



CASE STUDY: HISTORY AND REFURBISHMENT OF 145 YEAR OLD RAIL BRIDGE PIERS, SOUTHWEST MIRAMICHI RIVER BRIDGE IN MIRAMICHI, NEW BRUNSWICK

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1 Introduction

The CN Rail Bridge over the Southwest Miramichi River in Miramichi, NB was built between 1871 and 1874 as part of the Intercolonial Railway system, with Sir Sandford Fleming overseeing the design and construction as Chief Engineer. The bridge has been in continuous service since its completion over 140 years ago and is part of CN Rail's Newcastle Subdivision line, carrying both freight and passenger train traffic. Over the last 100± years various repairs and upgrades have been made to the bridge. CN Rail recently initiated a rehabilitation program to address deterioration of the masonry piers and local scour around the piers. This case study outlines pertinent details of the original design and construction, summarizes various repair works that have been undertaken over the years, and outlines the approach taken with the recent refurbishment.

2 Original Construction

The bridge was constructed as a six-span through-truss structure approximately 380 m long, with an approach embankment approximately 100 m long extending out from the south bank of the river. Figures 1 and 2 show the general arrangement and a recent photo of the bridge, respectively. The river has a drainage area of 7,685 km² upstream of the bridge, and is tidal, with the head of tide located approximately 22.5 km upstream of the bridge. The nominal tidal range is 1.5 m, but extreme tides of 3 m have been observed. The thalweg in 1870 was located on the north side of the river at elevation -6.0 m (CGVD28). Borings made in 1870 by Fleming (1876) show that the river bed sediment is sand underlain by dense gravel (bearing stratum), which is underlain by till and finally, bedrock. Recent grain size analyses show that the bed sediment is poorly graded medium sand with a mean grain size of 0.4 mm (GEMTEC 2016).

The bridge foundations are wooden caissons, which were sunk down to foundation level by excavating from the inside through the open bottoms, and then were filled with concrete. Foundation elevations vary from elevation -10.2 to -12.5 m, corresponding to 4.2 to 10.5 m below the 1870 river bottom. The actual piers, which are about 11 m high, were constructed of stone masonry on top of the concrete-filled caissons. Local sandstone was used for the majority of the masonry, but imported granite was used to face the upstream ice breakers installed on the piers. Figure 3 shows pier and caisson details of the original construction from Fleming (1876). Additional details of the original design and construction are also provided by Fleming

(1876). Figures 4 and 5 show photos of the original construction that were discovered at the Provincial Archives of New Brunswick earlier this year.

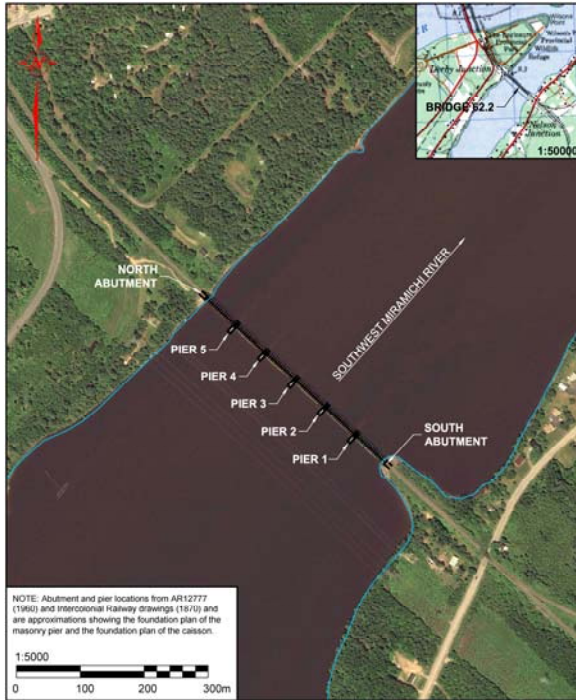


Figure 2: Photo of the bridge looking downstream from the south approach embankment.

Figure 1: General arrangement of the CN Rail bridge crossing the Southwest Miramichi River (GEMTEC 2016).

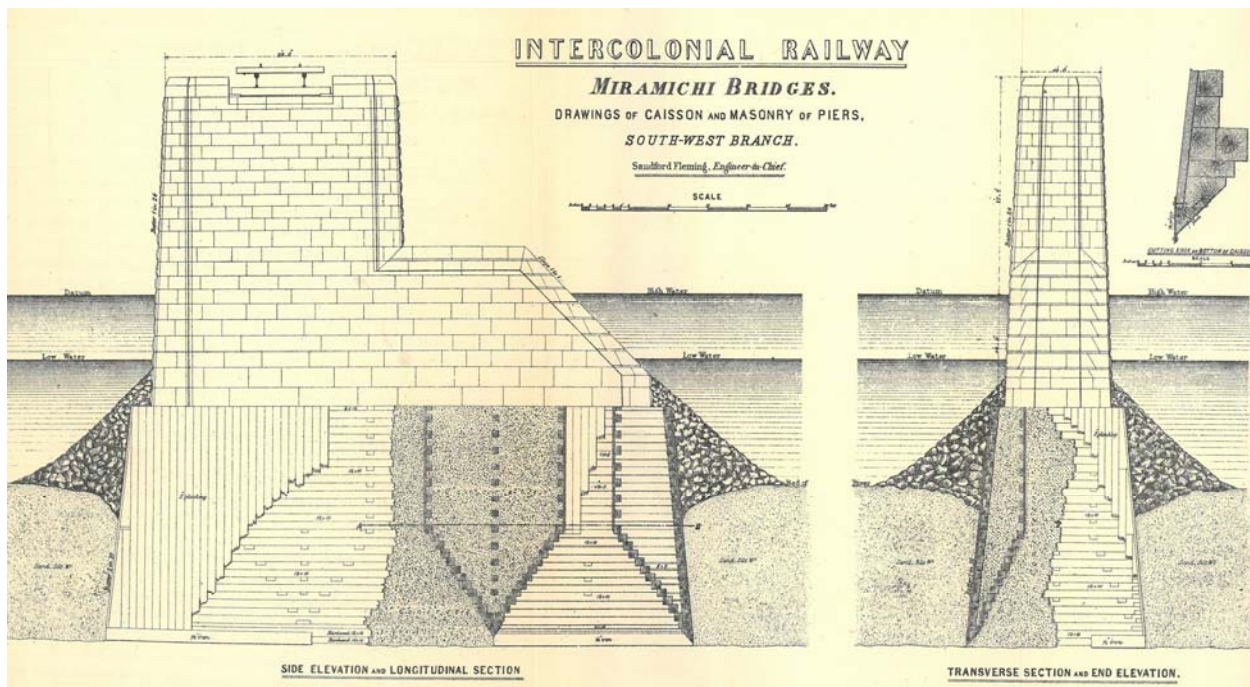


Figure 3: Details of the original pier and caisson construction (Fleming 1876).

Some scour of the river bed material was noted during construction of the caissons, generally in the order of 1.5 m around the upstream ends of some of the caissons. Scour protection in the form of mounded riprap was placed around each pier up to an elevation of -0.8 to -1.5 m, sloping down to the river bed (see Figure 3). Due to the variation in river bed elevation those piers to the north, in deeper water, had much more riprap than those to the south, in shallower water. This scheme would have inadvertently increased the effective width of the piers, resulting in additional local scour.

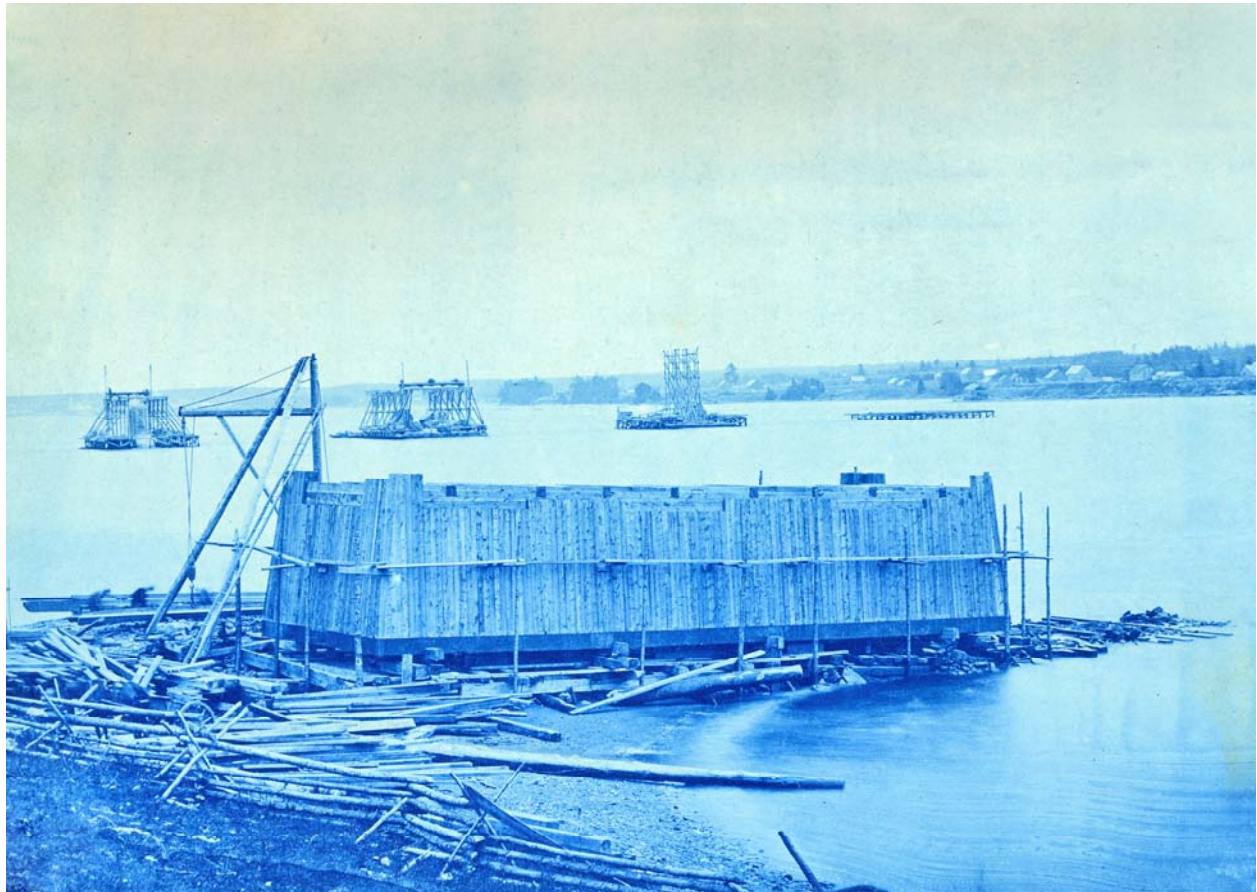


Figure 4: Timber caisson constructed on land prior to being floated into place and sunk, circa 1872 (Provincial Archives of New Brunswick, P119 Frank Sayer collection, P119-MS2I-109).

3 Modification and Repairs, Pre-2017

3.1 Changes in River Bed over Time

Table 1 summarizes observed changes in the river bed at the bridge location over the past 145 years. Data for Table 1 was obtained from Fleming (1876), CN record drawings from the 1900s, and a hydrographic survey in 2015 (GEMTEC 2016). Since the original construction, the thalweg has moved from the north side of the river to the south side, which is likely due to scour at the toe of, and induced by, the southern approach embankment. The cross sectional area of the waterway was initially reduced by 25% due to the bridge and approach embankment construction, but had increased to 4% over the pre-bridge area by 1901. By 2015 the cross sectional area had increased to 10% greater than the pre-bridge area. Sea level rise likely accounts for some of the increase in waterway area.

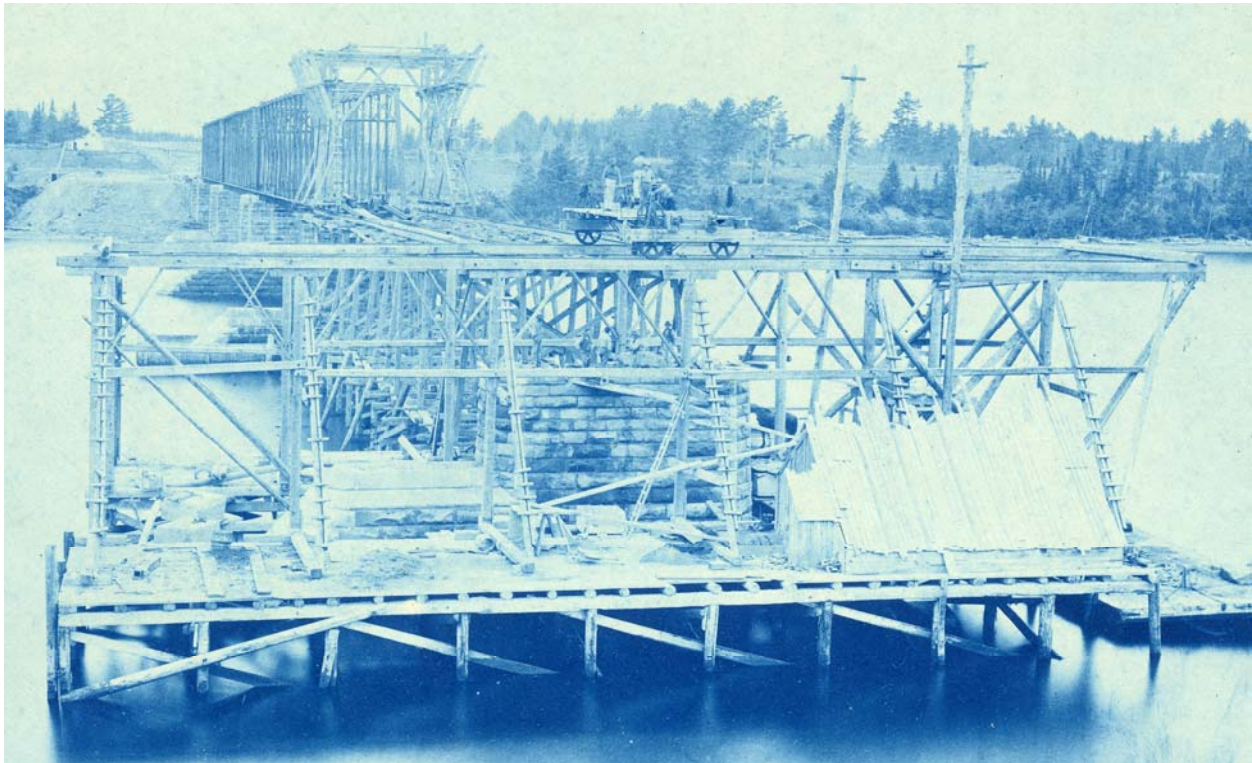


Figure 5: Construction of bridge, circa 1874 (Provincial Archives of New Brunswick, P119 Frank Sayer collection, P119-MS2I-093).

Table 1: Recorded river bed elevations* over time (note change in **thalweg** location with time)

Year	Mid span Abut.- Pier 5 (m)	Mid span Pier 5-4 (m)	Mid span Pier 4-3 (m)	Mid span Pier 3-2 (m)	Mid span Pier 2-1 (m)	Mid span Pier 1- Abut. (m)	Waterway area at mean sea level (m ²)
1870	-4.0	<u>-6.0**</u>	-3.3	-1.7	-2.5	-3.0	1,561 (pre-bridge) 1,172 (post-bridge)
1901	-4.5	<u>-8.8**</u>	-4.0	-4.0	-5.8	-6.5	1,618
1917- 1933	-3.8	<u>-7.4**</u>	-4.8	-3.7	-6.7	-6.7	unknown
1962	-3.8	-5.5	-5.0	-5.5	-7.5	<u>-8.2**</u>	1,739
2015	-5.0	-5.4	-4.3	-3.8	-6.0	<u>-6.7**</u>	1,713

* Elevations are referenced to CGVD28

** Thalweg elevation

3.2 Bridge and Piers

In 1901 the original through-trusses were replaced by new steel trusses of the same spans supported on the original piers. Measurements at that time indicated that the riprap mounds around the piers were 2.0 to 3.9 m below the original 1874 levels, likely due to local scour of the fine bed sediment from beneath the toe of the mounded riprap.

Underwater surveys of the piers around 1917-1918 indicated considerable degradation of the sandstone masonry in the vicinity of the low water level, which had worn in by 200 to 225 mm from 0.6 to 1.0 m above the low water level down to the top of the caissons. As a remedial measure, the lower portion of the masonry was encapsulated in 0.6 m of concrete reinforced with wire mesh, up to approximately the low water level. At some point between 1933 and 1956, light steel sheeting was installed along the sides and downstream ends of the piers between the top of the concrete encasement to above high water level, and grout or concrete infill was placed behind the steel sheeting. Pressure grouting of the masonry piers was also carried out, probably at about the same time the steel sheeting was installed. Surveys of the river bottom indicated additional riprap was placed around the piers between 1917 and 1933, and again between 1956 and 1962.

4 Recent Inspections

In 2011, 2015, and 2016 underwater inspections indicated that a considerable amount of the lower concrete encasement had deteriorated and fallen off along with some of the concrete infill between the steel sheeting and masonry. Mortar joints in the masonry were significantly deteriorated, especially on the upstream noses, and the lower portion of the steel sheeting was extensively perforated by corrosion. Figure 6 shows a high resolution scanning sonar image of one of the piers in 2015 (Amec Foster Wheeler 2015). Remnants of the concrete encapsulation are visible along with the steel sheeting above it. The original caissons appeared to be in good condition, although some of the exterior wood formwork was damaged or missing.

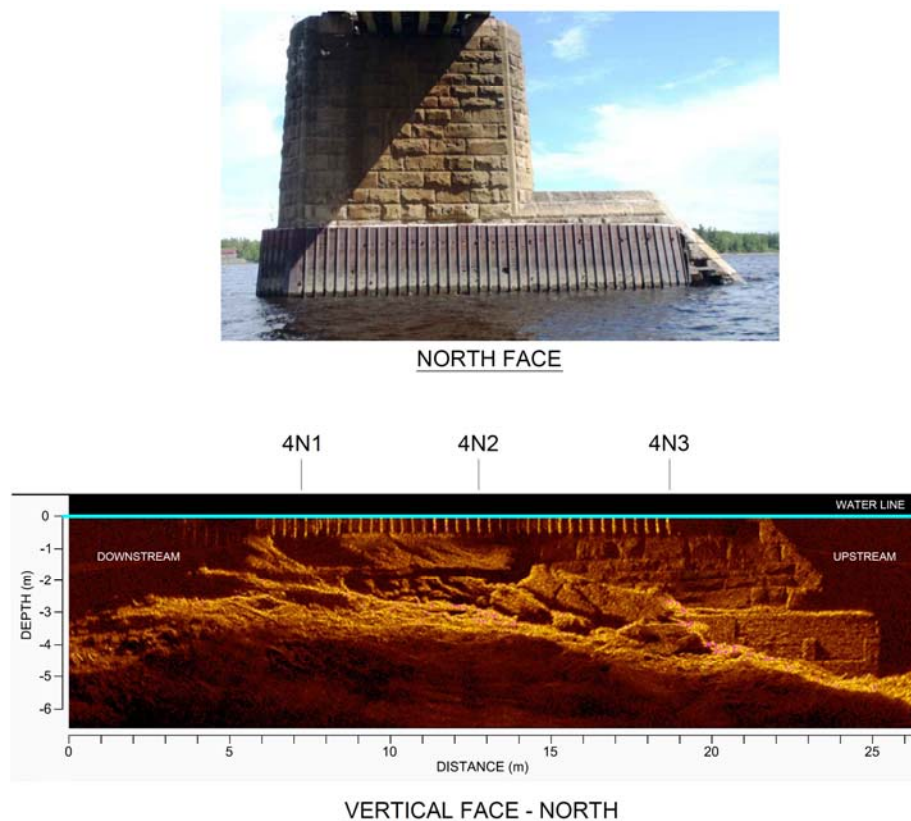


Figure 6: High resolution scanning sonar imagery of Pier 4 (Amec Foster Wheeler 2015). Note caisson, remnants of previous concrete encasement, stone masonry, and steel sheeting.

Scour holes were noted around the upstream ends of the piers and very little riprap was visible. The 2015 hydrographic survey revealed that the magnitude of local scour varied from 0.5 to 3.8 m around Piers 2, 4 and 5 (see Figure 1 for pier numbering). Probing of the river bottom around the piers indicated that there was riprap buried under the sand bottom. A detailed review of the 2011, 2015, and 2016 inspections, historical records, and the hydrology/hydraulics of the site indicated that there was a total deficiency in scour protection around the piers in the order of 400 to 1,500 m³ compared to recommendations set out in the TAC Guide to Bridge Hydraulics (Transportation Association of Canada 2001).

5 Present Refurbishment

The Southwest Miramichi River is an internationally recognized major salmon river. The nature and timing of construction activities in the waterway therefore required careful consideration of the potential environmental impacts, as well as approvals from regulatory agencies. The scope of the present refurbishment was limited to the portion of the piers below the high water level, with the intent being to restore their original section and to further extend their service life. Repairs to the piers consisted of removing the remaining concrete encasement, steel sheeting, and concrete backing, and constructing a new reinforced concrete encasement 0.6 m thick from the top of the original caisson to above the high water level as shown in Figure 7.

During the design phase, due consideration was given to the methodology a contractor could practically employ in undertaking the proposed repairs. The presence of buried riprap around the caissons, along with the likelihood that the caissons would not be water tight, and limited overhead clearances, made the construction of cofferdams impractical. Thus, the approach was to carry out the work underwater by aid of divers with concrete being placed by tremie methods. Steel nosing was added to the face of the new concrete encasement on the upstream ice breakers. Following the placement of the concrete encasement and steel nosing, the open mortar joints were filled by pumping grout through tubes that had been placed in the joints beforehand. The encasement was dowelled to the existing masonry and high strength pre-stressed anchors were installed through the masonry to further reinforce the piers. Additional riprap was placed around the piers to fill the existing scour holes and to provide adequate scour protection.

Repairs to two piers were successfully completed in 2017. Figure 8 shows a photo taken during the 2017 work. The contractor constructed a temporary wharf on the north river bank to facilitate movement of equipment, concrete, formwork, etc. by barge to the piers. Floating work platforms were also constructed around the piers to facilitate the work. The contractor installed current deflectors on the upstream ends of the piers to minimize the effects of tidal currents on the divers' underwater work. The remaining three piers are scheduled for rehabilitation in 2018.

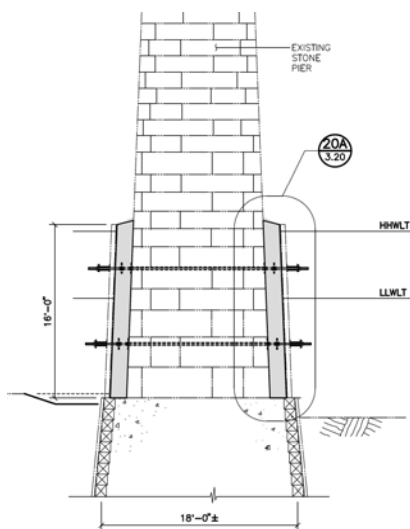


Figure 7: General refurbishment scheme.



Figure 8: Repair work in 2017.

6 Conclusions

This rail bridge was constructed as one of Atlantic Canada's first major bridges and continues to stand today as a testimony of the critical roles played by civil engineers in the construction and maintenance of sustainable infrastructure. Sir Sandford Fleming faced much opposition from both the Railway Commission and politicians in his day for insisting the bridges on the Intercolonial Line be built of iron with masonry abutments and piers, rather than less expensive and more commonly used wooden structures. With considerable effort he eventually succeeded in convincing his opponents and was authorized to use iron and masonry. This case study is an excellent example of the important role of civil engineers in decision making, design, construction, and maintenance of critical infrastructure. In the present case it has resulted in good performance for over 140 years, and, with the recent refurbishment, the service life of the piers is expected to be extended by several more decades.

As Canada's infrastructure continues to age, rehabilitation of old structures will become a more common and important challenge faced by the civil engineering community that must be met with innovative engineering analyses and designs, as well as new construction techniques. In addition, civil engineers must continue to strive for sustainability in the design and construction of new infrastructure, which will serve the public for generations to come.

Acknowledgements

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