed link suitable for motor vehicle or train traffic. As early as the 17th century, canals made it possible to cross rivers, rapids or valleys. Then, with the development of means of transportation and the advent of industrial society, building projects multiplied. The expansion of railways during the 19th century, and the need to reduce slope grades and cross numerous obstacles in North America, made the building of viaducts and bridges essential.

To carry out these tasks, engineers and other workers had to be familiar with the terrain and evaluate all of the parameters that would make it possible to establish railway lines and bridges in places said to be inaccessible. Technical progress contributed to the control of nature like never before.

Page 2.2 / Sub-Theme 2.2 The flattest route
Prior to 1860, several railway bridges were built over the Mississippi and Ohio rivers, as elsewhere in the United States and Canada, for transporting goods and passengers. Between 1820 and 1860, engineers built and tested four types of bridges. Since there was as yet no formal theory governing bridge construction, and even less so where railway bridges were concerned, calculations of probability with respect to solidity, resistance to vibrations and load-bearing capacity played a key role in this emerging profession.

With industrialization, the use of new and less costly materials gave rise to major structural innovations that would revolutionize the profession and, in particular, permit the opening up of corridors that were previously unfeasible.

Of all the existing types of bridges, which one was most suitable for spanning the St. Lawrence River?

Page 2.2.1 / Chapter 2.2.1 Wooden bridges. Widely used in 19th-century North America for large railway viaducts (the trellis bridge was very popular), these were inexpensive due to the proximity of thick forests, particularly in Western Canada and the United States.

Page 2.2.2 / Chapter 2.2.2 Stone bridges. Railway construction in the 19th century served as an impetus for the design, particularly in France and Great Britain, of large masonry railroad viaducts, which were very solid and costly structures. In North America, the stone arch bridge was frequently employed due to its great solidity, but since it was very costly it was abandoned during the 19th century.

Page 2.2.3 / Chapter 2.2.3 Suspension bridges. The first suspension bridges in the West date from the early 19th century. The record for bridges of this type was beaten in 1883 by J. Roebling, with New York’s Brooklyn Bridge. Spanning a distance of 486 metres, it was kept aloft by parallel steel cables. But numerous suspension bridges would be brought down by heavy winds or vibrations (for instance, by troops marching in step). Only in the late 19th century did actual piers make their appearance.

Roebling, an American of German extraction, developed the lighter system of the suspension bridge in the United States. In 1848, he built his first bridge of this type at Lackawaxen in Pennsylvania. His Niagara Bridge followed in 1855. The first suspension bridge capable of carrying a train, this had a railway line above a lane for motor vehicle traffic. But its limited load-bearing capacity, the vibrations generated by the train’s passage, the wind and so on made it less safe and solid. Roebling used steel when building the Brooklyn Bridge in 1883.

Page 2.2.4 / Chapter 2.2.4 Metal bridges. In the West, this type of structure goes back to the industrial era in the late 18th century, when bridges were made from cast iron. All cast iron bridges built prior to 1850 would eventually collapse, since this material has low tensile strength and resistance to shocks. These works were, however, quite revolutionary for their time.

Thanks to the development of the steel industry, steel replaced cast iron: first puddled steel, then steel produced directly through the refinement of cast iron, were widely used toward the middle of the 19th century. One of the most celebrated bridges was the Britannia Bridge built in 1850 by Robert Stephenson, chief engineer on the Victoria Bridge project. It had two parallel 140-metre spans and a tubular structure. The beams of these bridges generally rested on stone masonry piers, which were employed for the stability they provided.

The two main types of railway bridges that existed in the 1850s were:
A- The tubular bridge, which was very popular in Europe in the 1840s and ’50s. It was built in accordance with the principle of the hollow beam, through which trains can pass. Because of problems with vibrations and weight restrictions, the tubular bridge would be phased out after the death of its inventor, Robert Stephenson, in 1859.

This beam bridge bears a good resemblance to the tubular bridge since it also consists of a beam (this time solid) over which the train passes. This type of structure is favoured for short-span bridges. The Grand Trunk often made use of it, and examples of it can be found throughout the country.

B- The trellis bridge, widespread in the United States, grew in effectiveness and popularity from the late 18th through to the late 19th century, and came to occupy the front ranks of railway bridges. It composed a very large family (with its Burr, Moore, Town, Howe and Fink types) and was appreciated for its solidity. It could be either in wood (covered bridges) or metal. In the latter case, the compensatory measure was quite simple: one had only to add units to make a system that could be extended indefinitely. Today’s Victoria Bridge, a Howe type trellis system in metal, was repaired for Queen Victoria’s Diamond Jubilee in 1897.

Page 2.3 / Sub-Theme 2.3 Two designs square off
Page 2.3.1 / Chapter 2.3.1 May the best one win!
At the time of the Victoria Bridge project in 1851, the art of bridge construction was poorly developed and relatively unknown in Canada. Moreover, a great number of bridges were made of wood, a flammable material with poor durability. When Stephenson proposed using cast iron to build the Britannia Bridge, a structure that had to withstand tides at speeds of over seven miles an hour, he made a considerable innovation.
Thus two opposing approaches can be distinguished: one opts for solidity through weight (tubular bridges), while the other favours lightness (suspension bridges). Before the Victoria Bridge was built, engineers knew very little about structural stress phenomena in bridge construction, or about the resistance of materials. Because of this lack of knowledge, they found it necessary to test their theories on scale models. During this period of experimentation, considerable progress was made in structural design, although little was yet known about the tensile strength of steel, or its load-bearing capacity and limitations.

Page 2.3.2 / Chapter 2.3.2 The tubular bridge: A revolution
The construction of the Britannia and Conway bridges in Great Britain demonstrated that it was possible to overcome obstacles that had previously been considered insurmountable. From a psychological standpoint, this achievement had enormous repercussions on engineers and builders, as well as on those who used the bridges or merely came to see

them. It gave engineers a new impetus, and the conviction that boundaries could be continually pushed back. This idea of surpassing earlier achievements reinforced the perception that all human achievements are imbued with a sense of wonder because of their power over nature.

Spurred on by this success, engineers believed in their ability to triumph over the numerous obstacles presented by the St. Lawrence River. With the Victoria Bridge they would prove that it was indeed possible to design a structure that could withstand a current running at more than 11 kilometres an hour, and that one could control the devastating power of ice and ice jams, in addition to spanning the several kilometres separating the two banks of the river.

Moreover, engineers and labourers were getting ready to build the longest bridge in the world, a major challenge impressive in its ramifications. The first tubular bridge, the Britannia, was made up of two 140-metre spans, for a total of 280 metres, hence the longest bridge until 1855, when it was dethroned by Roebling's on the Niagara. In 1860, it was the Victoria Bridge's turn to defy all standards with its 2.7 kilometres in length, totalling 2 009 metres of steel.

Page 2.3.3 / Chapter 2.3.3 Experiments

When Stephenson designed the Britannia Bridge, he adopted the empirical approach of trial and error. Tests were carried out on models, which were reinforced at the points where they failed and tested again until satisfactory results were achieved. The challenge, considerable for the time, involved anticipating the various effects of structural stress and resistance in the absence of any coherent theory. In 1845, Robert Stephenson, the railway engineer, began collaborating with William Fairbairn, a mechanical engineer and prolific author. Together they embarked upon a series of experiments pertaining to the properties of metals, the solidity of riveted joints, and the use of steel in building and ship construction. Fairbairn's writings apparently made significant contributions to the scientific thinking of engineers of the period. Some thirty years later, a body of theory came together and debates were conducted in numerous publications and analytical papers, providing the art of bridge construction with much more solid foundations.

Innovations were soon supplanted by new developments and, in a race for new inventions spurred on by the belief in progress, efficiency, time saving and the reduction of costs were widely viewed as the proper means to develop an extensive railroad system. By the time the Victoria Bridge was completed, its construction costs were judged to be so enormous that builders sought out more economical models.

Appendix: The birth of an idea

Few people are aware that Stephenson drew his inspiration for his inventions from nature. In fact, before proposing a definitive structure, he experimented with various models of tubes reproducing the stems of different plants. He apparently got this idea from observing the rigidity and strength of certain plants like wheat, reeds and the giant bamboo. He was fascinated by how they could be both light and rigid at the same time. His observations led him to undertake experiments that ended with the construction of tubular bridges like the Britannia, Conway and Victoria. He carried out:

- 12 experiments on cylindrical tubes
- 7 experiments on elliptical tubes
- 14 experiments on rectangular tubes

He concluded that the rectangular tube was the most solid.

Stephenson was at the summit of his career when he was approached in his capacity as an expert and asked to decide upon the best location and structure for the Victoria Bridge, and to approve the plans proposed by the engineer Alexander Ross. At the time, the Britannia Bridge and the Victoria Bridge represented spectacular advances in the construction of this type of structure. Moreover, the tubular system would be the precursor of tens of thousands of beam bridges, which is the type most commonly used for rail traffic.

Theme 3. The Victoria Bridge: The world's longest bridge

The proposal to build a bridge over the St. Lawrence River to link the Saint Lambert railway line to Montreal was initially viewed as too ambitious. Public response was cool and the project, considered absurd, was ridiculed. But with the passage of time, the strength of John Young's convictions, and the persuasive effect of newspaper articles and presentations to the Council of Railway Companies, the project finally won over hearts and minds. The construction of the Britannia and Conway bridges immediately provoked a keen interest in the design of tubular beams, which had been very much in vogue during the 1850s. The tubular bridge was, for the moment at least, the best solution to the numerous challenges presented by the construction of a bridge over the St. Lawrence River.

Page 3.1 / Sub-theme 3.1 Increased trade

Page 3.1.1 / Chapter 3.1.1 At the heart of trade

In the 19th century, Montreal was at the hub of shipping lanes to Europe and domestic river traffic. Trade between Montreal and the coastal regions was provided by several transportation companies. Ferries formed the link between Montreal and the south shore, but this mode of transportation was interrupted during the winter, when ice bridges were the only means of getting from one bank to the other. In the 1840s, trade with the United States increased thanks to the efforts of the Champlain and Saint Lawrence Railway, which provided a commercial link between the Richelieu Valley and that of Lake Champlain.

Page 3.1.2 / Chapter 3.1.2 A hub

In 1846, construction began on a rail line that would connect Montreal and Portland, Maine, by way of Sherbrooke. In winter, however, Montreal was cut off from any access to the sea, except for its land routes to Portland, Boston and New York. The development of the railroad made Montreal the ideal site for an interprovincial and international rail terminal. A number of factors gave it an advantage over other cities like Quebec City: it had a larger population, was home to most of the leading industries (with the exception of the naval industry), possessed numerous warehouses and large commercial establishments essential for moving freight, and had room for railway yards and workshops in the surrounding area.

Page 3.2 / Sub-Theme 3.2 An ambitious project

Page 3.2.1 / Chapter 3.2.1 The challenges ahead

The construction of the bridge posed numerous technical challenges for engineers and builders; a bridge of this length had never been built. In addition to the problems inherent in the construction of any bridge, this one came with its own particular constraints: although the water level was low at the chosen site, the current was very strong; add to that the spring break-up, which caused spectacular build-ups of ice between Montreal and Île Sainte-Hélène (this would not change until the mid-1950s).

The climate, too, presented a major problem. The extreme cold and the freezing of the river in winter, the high tides caused by the spring thaw, and the headlong current running at more than 11 kilometres an hour were enormous challenges at the time. But in spite of the difficulties presented by nature, the designers, engineers and workmen put into motion everything they needed to find the structural solutions that would enable them to provide a link between Montreal and the south shore.

During this period suspension bridges like the Niagara railway bridge were the most economical solution and thus represented the ideal structure when there was only one span. But this was not the case when it came to long bridges requiring a succession of spans. An overly long suspension bridge would have been unable to withstand destructive vibrations or bear the enormous weight of a train. Thus the tubular bridge came into favour.

Page 3.2.2 / Chapter 3.2.2 The partners

On the invitation of the provincial government, the British entrepreneurs Peto, Brassey and Betts studied the possibility of building a Montreal-Toronto line and a bridge over the river. They signed their contract on September 16, 1852 and sent their engineer Alexander Ross to Montreal. John Young, the Commissioner of Public Works, entrusted Thomas Keefer with the task of looking at possible sites for the future bridge. Eminent engineers were also consulted. Robert Stephenson, who designed the structure, oversaw all the calculations and required tests. Alexander Ross, the resident engineer, chose the site based on Keefer's study, drew up and adapted the final blueprints and prepared the construction manifests. In December 1853, he finished his design for the bridge, which would be equipped with 24 ice-breaker piers and a steel tubular structure.

Page 3.2.3 / Chapter 3.2.3 The studies

Several studies were required before the Victoria Bridge project was born. The first study, that of Keefer in 1851, proposed an elevated bridge with a span of 122 metres above the main channel. Trains would run through the tube on the central span, but above the tubes on other spans, all the way from solid embankments to abutments. The central span would be in steel and the others in wood, to reduce construction costs, which were evaluated at $1 600 000.

The second plan he submitted, in 1852, advocated building exclusively in steel at a cost of $3 000 000, a solution that Keefer preferred because it was safer and, over the long term, less costly in terms of maintenance. In accordance with this new concept, trains would run through the tube over the bridge's entire length. Keefer's design featured stone piers with the upper portions in the shape of ice-breaker hulls, which would become the norm for all bridges required to withstand sheet ice.

Steel bridges were still not widely used in the North American rail system; wooden bridges, being less expensive, were much more popular. But despite higher costs, the Victoria Bridge engineers stressed the importance of replacing wood, a flammable material of limited durability, with steel, a durable material. Experiments conducted at Menai during the construction of the Britannia Bridge had demonstrated the superiority of the tubular structure in cast iron, the life of which was then estimated to be a half century.

Page 3.2.4 / Chapter 3.2.4 An ideal site

Keefer made several studies of the proposed site for the bridge. An in-depth analysis was then carried out, using precise measurements marked out on the ice. This study was followed by others intended to determine the best site in terms of the river's natural impediments. Finally, the site that elecited the most interest was the one joining Point St. Charles on the Montreal side with Saint Lambert on the opposite bank. This site was picked for a number of reasons:

- The river was shallow (1.5 metres) all the way across at this point, and in summer the main channel attained a depth of 7.5 metres over a width of 90 metres.

- The pressure of the ice was less here than farther down, where the narrowing of the river resulted in ice build-ups that could reach a height of 9 metres.
- The site was close to the port, as well as to warehouses, factories and manpower.
- The train yards and buildings could easily be expanded.
- The site was away from the route taken by tall-masted sailing ships, while the Lachine Canal made it possible to reroute maritime traffic toward Upper Canada.
- Around Point St. Charles the bridge would not need to be elevated, since it would be high enough to allow steamboats to go down the Lachine Rapids.

Page 3.3 / Sub-Theme 3.3 The challenges posed by construction

Page 3.3.1 / Chapter 3.3.1 The first stone is laid…

The firm of Peto, Brassey and Petts appointed James Hodges as main agent and chief engineer, in addition to making him responsible for manpower. Much admired for his leadership abilities, he was considered the only one capable of bringing a project of this size to term. He would have to oversee more than 3000 individuals on the site for the entire length of the project. In the winter of 1853-1854, after the concept had been worked out, he marked out the distances between abutments and piers directly on the ice, then sunk metal rods (attached by chains to buoys) into the river bottom. After the thaw, it was very easy to locate the positions of the future piers. The first stone, which came from the Kahnawake quarry, was laid to the north of the abutment on July 20, 1854, and the ceremony celebrated on July 22.

During the period of his mandate, Hodges devised an ingenious derrick system that made it possible to lift and transport the stones for the piers. This system would be left in place once the bridge was finished, to facilitate maintenance and painting. An innovative engineer by the name of Chaffey developed steam-driven cranes that would change construction methods and speed up the work.

Page 3.3.2 / Chapter 3.3.2 The piers

The construction of piers, which had to be placed with remarkable precision, required the development of new methods for dealing with currents and clearing the river bed of large stones. Taking, as his point of departure, one of Keefer's early proposals for wooden ice breakers, Ross devised ice breakers that could be incorporated into the stone piers. The sharp edges of the stones cut through the moving ice, the pieces of which then flowed by on either side of the pier.

To drain the river bed, an innovative solution was adopted using floating coffer dams that offered little resistance to the currents. Each of these had a sort of "box" in the centre. One the water was pumped off, one had only to remove obstacles from the river bed and raise the piers. Three additional coffer dams made it possible to build several piers at the same time. English engineers discovered and adapted these structures, which were already widely used throughout Canada in the construction of bridges, dams, wharves and foundations.

Page 3.3.3 / Chapter 3.3.3 The superstructure

The construction of the superstructure began in the spring of 1857. Crews worked from both banks toward the central span, while the task of raising piers continued through to the fall of 1859. The steel used in the bridge came from several foundries in Great Britain. Lower Canada's meagre supplies of coal and iron ore were not sufficient for steel making. Thus the primary products had to be imported.

The steel was rolled and puddled in the Birkenhead factories. Each sheet was rolled into sections and numbered in keeping with the blueprints, before being shipped to Canada. Each span was made up of about 5 000 parts and nearly a half-million rivets. British manufacturing methods were so precise that the parts fit together perfectly after only minor adjustments.

Page 3.3.4 / Chapter 3.3.4 A seasonal job

The construction of the bridge construction was seasonal work, and only a handful of tasks could be carried out year round. These included cutting stones, supplying wood, taking soundings and sinking caissons, which could be done even through the ice. In 1858-1859, however, work continued through the winter in order to meet the project deadline. Crews worked on both ends of the bridge at the same time. In fact, the Grand Trunk offered entrepreneurs a bonus of £60 000 if the bridge were completed in 1859 instead of in 1860. Thus one can easily understand why the central span was finished and in place in the winter of 1859, just before the ice began to break up!

The Victoria Bridge differed from the Britannia and Conway bridges in two major ways. First of all, the rigidity of the roof was provided by layers of thin plates riveted together. In another innovation, the rivets were not hammered but drilled in, a task requiring five-man teams composed of two riveters, a porter and two young assistants). Each team could sink up to 180 rivets per day.

Pier pit excavation was the most dangerous job, since flooding could occur at any moment. Twenty-six workers lost their lives over a six-year period, mainly by drowning in the river's whirlpools.

The final span was laid on December 12, 1859, and the bridge opened five days later. To celebrate this achievement, a banquet was held on the longest bridge in the world.

Page 3.4 / Sub-Theme 3.4 Let the party begin!

Page 3.4.1 / Chapter 3.4.1 A memorable inauguration

The inauguration of the bridge was an event of national importance, made all the more significant by the fact that the Prince of Wales, the son of Queen Victoria, presided over the ceremony. In a joyful and festive atmosphere the population welcomed the Prince in St. John's, Newfoundland on July 23, 1860. This marked the beginning of a series of official activities that led him first to Quebec City and then to Montreal, where he arrived on August 24.

The following day, after a ceremonial procession from the landing dock to the Crystal Palace, the prince was escorted to the bridge where a delighted James Hodges presented him with a wooden mallet and a silver trowel. In a symbolic gesture, the Prince flattened mortar around the final stone and then proceeded to the centre of the bridge where he secured the last rivet. The bridge was then officially finished and bore the name of the Queen Mother, Victoria. In his inaugural speech, the prince stressed the greatness of the event and did not hesitate to compare the bridge to the splendours of Rome and Egypt. For him and his contemporaries, the bridge was worthy of being known as the eighth wonder of the world, having surpassed other structures by virtue of the challenges that had to be met to build it.

Page 3.4.2 / Chapter 3.4.2 The festivities

A banquet was then prepared in one of the company's barracks, which had been decorated for the event. That same evening, the skies over Montreal were lit up by fireworks projected along the bridge's entire span and from Île Sainte-Hélène. On August 27, 6 000 people showed up to a gala citizen's ball. The ball was such a success that a second one was organized for the following night. On August 28, a huge concert drew an audience of 8 000. The next day, the prince was regaled with a canoe trip. This was followed by a regatta on the Lachine Rapids.

Banquets, balls and fireworks followed one upon the other, showing the extent to which the achievement represented by this bridge's construction had impressed itself upon people's minds. It even inspired musical compositions that were published and distributed, mazurkas and polkas that celebrated the incredible structure.

In 1859, the Victoria Bridge was already considered to be the eighth wonder of the world and a masterpiece of engineering. It was a technological marvel that Montreal and its inhabitants, as well as the region and the country as a whole, were to benefit from. On August 31, the Prince of Wales left Montreal en route to Ottawa, Toronto, Niagara and Hamilton, before going on to the United States.

Page 3.4.2 / Chapter 3.4.2 A turning point

The Victoria Bridge stirred people's imaginations; they could now envision new ways of spanning the river. During this period, it was still widely held that any idea that a bridge might be built over the St. Lawrence at Quebec City was nothing more than a pipe dream, given the nature of the terrain. But the engineering exploit represented by the Victoria Bridge was very real indeed. Tests confirmed its solidity and resistance to vibrations as a train was driven over it at different speeds.

The opening of the port stimulated industrial growth. The metallurgical sector made notable progress, so much so that in 1861 it comprised 12 foundries, mechanic's workshops and mechanical manufacturing installations employing nearly 700 people – in addition, that is, to those working for the Grand Trunk. In 1971, more than 2 000 people worked in this sector. Rail transportation facilitated the development of new industries, like the lumber industry, and sped up the production of consumer goods, tobacco, textiles and clothing. More mines and quarries could be operated and connected to major cities like Montreal. Even if rural areas lagged behind, they still felt the impact of all this change.

Page 3.5 / Sub-Theme 3.5 A considerable heritage

Page 3.5.1 / Chapter 3.5.1 A huge undertaking

Countless 19th-century prints and photographs convey people's fascination with the Victoria Bridge. This symbol of modernity contributed to the growth of Montreal and the surrounding area, and breathed new life into industry throughout the country.

Works on the scale of the Victoria Bridge also exerted considerable influence on the practice of engineering as a whole. Stephenson and Fairbairn had experimented with materials that had never been used, yet proved to be very innovative. This taste for exploration was also encouraged my most engineers. By using techniques derived from other forms of construction, and particularly from Fairbairn's ship building experience, these men and all those who assisted them made it possible to build extensive structures. Thus the principles articulated in the construction first of the Menai Straits tubular bridge and then of the Victoria Bridge enabled engineers to come up with a more rational approach to structural design.

Page 3.5.2 / Chapter 3.5.2 A job well done

After its opening, the Victoria Bridge continued to enjoy the same popularity it had known throughout its construction, thereby attesting to the incredible admiration elicited by this gigantic achievement. In spite of this, however, the tubular structure would eventually lose its status as the style of choice for railway bridges. Because of the extraordinary quantities of material it required and its exorbitant costs, which promoters deemed prohibitive, it lost favour as a viable solution. There was a change in attitudes and ways of thinking with respect to the amounts of funding that could reasonably be allotted for such structures. During the decade of intensive experimentation that began with the construction of the Britannia Bridge in 1850 and ended with that of the Victoria Bridge in 1860, governments and business cut back on spending. Also, with the death of Stephenson the tubular structure was soon forgotten, eclipsed by more economical structures. The beam bridge, and particularly the trellis bridge, soon held the field.

Page 3.5.3 / Chapter 3.5.3 Time and tide

By 1897 the Victoria Bridge had withstood heavy rail traffic for nearly 40 years. Still, it did present numerous drawbacks: its limited load-bearing capacity and its narrow tubes did not allow it to accommodate larger trains. Moreover, its single deck was suitable for only one train at a time, which proved an impediment as traffic became heavier. Another major handicap was that the bridge remained inaccessible to motor vehicles and pedestrians. Moreover, the interior of the tube was hot and smoky, the metal structure having been corroded by sulphurous fumes and salt.

For Queen Victoria's Diamond Jubilee in 1897, the tube was replaced by the Howe trellis system we know today. Only the piers remain, and these were broadened near the top to support the new structure. The bridge was adapted to the growing needs of rail traffic and to new means of urban transportation. The deck was widened and outfitted with two side-by-side rail lines capable of accommodating heavier traffic and larger, heavier trains. Two new lanes were opened, one on each side of the bridge. One of these was for the streetcar connecting Montreal with the South shore, while the other was for automobile traffic.

Page 3.5.4 / Chapter 3.5.4 A memory worth preserving

The Victoria Bridge is a major feature of the city and one of the numerous motor vehicle lanes joining the Island of Montreal to the mainland. In the 20th century, other bridges were built to absorb the rapidly increasing flow of traffic. The Jacques Cartier Bridge was opened in 1930, and the Champlain Bridge in 1962, not to mention all the other bridges surrounding the island.

The look of the Victoria Bridge has changed considerably since the late 19th century. On the south shore side, the opening of the St. Lawrence Seaway required the construction of locks to allow ships to pass. This task involved dividing the access ramp to the bridge into two, again changing the bridge's appearance. On the Montreal side, the use of landfill made it possible to open a highway under the bridge. All of these things together made the river narrower and, in the process, tamer.

For some people the Victoria Bridge is the historical representative of an age characterized by technical prowess, and ranks among the greatest innovations of the 19th century, to the point that it can lay claim to being the eighth wonder of the world. It is still undeniably one of the jewels of railway architecture, a precious inheritance from the heydays of the railroad.

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