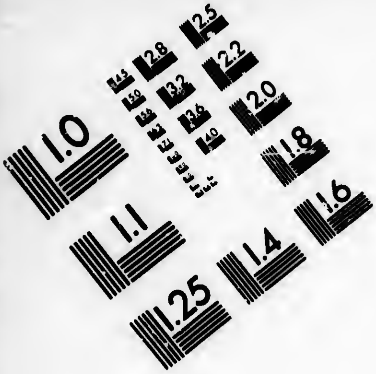

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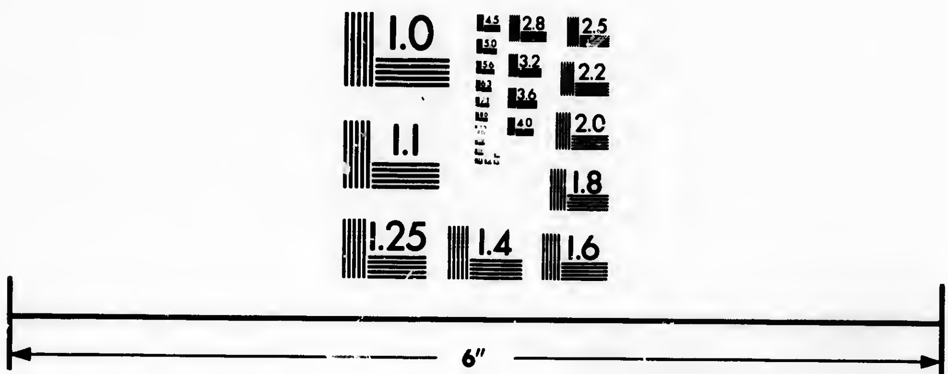


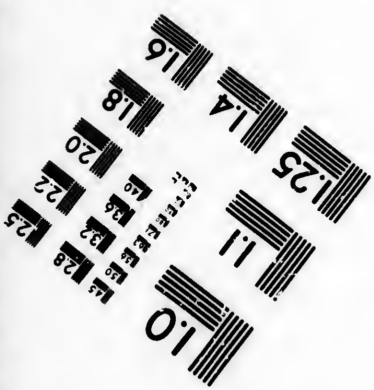


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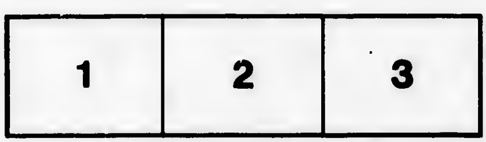
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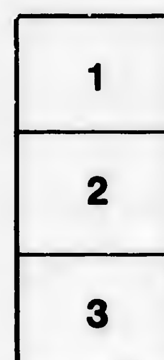
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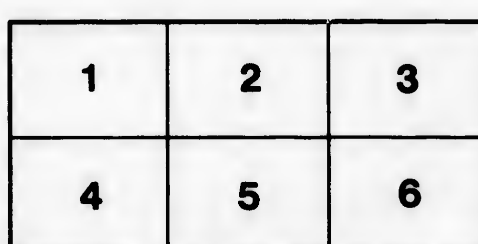
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**Canadian Society of Civil Engineers.**

INCORPORATED 1887.

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## THE CONSTRUCTION OF COTEAU BRIDGE

BY

GEO. A. MOUNTAIN, M. CAN. SOC. C.E.

To be read Thursday, 26th March.

In the autumn of 1888 the Canada Atlantic Railway Company decided to replace the ferry used for the transportation of cars across the river St. Lawrence, between Coteau Landing and Valleyfield, by a bridge, the ferry being found inadequate for the company's constantly increasing business.

After numerous careful surveys extending over a period of three seasons, the site finally selected for the bridge was at the head of the Coteau Rapids, 37 miles west of the city of Montreal. This site, while it possessed many advantages of importance to the company on the score of economy, on account of the islands situated on the line of the proposed bridge, also possessed many difficulties from an engineering point of view, principally the depth and velocity of the water.

The width of the river, which at the bridge site is narrower than at any other point in the vicinity, is divided by two islands into three distinct channels. The north or steamboat channel from the north shore to Giroux Island being 885 feet in width. The centre channel from Giroux Island to Round Island being 2210 feet in width, and the south channel from Round Island to the south shore being 930 feet in width. The length across Giroux Island being 905 feet, and across Round Island 1220 feet, making a total length of 6150 feet from north to south shore, with 4025 feet of bridging.

The banks of the river on either side of the bridge site and the intervening islands are low, and sloping toward the water, and it was on this account that a low level bridge, with a swing over a portion of the north or steamboat channel, was decided upon.

The elevation of the rail level of the bridge, which is a through truss from end to end, is 25 feet above the ordinary summer water level, and the aligament of the bridge is a tangent from shore to shore, and is divided into spans, as follows: The north or steamboat channel being composed of two fixed spans of 175 feet each centre to centre, one of 139 feet centre to centre, and one swing span of 355 feet centre to centre of toe-seats, giving an opening on either side of the pivot pier of 160 feet in the clear. The centre channel is composed of ten fixed spans of 217 feet each centre to centre, and the south channel of four fixed spans of 223 feet each centre to centre. The islands are at present crossed by trestle work, which it is the intention of the company to fill and form a solid embankment.

In the north or steamboat channel adjoining the Coteau shore, the velocity of the current is seven miles per hour, and on account of navigation the course of steamboats and rafts passing down had to be kept clear, and the dredges, barges, and plant used in the construction were in constant danger of being run into and sunk. The velocity of the current in the centre channel was between five and six miles per hour, and the shoal water 1000 feet above the bridge line rendered the navigation of the tugs and barges very difficult. In the south channel the velocity of the current being six miles per hour, and the bed of the river above the bridge line bare rock, great difficulty was experienced in the anchorage.

The maximum depth of the water in the north channel, in which were placed four piers, including the pivot pier and two abutments, is 30 feet, the minimum being 24 feet, and the borings showed a covering of from 4 to 6 feet of cemented gravel and boulders above the bed rock.

The maximum depth of the water in the centre channel, in which were placed nine piers and two abutments, was 26 feet, the minimum depth being 20 feet, and the borings here showing a covering of from 3 to 8 feet of cemented gravel and boulders above the bed rock.

The maximum depth of the water in the south channel, in which were placed three piers and two abutments, was 24 feet, the minimum depth being 20 feet, with a covering of from 3 to 6 feet over bed rock of a similar material to that found in the other channels.

No trouble whatever was experienced from the variation of water level, the rise and fall not exceeding 2′ 6″.

It might be in place here to mention the manner in which the triangulations were performed to obtain the widths of the different channels, and in which the positions for the piers were arrived at.

The instruments used were an eight inch transit, a 300 foot steel tape, and pickets.

Owing to the marshy ground on the north shore on either side of the bridge site it was no easy matter to obtain a base line, and advantage was taken of the winter when these marshes were a solid level field of ice; on them a base line was measured at right angles to the line of bridge, and from this base the width of the north or steamboat channel was calculated. The hypothenuse of this right angle triangle was then used as a calculated base line to establish a point on Maple Island, situated mid-way in the centre channel, and about 1200 below the line of bridge, by connecting this point with a point on line of bridge on the south shore of Giroux Island, gave a calculated base from which the width of the centre channel was obtained; these operations were carried on in a similar manner from the south shore, and the point on Maple Island was again established from this side, giving the adjoining side of the centre triangle, taking this side as a calculated base, the distance across the centre channel was again obtained, checking with the distance calculated from the north side to within .06 of a foot. The point thus established on Maple Island was used in laying off the angles for the position of each of the nine piers in the centre channel. A point was similarly established on Swan Island situated in the south channel about 1000 feet below the line of bridge, and from which the angles were laid off for the position of the three piers in the south channel. A point was also established on McIntyre's Island, situated in the north channel about 1200 feet above the bridge line, and from which angles were laid off for the position of the four piers in the north channel. The angles were taken by two engineers, and by the method known as repeating the angles and the mean of this repetition taken, any little variation found in the three angles of a triangle from 180° was divided proportionately among the three angles. Two months were spent in this manner during the winter, until the engineers were fully satisfied that the widths of the channels and the position of the piers were accurately obtained. A plan was then made on a scale of 50 feet to the inch, and with all distances and angles marked on it, little trouble was necessary to fix the position of a pier at a few moments' notice.

The specifications for the substructure required a bottomless caisson 20′ in width and 67′ in length over all, and pointed at both ends, the bow being a right angle and the stern somewhat more acute; this was done for the purpose of steadying the caisson in the rapid current, and also to prevent the formation of an eddy. The walls of these caissons were built of 12″ x 12″ pine timber, and were stiffened by means of 30 uprights fastened to the wall on the inner side, and tied across by 45 cross ties placed about 4 foot centres, all of the same material and dimensions, they being heavily spiked and bolted together.

The caisson used for the pivot pier was designed in the shape of an octagon 36′ in width with sides of 17′ in length, and was built of similar material and dimensions as used in the caissons for the other piers.

The specifications for the masonry in the bridge abutments and piers required to be first class in every respect, and of the best and largest stone that the quarries afforded. They required to be sound and durable, free from all drys, shakes, or flaws of any kind whatever, and must be of such a character as to withstand the action of the weather. No course less than 15″ in thickness was allowed. The beds of all stone for face work, and the backing, where required to receive headers, were dressed parallel throughout, so as to form quarter inch joints, and the vertical joints of the face stone were dressed back square for 9″, so as to form quarter inch joints.

Headers were built in every course not more than 6′ apart, and so arranged with the adjoining courses as to leave them equally distributed over the faces of the structure; they have a length in the face of work of not less than 24″ and a depth of at least two and one half times their height.

Stretchers required to be not less than 30″, and their breadth must be at least one and one half times their height. The vertical joints must be so arranged as to overlap those in the course below at least 1 foot.

The copings and bridge seats of all piers and abutments required to be 24″ in thickness, and dressed square throughout to quarter inch joints.

The vertical joints of the cutwater stones were dressed back square to the full depth of the stone. Iron clamps of 10″ in length were used in clamping the cutwaters. Dowells of an inch and one half round iron were let through one course and one half of masonry. Over the cutwaters nose pieces of ¾ inch steel were placed 12′ in length and running back 2′ on either side, bolted by means of fox wedges to the masonry.

All masonry was laid in fresh ground Portland cement, thoroughly mixed with good, clean, sharp, coarse river sand, in the proportion of one part of cement to two parts of sand. The cutwaters and bridge seats were laid with mortar in the proportion of one part of cement to one part of sand. The cement was tested from time to time by a Fairbanks cement testing machine, and after setting from 10 to 20 days stood a breaking strain of from 275 to 410 pounds to the square inch.

The dimensions of the piers which are shown in the accompanying sketch are 48′ x 11′ 6″ at the base and 24′ x 8′ at the bridge seat, the pivot pier differing from the others in being a cylindrical column of 27′ in diameter, with a footing course of 29′ 6″.

Towards the end of the autumn of 1888 the contract for the substructure was awarded to Messrs. Neelon, McMahon & Shea, of St. Catharines, and during the following winter quarries were opened, stone was cut, barges built, dredges overhauled, and all necessary plant put in readiness for the undertaking.

On the 1st of April, 1889, ground was broken in excavating the foundation for the abutment on the north shore, and this was carried on while waiting the breaking up of the ice on the lake above. The ice having passed down on the 21st and 22nd of April, a dipper dredge was brought down to the bridge site on the morning of the 24th, and ranged up into position to prepare the foundation for pier adjoining the north shore, dredging down stream. This operation occupied 15 days, and the dredge was then moved over to the position of the next or pivot pier. It was while working at the foundation of this pier that an accident befell the dredge, a raft, composed of nine drams, passing down in the early morning, struck the dredge, smashing a hole in the stern of about 15″ in diameter, and notwithstanding that every effort was made to save her she sank a half an hour later, in 28′ of water, the bow being pinned up on her spuds held her partly above water at that point, which greatly facilitated the operation of raising her, which was successfully done in a very short period. A similar dredge was placed in position on the pier adjoining the south shore, and worked towards the centre. It was not permitted to make the excavation for the caissons more than a week ahead, when they should be placed in order to avoid any danger of the excavation filling up.

To do this dredging successfully in from 20′ to 30′ of water, and a current of from 5 to 7 miles per hour, required very careful management and extraordinary precaution. Frequently during the progress of this work oak spuds of 18″ × 20″ were snapped off.

The next operation was the placing of the caissons. These when completed were placed between two barges, on each of which was erected a frame to a height of 20′ above the deck; across these frames two 24″ square pieces of oak were placed, and from these 4 tackles of large quadruple blocks reeved with 6″ manilla rope, guided by lead blocks, to winches on board the barges, were used to lift the caissons.

The first caisson was lowered with hydraulic jacks from cobhouse cribs on the deck of the barges; but this method was found to be extremely slow, and was abandoned for the block and tackle system above described.

The caissons were provided with 3 anchors, varying in weight from 1½ to 3 tons, and the barges with 1 each all hove with 1½ inch steel wire cables.

When the excavation was ready the caisson and barges were towed out into the current from where they were built, about 1 mile above the bridge site, by from two to five tugs, and were allowed to drift down to their position, the tugs steaming slowly up stream; 800 feet above the line of bridge the main anchor was let go, the others following in quick succession. On the anchors taking hold the tugs were let go, and by paying out the cables the caisson was allowed to drift down to within 25 feet of its position; it was here heavily weighted with railway iron, and lowered to within a few feet of the bottom. The caisson was then eased back until it was brought to the exact position previously fixed by triangulation; all that was then necessary to sink it was to ease away on the tackles simultaneously until it reached its bearings on the bed rock.

Should it not set in true position the first time some of the weight was removed, and the strain taken upon the tackles when it could be raised without difficulty; but it only occurred once or twice that a caisson had to be lifted after once having been placed upon the bottom. When it was finally settled in position it was additionally weighted with railway iron, and the footing course of masonry was also placed upon the wall of the caisson. In taking the caissons down it was sometimes found necessary, owing to shoal water, to raise them to a 6 foot draft, and for this purpose the block and tackle system was found exceedingly successful.

In placing the caisson adjoining the pivot pier on the south side, considerable difficulty was experienced, owing to the great depth of water 30′ and the velocity of the current, which at this point is the swiftest in the vicinity of the bridge, and being in close proximity to the steamboat channel, the swell made by the steamboats passing down was severely felt. After two unsuccessful attempts to place the caisson it finally capsized, damaging one of the barges used in transporting it, and throwing its load of railway iron into the excavation. The top of the caisson was so badly damaged as to necessitate cutting it down, and using it for a pier of less depth of water, and building a new one to replace it. A dredge was again brought down to redredge the excavation, which was partly filled up by the load capsized from the caisson. The next attempt to place it was successful, and no further trouble was experienced at this point. This caisson was considered, next to the octagonal caisson for the pivot pier, the most difficult one of the bridge to set.

The pivot caisson on account of its construction presented a tremendous resistance to the current. 5 tugs and a large sidewheel steamer being unable to hold it in the swift water, 8 anchors each hove with a 1½ inch steel wire cable were let go 1000 feet above the bridge line, and the cables slacked away and the caisson dropped back into position. Two of the 1½ inch steel wire cables to anchors were led to blocks made fast near the bottom of the caisson, and taken to timber heads on deck, in order to hold the caisson in an upright position, and prevent its being carried out of plumb by the stiff current

It was at this pier that the only fatal accident during the construction of the work was sustained, resulting in the loss of the lives of two men; both by drowning,—one during the construction of the substructure and the other during the erection of the superstructure.

Owing to the current striking the bridge line nearly at right angles, the caissons for the piers in the centres of the channels were subject to little or no side current; but those adjacent to the shores and islands received the full force of the current on one side of the bow, and great precaution had to be taken to prevent them from being swept out of position; this was done by means of anchors placed on the inshore side, and from which the cables were brought to the capstans fixed at both bow and stern of the barges, and in this manner held in position till sunk.

It was not found necessary to scribe the bottoms of the caissons, as they invariably fitted close to the bed rock, which was remarkably level and dredged thoroughly clean.

At the early stages of the undertaking it took three days to place and sink a caisson, but as the work progressed they were placed and sunk in a day.

On the caisson finally being settled and weighted in its position, the barges upon which it was transported were then removed. Divers were then sent down, and a canvas curtain, 6 feet wide, which had been previously nailed on the inside of the caisson 2 feet from the bottom, was unrolled, and upon this were piled bags of concrete to prevent any wash to the concrete afterwards to be deposited. Once commenced the concreting was carried on continuously day and night, until completed. A floating electric light plant furnished the light for the night work. A derrick scow was placed alongside the caisson, and as the concrete was mixed it was deposited in iron boxes with false bottoms holding from one to two cubic yards, and lowered slowly into the caisson, and the bottom tripped, thus preventing the separation of the materials which would ensue from allowing the concrete to fall unprotected through the water.

The composition of the concrete was: one part of English Portland cement, three different brands being used,—White's, Johnson's and Union,—one part of sand, and between three and four parts of broken stone of 2″ cube.

A bed of concrete was thus obtained, varying in depth from 8′ to 12′ and all brought to the uniform height of 12′ below water level, at which point the masonry in all cases was started from.

After allowing the concrete 48 hours for setting, the caisson was pumped out with an 8″ horizontal centrifugal pump driven by a 30 horse power engine, both on a scow alongside and connected with the caisson by a rubber suction hose. The pumping of a caisson usually took from 20 to 40 minutes, and little or no trouble was experienced in keeping them dry, they being thoroughly caulked from top to bottom. When this was accomplished the masonry was commenced and carried on to completion.

The concrete was found in all cases to have so thoroughly set as to make it as difficult to dress it to receive the masonry as an ordinary footing course.

The caissons were riprapped on the outside to the level of the top of the concrete.

The stone used for the piers and abutments is lime stone, and was taken from the quarries at Apple Hill and Caughnawaga, the last stone being laid on December the sixth, thus occupying the space of eight months and six days in the construction of the substructure.

The quantities were 8000 cubic yards of masonry, and 7000 cubic yards of concrete, in which were used 25,000 barrels of Portland cement.

In the winter of 1888, the contract for the construction and erection of the superstructure was awarded to the Dominion Bridge Company of Lachine, and preparations were at once commenced for the undertaking.

Specifications prepared by the railway company for the superstructure required that it be of the rivetted lattice type, and the general design finally adopted had a double system of triangular or inclined web members, inclined batter or end posts extending over one panel and girders of the swing span, and the longer fixed spans of varying depth, only the central upper chord panel of the fixed spans being horizontal, the chords sloping each way from the central panel to a junction with the batter posts, the depth of the girders at ends being made just sufficient to give the required clearance between track and portal bracing.

The use of inclined chords results in small economy of material, reduces wind surface, and gives good depth at centre of span with corresponding small deflections when loaded, and hence small secondary strains at and near the connections of web members on chords.

The depth of water, force of current, and nature of the bottom were such, that the setting of false work and the assembling of the metal work in place in the usual way would have been difficult, and attended with great risk of displacement by the heavy waves often running down from the lake just above the bridge.

The contractors for the superstructure decided to erect the spans in a sheltered bay, about three miles distant from the bridge, and when fully completed to take them on barges, float into place, and lower on to the masonry.

This was done in the following manner: Two scows built for this purpose, 90′ long by 40′ in width, were provided with 4 large trestle bents on each; these scows were lashed together with a space of 70′ between them. By means of valves, water could be admitted into the hulls, so as to sink them about 2′. When these scows were immediately underneath the span, the water was siphoned out, and the scows rising lifted the span off its false works, allowing the two panels on either end of the span to project over them.

They were then towed to the bridge site, placed in position between the piers, and by sinking the scows again the span was lowered to its permanent seat on the piers. The details of the scows and trestles used, and the method of placing the span in position between the piers, are fully shown in the accompanying sketch.

Notwithstanding the velocity of the current, the work was very successfully carried out. The 14 spans for the south and middle channel having been floated and placed on piers in 42 days, from October 12th to November 23rd.

Provision was made for storing a number of spans in the bay, when erected, by building the false work or staging, on which to erect them along the shore of the bay, and at right angles to this staging building out into the water two pile piers, or trestles, spaced the length of the spans apart. On these trestles a number of lines of railway iron were laid, and as the erection of each span was completed it was moved sideways out on to the trestles sliding on the railway iron.

Before the work of floating the spans into place began, seven spans had been assembled and rivetted complete, and moved sideways on the trestles into position, to be taken off in turn by the barges, thus enabling the work of assembling and rivetting to progress without interruption.

Spans have before been floated on barges into position, but it is thought this is the first instance in which a large number of spans have been made ready and stored until it was desired to place them on the masonry, and also the first time false work has been so built that the spans when assembled could be moved off it and loaded on barges, without tearing down any portion of the false work or interrupting the work of erection, the usual course having been to erect the span on staging built over the water, and to take down enough of the trestles to admit of the barges being placed beneath the span.

The erection of the superstructure was commenced on the 1st September, 1889, and the last span was floated into position on the 19th February, 1890. Trains going over the entire structure on the following morning. The entire bridge thus occupying ten months and twenty days in construction.