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The Lamar Boulevard Bridge crosses Colorado River (Lady Bird Lake) in Austin, Texas. Completed in 1943, this bridge was notable for being built during World War II despite steel shortages. The crossing was considered essential to defense operations and thus the reinforcing steel for this reinforced concrete bridge was approved for use in this bridge. *Photo by Nathan Holth.*

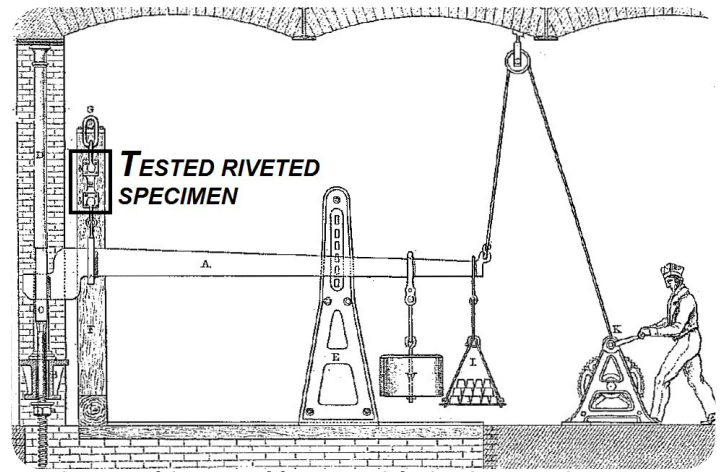
Unraveling the Design of Structural Riveted Connections: A Review of European Literature

By Quentin Collette, PhD

The appraisal of existing riveted metal structures generally involves the understanding of their connection details. Unfortunately, it is tough to decipher how historical riveted connections were designed given the obsolescence of the hot-riveting technique. The design of riveted connections has to be investigated to support the structural assessment and potential repair interventions. Engineers, architects, and historic preservation specialists need to gain insight into the original design philosophy of the connection details to preserve both the service life and heritage value of iron and steel bridge structures. This paper reveals the design philosophy of structural riveted connections of the end of the nineteenth century based on literature published in Europe.

Current knowledge on the structural behavior of riveted connections results from the genesis and progressive evolution of the theory of riveted connections that occurred during the two past centuries. In the 1830-40s, the prominent experiments performed by William Fairbairn and Edwin Clark in the UK laid the foundations of the theory of riveted connections, which in turn influenced engineers and theoreticians on an international scale for decades (Fig. 1). The large amount of experiments that were subsequently carried out underlines the intense desire of 19th and 20th-century investigators to get a clear insight into the structural behavior of riveted connections and their failure modes. The results of those experiments characterizing the behavior of riveted connections at ultimate were prerequisites necessary to their design.

The evolution of the design methods of riveted connections is characterized by a balance of power between science and technique. The technique—riveting teams' experience and practices in the shop/on the job site—conditioned first the design philosophy formulated by engineers and



Testing machine used by W. Fairbairn in 1838 in a 5-story-high building to carry out an extensive shear tests campaign. Adapted from Fairbairn, 1850.

theoreticians. Over a period of almost 100 years (1850s–1940s), technique progressively interacted with science—experimental results, ultimate strengths—to develop more accurate methods that were the forerunner of today's standards.

The design of a riveted connection involves a large number of parameters dealing with geometry, strength, and applied loads. Those parameters were not, however, simultaneously taken into account within the evolution of the design methods. Prior to the 1880s, the design of riveted connections resulted merely from geometrical considerations. Parameters needed in a design such as the rivet shank diameter d , the number of rivets n and the rivet pattern were empirically deduced. A major change in design philosophy occurred at the end of the 19th century. From the 1880s onwards, the design involved the geometry, the strength, and the applied loads. The load-bearing capacity of the rivets was eventually related to the magnitude of the applied loads. The rivet shank diameter d was, however, still deduced by using the empirical formulas peculiar to the period prior to the 1880s. End-of-the-19th-century design methods are delicate to assess since they combine the introduction of more accurate theoretical insights with the use of older commonly used statements and their inconsistencies.

Louis Lemaître's empirical formula

Between the 1840s and 1870s, the design of structural riveted connections was based on the methods peculiar to the field of industry that had introduced the hot-riveting technique, namely

ÉPAISSEUR DES TOLES en millimètres.	DIAMÈTRE DU CORPS DES RIVETS en millimètres.	ÉCARTEMENT DE CENTRE EN CENTRE en millimètres.
1	4.5	20
2	6.5	22.5
3	8.0	25
4	10.0	27
5	12.0	30
6	14.0	35
7	16.0	40
8	18.0	45
9	19.0	50
10	20.0	52.5
11	21.0	55
12	22.0	57.5
13	23.0	60
14	24.0	62.5
15	25.0	65
16	26.0	67.5
17	27.0	70
18	28.0	72.5
19	29.0	75
20	30.0	77.5

French boilermaker Lemaître broke new ground in 1856 with his design table providing the rivet shank diameter (center) and rivet pitch (right) based on the plate thickness (left). Source: L. Lemaître, 1856.

boilerwork. Boilerwork had laid the foundation for the traditional craftsmanship of hot riveting. The technical know-how had been successively handed down from one boilermaker to another. The design resulted solely on the experience of a given boilermaker. Rules of thumb became publicly spread through the publication of some manuals from the 1840s onwards, such as the *manuels Roret*. Riveting practices and techniques of renowned boilermakers had a powerful impact on the design of riveted connections, as experience was synonymous with reliability.

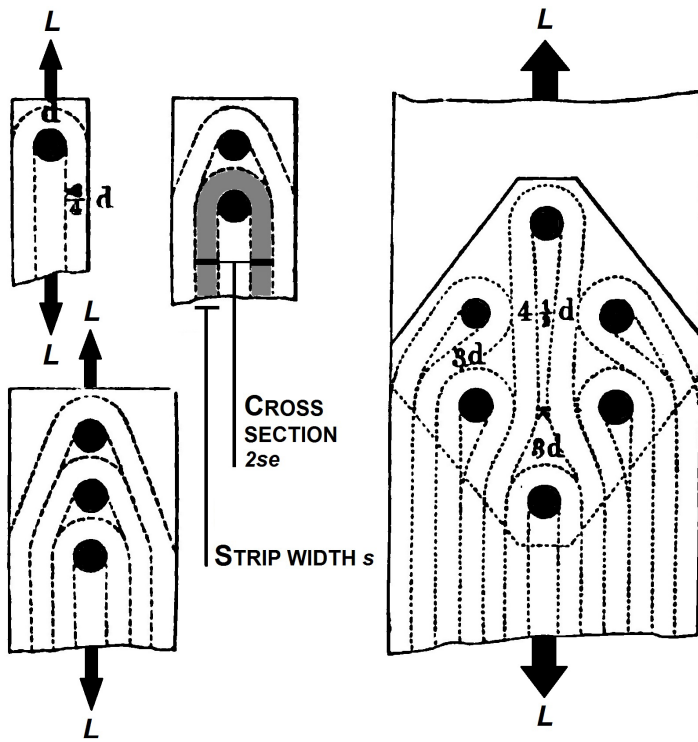
In 1856, the French boilermaker Louis Lemaître from *La Chapelle-Saint-Denis* near Paris published a design table that provided the rivet shank diameter and rivet pitch to be adopted for a range of plate thicknesses (Fig. 2). The rivet pitch is the distance between the axes of two adjoining rivets. By publishing the proportions of riveted connections

he commonly used in his shop, Lemaître marked an important milestone within the evolution of the design methods of iron and steel riveted connections.

The widespread use of Lemaître's rules of thumb was possible thanks to the mathematical translation made by Aîné Armengaud the following year in 1857. Based on Lemaître's table, Armengaud suggested an empirical formula for the rivet shank diameter d that was valid for any plate thickness e (Eqn. 1). This relationship better known as *Lemaître's empirical formula* predominantly influenced educator-engineers and theoreticians of the decades that followed.

$$d = 1,5e + 4 \text{ [mm]} \quad (\text{Eqn. 1})$$

In a design, the plate thickness e was the starting point of the whole geometry of riveted connections. It allowed for defining the rivet shank diameter d through the d/e ratio, which can be derived from



Schwedler simplified the shear behavior of riveted connections by conceptually subdividing their plates into several strips surrounding each a rivet. Adapted from J.W. Schwedler, 1867.

equation 1. In turn, the rivet shank diameter d was the geometrical parameter that prevalently conditioned the pattern of the rivets from the 1840s onwards, and allowable loads calculations from the 1880s onwards. The d/e ratio was a convenient pre-design criterion that fundamentally influenced all the design methods of riveted connections between the 1840s and 1940s.

Johann Wilhelm Schwedler's method: towards an analytical approach

The philosophy of end-of-the-19th-century design methods was primarily analytical, the allowable stress design model was effectively implemented, and the number of rivets needed per force transmission n was calculated. Paradoxically, these methods were combined with simple derivations related to the rivets pattern. The theory of the German engineer Johann Wilhelm Schwedler was one of those derivations commonly used from the 1880s onwards.

Schwedler broke new ground with his semi-analytical approach to design riveted connections. Published in the issues N°47 and 48 of the *Wochenblatt herausgegeben von Mitgliedern des*

Architekten - Vereins zu Berlin in November 1867, Schwedler's discussions dealt with the structural behavior of riveted connections—friction and shear, the joining typologies as well as the rivets pattern. His analyses laid the foundation of numerous subsequent theoretical investigations, even up to the 1940s. Unfortunately, the theoretical inaccuracies and simplifying assumptions inherent to the semi-analytical design methods formulated by the end of the 1860s—like the one of Schwedler—contributed to hold up further progress for a long time.

Until the beginning of the 20th century, numerous educator-engineers, among others, referred to the convenient theory developed by Schwedler to arrange rivets. Schwedler's theory relied on an easy-to-use graphical method that defined the pattern and spacing of the rivets by means of geometrical considerations. He conceptually subdivided the plates of a connection into several strips of equal width s . Each strip had a loop that surrounded each one rivet (Fig. 3). Schwedler assumed a uniform distribution of the loads within the strips and that the joint behaved in pure shear.

Schwedler's principle belonged to the category of semi-analytical design approaches based on the method of equivalent bearing areas. It presumed that the allowable tensile load of a strip was equaled to the allowable shear load of the rivet it surrounded. Because of theoretical inconsistencies dealing with the shear-tension ratio, the strip width s depended solely on geometrical parameters, that is, the d/e ratio.

End-of-the-19th-century design methods improved the design philosophy of riveted connections but revived at the same time inappropriate reasoning by referring to the past theories of the end of the 1860s.

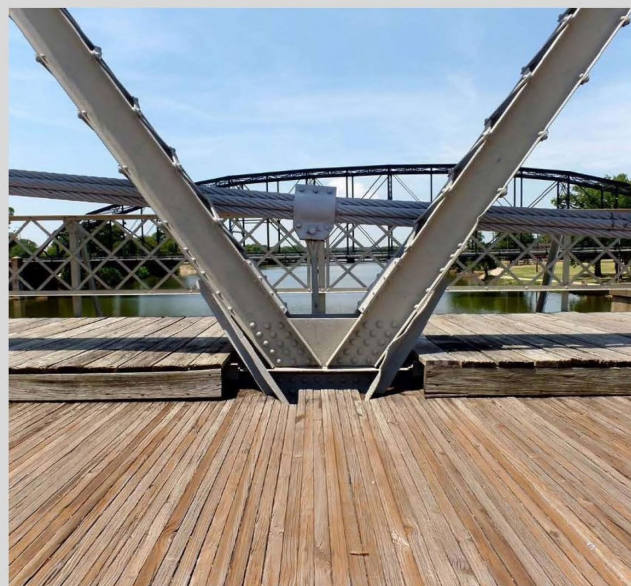
The study of historical design methods allows engineers to perform overall appraisal procedures of existing riveted structures with more confidence and can contribute towards more suitable remedial works.

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- Panel Discussion

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Muskoka's Diverse Bridges Connect Far More Than Land

By J. Patrick Boyer

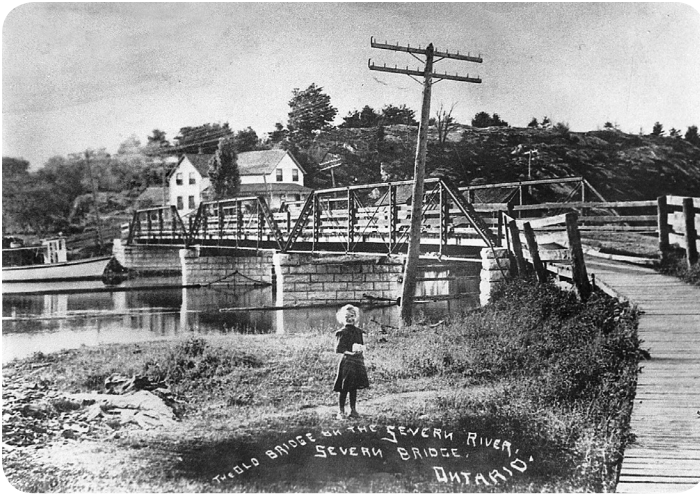
Muskoka's modern history began in 1858 with a basic beam bridge. Spanning the Severn River, it carried the Muskoka Colonization Road over the District's southern frontier into land where Indigenous people lived long before pyramids were built in Egypt.

Pushing north through untouched wilderness, this winding, hilly, crude "Muskoka Road" would be the most successful of 22 such routes by which Ontario's provincial government sought to open its northern wilderness for development. It became the main street of today's Gravenhurst, Bracebridge, and Huntsville towns, and many villages. Provincial, township, and private roads spread out from, or linked up with, this spinal route, as first homesteaders and latter vacationers (including American notables such as Woodrow Wilson) arrived. By the 1920s, construction of the Ferguson Highway (begun by

Premier Howard Ferguson into the far northland, and what is today Highway 11) shadowed the essential pathway of the Muskoka Road. And always, as the Severn proved from the outset, such road building over the Canadian Shield's rugged landscape and irregular watersheds depended on bridges.

In this small but far-famed District, from the 1850s to 2020, from Bala village on Muskoka's southwest to Dorset village at its northeast, from wood and stone to concrete slab and iron, from floating bridges to prefabricated ones, from single-lane to multi-use, Muskoka's bridges clear chasms and waterways. They expand freedom, save time, and serve as identifiable landmarks. As snapshot freeze-frames, they display successive eras' engineering skills, construction materials, and cultural values.

Including that first bridge across the Severn River, the basic design of Muskoka's early wooden bridges, using logs and stone-filled cribs, was the simple "beam" structure—a horizontal stringer or beam supported at each end by a vertical pier or abutment. Suited to short distances, they could also bridge wider spaces by using a series of beams supported



By 1896 the fourth bridge to span the Severn River into Muskoka was this steel truss bridge, with plank sidewalk. Muskoka Colonization Road historian Lee Ann Eckhardt Smith noted that, with Severn Bridge's largest employer a sawmill on the south bank, while James Jackson's general store and the school were on the north, "there was a lot of pedestrian traffic on this bridge." *Photo courtesy Muskoka Discovery Center Archives, Gravenhurst.*

on a number of piers, provided piers could be built on solid underwater surfaces that were shallow enough. This was the case for the first bridge across the Muskoka River at the top of North Falls, a central settlement that became Muskoka's capital. Despite fine construction, the bridges of ideally named "North Falls" got a bad rap when a distant Post Office official bizarrely, and unilaterally, renamed the village "Bracebridge."

Across Muskoka, as elsewhere, "truss" bridges came into vogue with the Industrial Revolution's possibilities of iron, steel, cables, meshwork, and reinforced concrete. A truss, usually some variant of a triangle, is a rigid form that transfers load throughout the bridge by working variations on the beam structure, with enhanced reinforcements. Trusses handle both tension and compression, with the diagonal ones (for instance, supporting the deck) in tension, and the vertical ones (holding the structure in place) in compression.

Beam and truss bridges represent major differences from arch bridges, which evolved from Roman times, and support load by distributing compression across and down the arch.

Engineered variations on beam, truss, and arch bridges have safely carried most loads in Muskoka since colonization began 160 years ago.



By 1930 the structure which gave its surrounding community the name "Severn Bridge" had yet again taken new form. Seen from the rocky ridge along the Severn's north bank, this southerly view shows the Age of the Automobile taking firm hold. The silo-like chimney was for the sawdust burner at the Mickle-Dymont sawmill. *Photo courtesy Muskoka Discovery Center Archives, Gravenhurst.*

The Bridge on Stephenson Road East

Roads running east and west from Muskoka's south-north colonization road helped homesteaders penetrate township interiors, claim free land, and start farming. Ontario offered free land to homesteaders in Muskoka in the same decade that Abraham Lincoln was elected president, promoting his Republican policy of land grants by urging electors to "Vote yourself a farm!"

Stephenson, one of Muskoka's larger original 22 townships with 40,000 acres of land and 3,000 of water, including scenic Mary Lake, is a good place to start talking about bridges because it's named for Robert Stephenson, one of the world's best bridge engineers. Among Stephenson's many ingenious structures was his 2-mile long tubular "Victoria Bridge" over the St. Lawrence River at Montreal, which for years was longest in the world.

Heading east from the Muskoka Road, the Stephenson Road (along the concession line with neighboring Macaulay Township) opened the township's rewarding interior to pioneers. In 1875 a wooden bridge thrown across the north Muskoka River enabled settlers to advance further. The two-span structure, with a mid-river pier and crib abutments on each bank, was dubbed "McCamus Bridge" for nearby homesteader James McCamus who had actively promoted its construction. The



This photo shows the 1892 bridge in Stephenson Township in 2015 before being replaced. *Photo by Nathan Holth.*

bridge quickly proved its value for land development; within three years road-builder W. Chalmers extended the Stephenson Road seven more miles east, at \$145 a mile.

Further upstream, settlers petitioned in 1876 for a road between Port Sydney and the Stephenson Township line. When the government stalled, they built themselves a floating bridge south of the second concession road to link other farms which the river bisected, since surveyors had not adopted natural boundaries when imposing their grid of lots upon the landscape. The bridge's huge pine logs supported heavy loads. Hinged ramps at each bank allowed the main section to rise or fall with seasonal water levels. In 1896 township council sought funds for a permanent bridge here, but with still no money from the province, the floating bridge continued its durable service into the 1920s.

As for McCamus Bridge, in 1921 a span fell away from its riverbank crib, creating a need to replace the 1875 wood structure just as one in nearby Bracebridge became surplus. The town's two-span pin-trussed iron bridge had crossed the same river, further downstream, since 1892 when the original wood beam bridge (that one with its mid-channel crib on bedrock) had been replaced by this iron one. After three decades of heavy and increasing use as the only river crossing for growing Bracebridge, council slated the 1892 bridge at the head of falls by Henry Bird's woollen mill for replacement. To prepare the site, the 1892 structure was detached, lifted aside by crane, and parked on the nearest flat land: lumberman George Tennant's lumber yard. Bracebridge's new

bridge was lowered into position and riveted down in February 1922. That spring its temporary wood planking was replaced by cement and the bridge's superstructure painted, just in time to harden and dry, respectively, for a May 23 opening ceremony.

Having a used bridge obstruct his lumber yard led Tennant to contract with the municipalities to move the iron sections of the used 1892 bridge to the Stephenson-Macaulay township line, where it was actually needed. Thus the two-span bridge, reassembled, continued in service over the same river, just several miles upstream.

This double service extended the 1892 structure's life, but in 2016 an entirely new bridge replaced it. The contemporary single-span steel crossing rests on concrete abutments, fortified against erosion, at each bank. Its 45-meter (roughly 147 foot) length accommodates two divided traffic lanes with planked surfaces. A stone cairn incorporates photographs of the two prior bridges at this locale, a welcome respectful nod to history.

Deciding to build anew was a joint decision of Huntsville and Bracebridge, since township amalgamations for District Government in 1971 made Stephenson Road the boundary between the two enlarged towns. On May 26, 2017 Ontario Premier Kathleen Wynne officiated at the bridge with mayors Scott Aitchison and Graydon Smith to mark its completion and celebrate intergovernmental partnering. The province contributed \$1.1 million, funding contingent on both environmental and heritage preservation studies.

The 1892 iron bridge did not, according to independent on-site evaluation by Nathan Holth, who maintains the website HistoricBridges.org, suffer intrinsic failings. It could, he reported, have continued in service by remedying one flawed coupling that caused twisting. Alternatively, it could have been relocated, as a similarly rare truss historic bridge of this design and vintage recently was in Michigan, for pedestrian use across a walking trail gully. However, despite its rarity, this 1892 specimen was destroyed. "This beautiful historic truss could have been preserved," Holth concluded, but became "a victim of bad abutments and a lack of local appreciation."

The only river crossing between Port Sydney and High Falls, this Stephenson Road Bridge crosses the north branch between River Valley Drive and Balsam

Chutes Road, uniquely tying together the many-layered saga of Muskoka bridges, from earliest to most recent.

Dorset's well-travelled single lane bridge

Dorset, like several other “Muskoka” border communities, is not entirely in the District. Its Haliburton half begins along the main street's center line. The village's mixed identity also owes something to name changes—from Cedar Narrows (an English translation of the locale's Ojibwe name), to Colebridge (instituted by colorful pioneer Zachariah Cole in his own honor), then next Dorset (as again revised by nostalgic settlers from southwest England.)

In any case, fur-trading oriented the settlement toward Lake of Bays, along whose shoreline Dorset nestles on a natural channel between aptly named Big Trading Bay and Little Trading Bay. In 1859 the Bobcaygeon Road, another of the province's colonization roads, reached the Cedar Narrows channel, over which the road-builders first placed a floating bridge. Zach Cole, one of the road surveyors, saw the area's potential and, returning in 1862 from the United States where he had raised funds, began fur trading with the Chippewas. He also started a farm, established a brick yard, and operated a still in order to swap liquor for fur. Then Cole changed the place's name and, in line with his expansionist vision, built a bridge more substantial than the floating one.

Shortly before the First World War, Cole's wooden bridge was replaced by a Warren pony truss structure manufactured by Western Bridge and Equipment Company of Chatham, set on a concrete base. During the war its wood plank deck was upgraded to

concrete. After the war, iron railings and a pedestrian sidewalk were added.

A “by-pass” bridge was built by Ontario's Department of Highways in 1957. In that decade many Muskoka communities, like towns across prospering North America, were getting this by-pass treatment to alleviate the booming postwar traffic congestion. Vacationers with cars turned the main streets of Muskoka towns and villages into summertime parking lots. The 1957 structure (seen in this picture beyond the “Downtown” arch bridge) became known locally as the “new bridge.” Another crossing, the Paint Lake Bridge, built along the line of a natural animal crossing, was for some time a humped structure like the Downtown Bridge. But in 1940, instead of resorting to traffic lights, which were developing but still uncommon in Ontario, the municipal government simply flattened its roadbed.

However, the “Downtown” Dorset bridge's unusual hump-back design remains intact. Providing greater clearance for boats, this alternative to swing or lift bridges shows the advantage of an arch bridge. Its metal 6-panel rivet-connected truss is fixed, as are the multi-beam metal stringer approach spans. With the constant increase of automobiles, the bridge's central rise still required drivers to gamble when starting across, often creating awkward summer traffic jams. But without changing the artful bridge, cars are instead efficiently metered onto its single lane by traffic lights at either end. Snowmobiling is banned year-round. Pedestrians can cross while maintaining social distance.

The Black Bridge on Matthiasville Road

Draper Township's 1870s pioneer settlement of Matthiasville, east of the Muskoka Road at a turbulent chute on the Muskoka River's south branch, boasted a miller, storekeeper, blacksmith, carpenter, cobbler, preacher, and land developer—all embodied in one man, William Matthias.

This high-achiever built a dike alongside the river above the falls, diverting water into a mill race to power his sawmill and gristmill. He constructed a village church for Protestant use, erected a splendid octagonal home for his family, and in 1880 filed subdivision plans for Matthiasville in the Bracebridge Registry Office, the village's name having been proposed by John Classon Miller, a lumber



The bridge at Dorset. *Photo by Tomasz Szumski.*

merchant and Muskoka's MPP at the time. Never idle, William Matthias also opened a black-smithy, ran a shoemaker's shop, and operated a general store. By the late 1890s he employed a dozen men in his sawmill, producing 10,000 feet of lumber daily, while his son Samuel ran the mills as a woodworking business and feed-chopping enterprise.

In 1870 at the start of it all, William had built a wooden kingpost truss bridge over the South Muskoka River, making his settlement the all-important crossing point in this region. His original wood crossing was replaced by an iron bridge at the top of the falls around 1922. That year, a second bridge was constructed further downstream, at a southerly bend in the meandering river, supported by concrete abutments on each bank. This 120-foot single-span steel through-truss bridge, of the Pratt design, was a metal 6-panel rivet-connected structure.

By 1949 most Muskoka waterfalls had been harnessed, but not that of Matthiasville, so here the Orillia Water Light & Power Commission built a million dollar hydroelectric plant. The huge 882-foot wide dam spanned the valley near the top of Matthias Falls and back-flooded a new lake for two miles upstream, drowning the historic village. The Commission had first purchased, dismantled, and relocated some of the buildings. As for the bridge, Gary Long, acknowledged authority on the Muskoka River, notes



This iron Matthiasville bridge (seen against the horizon) over the south branch of the Muskoka River dates from the 1920s. It supplanted an 1870 log bridge and served until the late 1940s, when the entire community was flooded behind a dam built by Orillia's Power Commission to generate electricity. Reading by the river is the brother-in-law of pioneer William Matthias. Photo courtesy Boyer Family Archives, Bracebridge.



The Matthiasville Road Bridge.

Photo by Tomasz Szumski.

that the bridge at Matthiasville near the top of the falls remained in operation “until the Orillia power development was built, at which time a new concrete bridge was built lower down the falls, just upstream of the powerhouse.”

Downstream, the 1922 bridge, long a light color, was in time painted black to blend more harmoniously into its scenic setting. It became known to locals as “the black bridge,” to differentiate it from Matthiasville Bridge. By 2016 Bracebridge engineers reported it unsafe; bubbling black paint even revealed its lighter undercoat. Replacing the bridge required an environmental impact study, consultation with locals on historic considerations, and Bracebridge pitching senior levels of government to split its projected \$2.5 million cost. The new bowstring truss bridge will replicate the former's single-span, one-lane design, use part of one 1922 abutment plus a deep pile foundation on the river's north bank, and footings keyed into the south bank's bedrock. The deck's surface is slated to be concrete, with a dedicated walkway for pedestrians incorporated on the downstream side.

The main historical input was to keep what people knew and liked—the general appearance of the 1922 bridge. Also, perhaps an upgrade from being named for a paint color, once built this new bridge could be called “Matthias Bridge” to honor the pioneering Muskokan whose life caused a road through this area to be built in the first place.

Bracebridge's prominent “Silver Bridge”

In 1861, when Muskoka Road contractors reached “North Falls” on the Muskoka River's north branch,



The narrowest crossing at Bracebridge was at the top of the falls, where a felled white pine served as a walkway. In this same location, by 1872, the north branch of the Muskoka River was bridged by this log beam structure, using cribs on both banks and atop bedrock midstream. Henry Bird built his woollen mill, seen here, when water-power drove industry. A bridge at this location still serves today for the town's Entrance Drive. Photo courtesy Boyer Family Archives, Bracebridge.

the easiest place to bridge was the narrowest—at the top of the falls. Three rock-filled log piers—one atop a midstream rock outcropping, the others on each bank—supported its wood beam flooring and side rails. In 1892 it was replaced by another two-span bridge, manufactured by the Central Iron Bridge Company of Peterborough, for which the town paid \$400, the Crown Lands Department, \$2,000. In 1893 the town made the contractor rebuild its faulty foundations.

In 1923 Howard Ferguson, an ardent proponent of Northern development, became Ontario's premier and soon the "Ferguson Highway" from Toronto to Cochrane was a major project. In Muskoka the highway tracked, where it could, the original colonization road. But in Bracebridge, as Lee Ann Smith explains in *Muskoka's Main Street*, the authoritative work on the Muskoka Road, it was "far too hilly and crooked to be part of a modern highway."

Government surveyors found a better route for reaching Bracebridge's main street by crossing the mouth of the Muskoka River's south branch, curving alongside the north branch to Bracebridge Bay's Kelvin Grove Park, edging past a dominating rock-face, and crossing the falls just downstream from the town's existing colonization and railway bridges. In 1929 town council approved plans for this gentler and

more scenic entrance which would also bypass two level railway crossings, important with that era's high frequency of trains.

In 1930, after council expropriated land needed for the Ferguson Highway, including the fine home of Dr. J.F. Godson at Ontario and Manitoba streets which had survived a devastating town dynamite explosion in 1906 only to now be demolished for the new highway, engineer Kenneth Rose of Ontario's Northern Development Department hired local laborers to clear the right-of-way for the alternate town entrance. William Lowe took charge of building a bridge over the south branch, while Birmingham & Sons of Kingston won the contract for the \$10,000 steel falls bridge, retention walls, and roadwork.

Work proceeded for a full year on this Pennsylvania-style through-truss bridge, its trusses joined across their top and its ten panels rivet-connected. In August 1930, grading through Kelvin Grove Park had been finished, one span of the bridge was in place, and a light railway on the new roadbed carried away blasted rock. Twelve months and another 10,000 rivets later, the superstructure was together, the cement flooring poured, two coats of paint applied, and new sidewalks completed. Electric lights on the bridge and its approaches highlighted Bracebridge Bay's new centerpiece, a crown atop the cascading falls. These small electric lights (in some eras, many-colored;



The narrowest crossing at Bracebridge was at the top of the falls, where a felled white pine served as a walkway. In this same location, by 1872, the north branch of the Muskoka River was bridged by this log beam structure, using cribs on both banks and atop bedrock midstream. Henry Bird built his woollen mill, seen here, when water-power drove industry. A bridge at this location still serves today for the town's Entrance Drive. Photo courtesy Boyer Family Archives, Bracebridge.

other times, white) have spread gentle enchantment into night-time darkness for generations.

Port Carling's two main streets and its moving bridges

Just when things might have normalized, Muskoka's bridges had to adjust to the Steam Era's revolution. Steamships traversing highways of water and traffic proceeding over land needed bridges engineered to enable them to cross paths.

In 1872, a swing-bridge and locks were put into service at Port Carling to allow movement of water and land traffic where river and road intersected. Apart from being functional, this transportation service provided onlookers with a fascinating drama in the heart of the village. Many times a day throughout navigation season, the bridge and the lock's gates swung open and closed, moved by the muscle-power of two men, usually the lock master and his assistant, as they alternated the traffics' turns to advance.

Such heavy moving pieces and their gears require continuous attention and intermittent changes. In 1902 and 1903 the lock was enlarged to accommodate longer steamships. In 1909 the lock gates needed replacement. When new oak ones were installed, the old waterlogged gates were safely hauled to deep water and sunk for convenient disposal, though some gullible onlookers believed the

public works superintendent who explained it was "to have them on hand in case of accident to the new gates." The second set of locks, for smaller boats, also required a second bridge.

But bridges themselves also need replacement. During 1921-1922, in the course of yet another major reconstruction of the locks, a better engineered swing-bridge was mounted on a round concrete base. The large amount of steel needed was delivered to Bala by train, transported to Port Carling over winter ice by teams and sleighs, and then, in an era before cranes, hoisted into place using a derrick pole.

There is also more than one way to shift a bridge so a ship can pass; what goes sideways might instead rise up. In 1973-74 the next replacement of Port Carling's main street swing bridge was a bascule bridge which, from the French for seesaw, means it rotates upwards. Several riverside buildings had to be demolished for the extra space needed. In the bargain, motors replaced muscle power to open and close the lock's gates, and to raise and lower the bridge. The first vessel requiring the bascule bridge to perform, on September 12, 1975, was *Lady Muskoka* out of Bracebridge.

With water navigation and road transport so important to life in Muskoka, maintaining and upgrading bridges and locks is significant. In 2018, for instance, Muskoka District spent \$2,245,900 for yet another set of new gates on Port Carling's primary and secondary sets of locks—necessary upkeep for a transportation corridor which Anne Duke Judd, describing the Indian River, aptly calls "the real main street of Port Carling."

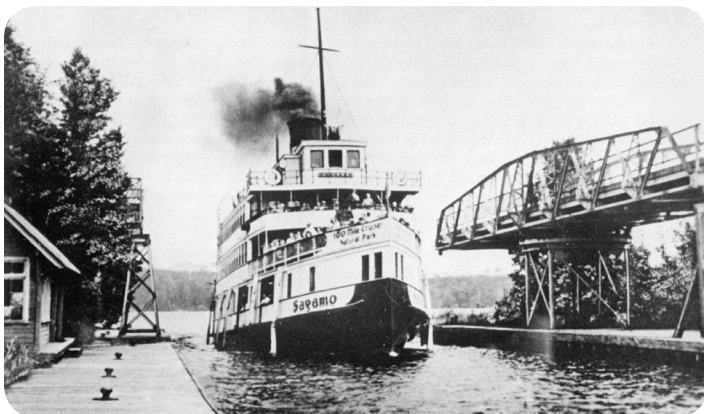
Port Sandfield's evolving and rotating bridge

Anticipating requirements of steamer travel gained high priority as Muskoka's central lakes became home to colonizing settlers and seasonal residents. In 1871-2 a channel was cut between lakes Rosseau and Joseph by dredging contractor Joseph Wallace. Bringing both to the same level saved people money and inconvenience by eliminating transshipment costs. The chance to do this only existed during a brief pre-development phase, before docks and boathouses dotted the higher lake's shoreline.

Although steamships and other craft now moved readily between both lakes through "The Cut," it took six years to reconnect the severed land. This might



From the bow of a steamship, Frank Micklethwaite captured an era of early Muskoka transportation history in this photograph of Port Carling's 1872 locks and swing-bridge. The bridge for roadway and pedestrian traffic has been moved aside at the right while the highway of water takes precedence. The lower lock is closed so one of the large steamships from Gravenhurst and a couple smaller steamers are at the level of upper lakes Rosseau and Joseph. Photo courtesy F.W. Micklethwaite / courtesy Bill Micklethwaite.



Largest vessel of the Muskoka Steamship Line, the *Sagamo*'s celebrated "100 Mile Cruise" carried thousands of tourists each summer from Gravenhurst's Muskoka Wharf to the top of Lake Joe, and back. The voyage included passing through The Cut at Port Sandfield, where the swing bridge facilitated Muskoka's interlocking water and land transport. Photo by F.W. Micklethwaite, courtesy Bill Micklethwaite.

have happened sooner if Port Sandfield, named for Ontario Premier Sandfield Macdonald, had been more than what Lake Joseph's historian William Gray aptly notes "was more geographic expression than a populated village." By 1876 an elevated timber trestle stretched high above The Cut restoring a land connection while maintaining the new open water passage.

This high-level stationary bridge was replaced by a more practical timber swing-bridge in 1887, which in 1924 was in turn replaced by a steel truss swing-bridge, constructed on the same plan and design as its 1887 predecessor. People, grown pleased with what had become familiar, sought to maintain the look. In 1993 the swing-bridge was again fully reconstructed by the District of Muskoka, but this time as a contemporary steel girder structure.

Huntsville's constant yet changing river bridge

"Since the earliest days of Huntsville," said the town's heritage committee two decades ago, "the focal point of the community has without doubt been the Main Street Bridge."

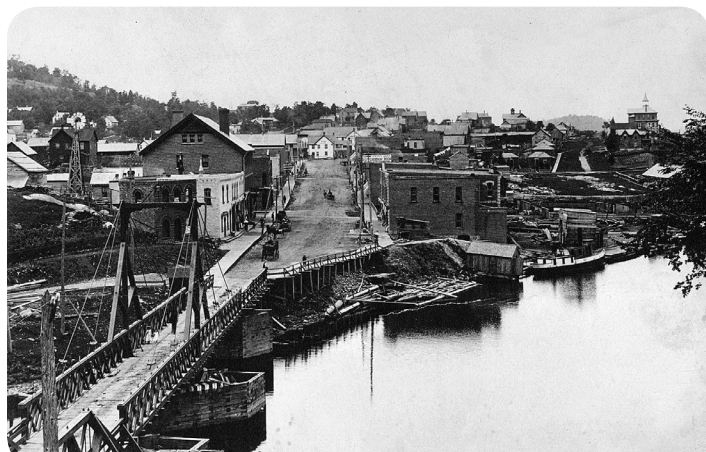
There were many reasons. When prohibition of alcohol applied to half of Huntsville, the bridge connecting the town's dry and wet sides became an essential service for many. By enabling boat and road traffic to interact, the swing-bridge also fostered a

lively downtown waterfront. And monopolizing traffic gave the bridge and downtown Huntsville merchants exclusive prominence for years, until by-pass bridges for Highway 11 and Center Street diluted traffic and customers.

Over decades the bridge itself has changed many times, but never its location. From the outset, veteran Ontario land surveyor John Stoughton Davis warned that although the spot between lakes Vernon and Fairy where a shoal created rapids and narrowing pointed to a bridge site, the actual distance between embankments would be some 30 meters (roughly 98 feet) making it more costly to build and harder to maintain. Yet that is precisely where was Huntsville's bridge was constructed and has remained ever since 1870—the year Ontario's Crown Lands Department spent \$1,701.44 for the crossing structure and approaching road work.

That first version of Huntsville's bridge crossed a considerably lower river than people know today. It needed to support only light traffic of walkers and animal-drawn wagons and sleighs. It was an all-wood beam bridge, with log piers and wooden planking.

Everything went well for five years. Then new locks on the river, downstream near the Brunel Road, elevated the water level, submerged river islands, and challenged the bridge's integrity. A specific problem faced steamship *Northern*, launched at Port Sydney in 1877. Navigating upriver from Mary Lake carrying



In 1888-89 Huntsville advanced from a fixed-link land bridge over the Muskoka River to this swing bridge. Located in the same place as the first bridge, it would itself be replaced in 1902, and again in 1938. Whatever the bridge, it carried the Muskoka Colonization Road, which, as seen here, is the town's main street. Photo courtesy Muskoka Heritage Place, Huntsville.

people and freight for Huntsville and lakes Vernon and Fairy, the bridge blocked her. The Crown Lands Department solved this by raising the bridge. In regular navigation season the *Northern* would pass under the structure.

But then it became clear height was not the only problem. The narrow channel between the piers (just 30 feet) caused the *Northern*, especially with spring flooding, to sustain damage trying to pass through. By 1879 the Department's next solution was removing one pier and constructing a 70-foot central span so the navigable passage under the bridge would be more than twice as wide. But that was not done. The Department for awhile just relied on the *Northern's* captain and crew honing their navigation skills instead.

With other Muskoka bridge designs enabling intersecting traffic to cross in sequence, as land bridges were lifted or swung aside long enough for vessels to pass, this solution began to percolate for Huntsville bridgework. By 1884, the Departmental estimates included funds for a new Huntsville bridge with a 135-foot swinging span. That year, though, the Department spent some of its general appropriation to repair the piers and deck planks, and later photographs still show the familiar fixed wooden beam structure on its piers. A decade and a-half later, the Department's 1901 report confusingly said the bridge had been built in 1884; it had merely been delayed until 1888. In any case, the 1901 report outlined plans for building a new swing-bridge to "take the place of one erected in 1884 which had become decayed to such an extent as to endanger the safety of the public." An entirely new swing-bridge

was constructed in Huntsville during 1901. A 1902 photograph of it, with the Anglican Church atop a hill behind, shows its clean-lined structure.

Just three and a-half decades later, in 1937, another replacement bridge was ordered up. It, too, would be a swing-bridge, of painted steel, from Hamilton Bridge Company—a rivet-connected polygonal truss bridge in the Warren Pony style set on large concrete piers. The Depression-era contract, let by Ontario's Department of Highways to Atkin & McLachan of St. Catharines, gave needed local employment through the winter of 1938. This winter-long work included a temporary bridge to carry traffic during construction.

The era's engineering design for the triangulated structure incorporated gusseted connector plates, exposed rivet heads, and grated deck. The bridge's outer sides had plank-and-plywood surfaced pedestrian sidewalks with a diamond-grill railing. Electricity played its helpful role, lighting each end of the 224-foot bridge and powering its swing mechanism. The bridge master's wood-framed cabin, atop the north span, gave a crow's nest view over the entire scene for the operator to conduct the dance of waterborne and roadway traffic—by swinging the 170-foot mid-section on its center-bearing pier sideways from the riverbank's fixed rigid-frame concrete approach spans—so that a majestic steamship like the *Algonquin* could pass, to the thrill of passengers and satisfaction of onlookers alike.

Ontario's Minister of Public Works, Collin Campbell, speaking from a decorated truck that served as a mobile stage for the impressive structure's July 1938 official opening, told a large assembly of proud Huntsvilleites their exceptional bridge had cost \$150,000, at the announcement of which Huntsville Citizens' Band filled the air with lively sound.

By 1952, the post-war boom had changed Muskoka's vacation economy. That spring, the bridge's wood sidewalks were replaced by durable concrete for the increasing summer pedestrians, but that fall, the last steamship to ever pass through the bridge completed its final voyage. Automobiles and motorboats brought down the curtain on the Steam Era in Muskoka. By the 1980s its swing mechanism, unused for decades, was welded shut. As centerpiece of a dynamic town, and as one of the few preserved historic truss swing-bridges in Ontario, in 1983



The present bridge at Huntsville.

Photo by Tomasz Szumski.

the provincial Heritage Board officially listed the Huntsville Swing Bridge for historic protection.

Bala's many bridges for railways

The Age of Steam had not only lifted Muskoka's vacation economy for decades, propelling a vast fleet of steamships through District waters and powering trains carrying thousands of visitors, but the passenger and freight cars steaming in had recast the local economy and society by providing a connecting link—a bridge between the far-famed vacationland and those seeking to enjoy it.

By 1906, railway interest in Bala hit fever pitch. The Canadian Northern Ontario Railway's route entered Muskoka through Washago, reached Port Stanton at Sparrow Lake, then continued via Torrance across Bala Park Island and on up the west side of Lake Joseph. That same year, the Canadian Pacific Railway's Toronto-Sudbury line was being run across the Severn River into Muskoka and up the west side of Muskoka through Bala then north right alongside competitor CNOR's tracks. Two thousand men of diverse nationalities, laboring to push these railways through Bala, dynamited tons of rock and built bridges over the south and north falls. Their work included a railway swing bridge, and three train stations, the main ones for each company, plus the CPR's "Summer Station" at Bala Harbour to handle the flood of eager vacationers.

Extensive blasting caused faulting in the Canadian Shield. It filled a channel into Bala Bay with rock, blocking steamships servicing Bala and damaging vessels and facilities alike. The social chaos for local police caused the Ontario Provincial Police to open

their very first detachment in Bala. The throngs of detraining Americans led Canada Customs to open an inland office here, as well. Bala, hub for the Muskoka Lakes western shores, throbbed with action.

The CNOR officially opened its Bala service in October 1906, the CPR in July 1907. CNOR brochures picturing Muskoka and listing train schedules and fares stimulated a frenzy of tourism. The CNOR's first train of the 1907 summer season arrived in June, across its Bala bridges, and pulled to a stop. Vacationers were delighted by the pleasing station, painted beige, with green trim and red roof. They happily proceeded to steamship *Islander*, arriving on schedule to meet them, as Muskokans, rail services, steamers, and resorts all seamlessly bridged their respective components into an integrated vacation economy.

Two railway bridges overcome Bracebridge's rugged typography

The Grand Trunk Railway's line to Bracebridge, being built north from Gravenhurst in 1885, required two bridges and a major rock cut. The first crossed the south branch of the Muskoka River by Sharpe's Creek, the second the Muskoka's north branch over the Bracebridge Falls, and between them a channel had to be cut through a dense barrier of bedrock.

The same South Muskoka River had challenged builders of the Muskoka Colonization Road, whose first bridges over the majestic South Falls gave breathtaking views. Today's Highway 11 concrete walled bridges and the speed of vehicles preclude many travellers from knowing they are even crossing a major river and waterfalls that might, alternatively, been developed as vacationland Muskoka's most dramatic natural venue. The lost tourist appeal of South Falls was not due to bridges but power dams.

The steel superstructure railway bridge over the south branch, further downstream, is one of Muskoka's longest spans. It is erected upon large cut-stone footings, as is the second railway bridge over the North Falls in the center of Bracebridge.

The rock cut itself proved arduous work for unpaid workers who remonstrated on the town's main street for their wages until Bracebridge Clerk James Boyer read the Riot Act to the mostly Italian-speaking navvies who then departed the scene. These adept laborers opened a fairly level passageway north



This pastoral view of the Bala Bridge, with a cow about to cross and a couple approaching as the woman's full length skirt glances over mud, also gives a view of the Canadian Pacific Railway's viaduct. Photo by F.W. Micklethwaite, courtesy Bill Micklethwaite.



First bridge over the Muskoka River, built in 1861 for the Muskoka Colonization Road and seen here from below, enabled spectacular views of the “Great Falls,” also known as Grand Falls, Muskoka Falls, and South Falls. Today’s concrete-sided walls of the Highway 11 bridge prevent glimpsing the relic of Muskoka’s most magnificent cataract, only partially shown here, and with low summer flow, and following clear-cut logging of the forest. Rather than being developed for tourism, Hydro harnessed their power for electricity. *Photo courtesy Library and Archives Canada.*

into town, leading onto the long trestle for the second bridge. Rock from the cut, produced by small dynamite blasts and much hand-labor with picks, heavy lifting, and wagons, provided fill for the bridge approaches. The 154-foot central main span is a rare example in Ontario of a pin-connected deck truss. The bridge’s two end spans are fixed metal-deck girders.

This sampling of Muskoka bridges opens wider topics about the protection of historic bridges, increased concerns for safety, jurisdictional overlaps, maintaining an aesthetic satisfying to permanent and seasonal Muskokans, reappraising the unappealing industrial-style of contemporary roads and bridges, and how crossings can best be incorporated into their attractive settings to enhance Muskoka’s all-important vacation economy.



This northbound Grand Trunk Railway freight train crosses the bridge over the Bracebridge Falls, built in 1885 and still in daily service for freight today. Henry Bird’s octagonal house stands on the horizon, fully visible from clear-cutting (unlike today, hidden by trees.) The log chute alongside the falls is well displayed, while the train’s flat-car with its logs further signifies the importance of Muskoka’s wood industry. *Photo courtesy Boyer Family Archives, Bracebridge.*

Dr. J. Patrick Boyer, Q.C. author of 25 books, writes a newspaper column and magazine features, has hosted television shows in Canada, and broadcasts a series on Muskoka history on FM radio. He was raised a typesetter and printer, has worked as a journalist in Saskatchewan, Ontario, and Quebec, and collaborated producing documentary films with the National Film Board of Canada. As a lawyer, he was partner of a major Toronto law firm, and member of the Northwest Territories Bar with a practice in the high arctic. For ten years he represented the Toronto district of Etobicoke-Lakeshore in the Parliament of Canada, chairing a committee on equality rights and the committee on the status of disabled persons, before becoming parliamentary secretary for External Affairs, then for National Defense. Professor Boyer taught law, politics, history and democratic accountability at University of Guelph, University of Toronto, Wilfrid Laurier University, and York University. He’s an alumnus of Georgetown University’s Leadership Forum and the Aspin Institute. He owns and operates a book publishing house, is past president of several Canadian public policy organizations, and in 1997 founded the Corinne Boyer Fund for Ovarian Cancer, since evolved into Ovarian Cancer Canada. His credo: build bridges, not walls.

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