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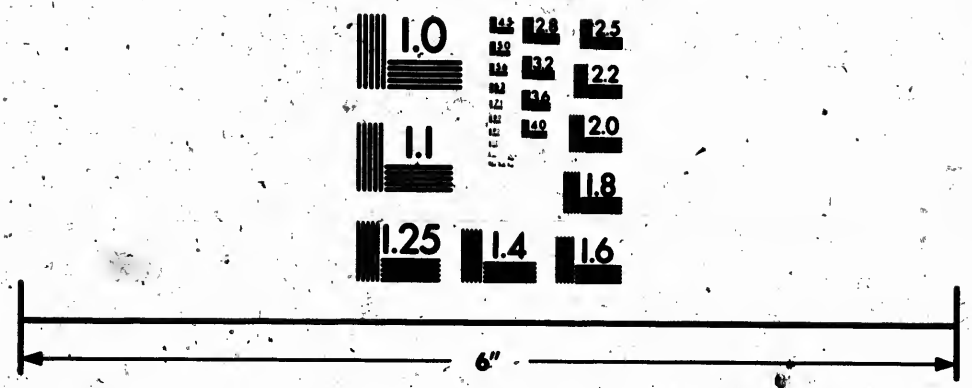

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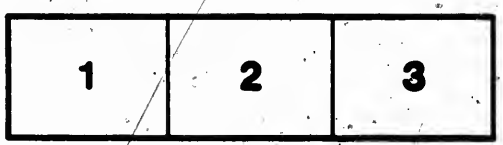

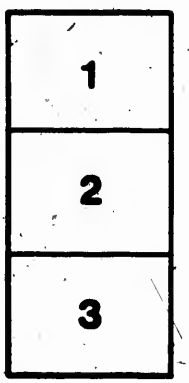

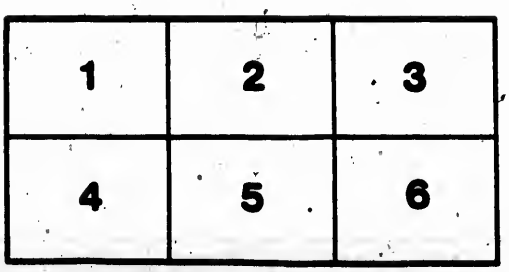

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Canadian Society of Civil Engineers.

ESTABLISHED 1887.

TRANSACTIONS.

This paper will be read on Tuesday the 26th April 1887.

FOUNDATIONS OF THE ST. LAWRENCE BRIDGE.

In the autumn of 1881 the A. and N.W. Railway Company decided to build a bridge across the St. Lawrence, in the vicinity of Montreal. Accordingly, in October, 1881 surveys were made at several places. The first line surveyed was at the Lachine rapids, crossing Heron Island. The river here proved to be very wide, but in other respects a tolerably favorable line was obtained. The next survey was made in November at the Nun's Island, this line showed deep water and a wide crossing more in every respect than the line at Heron Island, the third and last survey was made where the bridge now stands, at this point the sounding shewed the existence of a reef about 500 feet wide, extending from the north shore to the main channel with an average depth of from 18 to 20 feet of water, as shewn on the profile. The current here runs at a speed of from 2½ miles to 6 miles per hour at low water, and from 4 to 9 miles in high water, the difference between high and low water being about 6 feet.

The soundings were taken from a boat allowed to float down stream over the points where soundings were required, at a given signal from the man at the head line the exact position of the lead line was fixed by means of two transits at point on shore, to avoid any possibility of confusion or mistakes each sounding was numbered and the man in the boat who hooked the sounding held up a card with the unit figure of the sounding, so that each transit man and the man in the boat checked the number each time; by this means from 3 to 15 soundings were taken, according to the velocity of the current each time the boat dropped down stream the direction and velocity of the current were taken by floats in a somewhat similar manner, only the position of the float had to be taken at fixed intervals, say half a minute.

These soundings when plotted gave full information as to the surface of the river bottom, and from these soundings 7 trial lines were laid down and the position of the piers marked. A scow was then moored over the site of the piers and borings, taken with an ordinary steel rod 1¼ in. diameter furnished with a screw bit.

This rod answered very well, except at places where the depth of the water exceeded 25 feet and the current strong, in such cases it was found necessary to protect the rod by means of a tube 6 ins. diameter, 20 feet long, through which the rod was passed. The borings shewed bare rock near the north shore, but towards the centre the bottom covered to a depth of several feet with gravel and hard pan. The rock formation the bottom of the river is mostly Utica shale, interspersed with veins and floors of trap, above this formation the blue limestone appears on the south shore.

This was the amount of information furnished when it was decided to call for tenders. However, nothing further was done in the matter until August of 1885, when one or two other lines were tried, and the Company in the following November let the contract for the masonry, in which it was stipulated that the work should be finished by November 30th, 1886, thus giving 12 months for the completion of the contract.

The contract allowed the contractor to use "cofferdams or sink bottomless caissons fitting closely to the rock, into which he can deposit Portland cement concrete to a depth not exceeding ⅓ of the depth of the foundation from the surface of the water; when the concrete is perfectly set the caisson may be pumped out and the masonry commenced from its surface."

The latter method was adopted as being a much more expeditious method than that of cofferdams. During the winter of 1885-6 stone was cut for the masonry and broken for concrete, caissons and scows built and all made ready for spring.

The abutments on the north shore and piers Nos. 1 and 2 were built during March, April and May. On the 12th of May the first caisson was brought down for No. 4 pier. The foundation here was bare rock, so that all required to be done was to get the caisson into place and commence concreting. The caisson was towed out of Lachine harbor by two powerful tugs, both tugs pulling up stream, thus allowing the caisson to drop slowly down with the current. The caisson was built of 12 x 12 in. timber, spiked together by rag bolts, and braced at every 10 ft. with 12 x 12 braces, as shown on the plan; the joints were caulked and made water-tight, about 5 of the upper courses of timber were fastened to those below by long screw bolts, so arranged that by turning the bolts they could be taken out and the upper courses of timber detached after the pier was built, thus removing all timber which would otherwise appear above water.

Three strong posts were built into the front of the caisson for attaching the anchor cables to, and two similar posts at the stern end for fastening guy ropes to, when the caisson had to be twisted round so as to get it at right angles to the bridge centre line. A scow measuring 23 x 70 feet was placed on either side of the caisson, and two timbers stretched from scow to scow crossing the caisson at the bow of the stern, these timbers were made fast to the caisson by chains, and the ends jacked up from the sticks of the scows so as to lift the caisson several feet out of the water, thus lessening its draught, this was found necessary in order to avoid striking boulders or rocks on its way down.

The caisson carried 3 anchors weighing 4 tons each, and each scow carried one weighing one ton, the chains attached to the 4 ton anchors were formed of 1¼ in. links, and the steel wire rope 1¼ in. and 1½ in. diameter. The chain for the smaller anchors was made of ⅞ in. iron, the wire employed in the contract 12 4 ton anchors and 12 one ton anchors with 2 miles of chain cable and 2 miles of steel wire rope. When the caisson was about 600 feet above the site of the pier, which place was marked by a buoy, one of the 4 ton anchors was dropped, and the whole draft of scows and caisson allowed to hang on it so as to make certain of its having taken hold in the bottom, then this chain was loosened and another anchor thrown over, and this one tested in a similar way, and then the third anchor, so that each caisson had always three anchors out of any one of which was capable of holding it, besides the smaller anchors from the scows. The anchors from the caisson were not in one line, but spread a little so that by loosing one chain and keeping the others tight the caisson could be placed directly over the site of the pier. The caisson was thus lowered down till it was within a few feet of the bridge line.

As it happened towards the north shore the current ran very obliquely to the bridge line, thus necessitating the swinging of the caisson round, so as to bring it at right angles to the bridge line; this was often a slow operation, as the moving of the caisson round generally threw its centre north or south of site of the pier, it required about one day to place a caisson in position, as there was an allowance of 5 feet between the inside of the caisson and the masonry of the pier all round, it was considered sufficiently accurate if the caisson was placed within 6 inches of its intended position.

The foundation of piers 4 and 5 were bare rock, so when the caisson was placed over the site of the pier it was loaded down with ashlar laid along the top timbers.

The next operation to prevent any current passing between the bottom of the caisson and the rock, by driving sheet piles of 5 inch plank all round the bow and spiking them to the caisson.

A curtain of canvas fastened round the inside of the caisson, at a distance of a few feet from the bottom, was spread on the rock and loaded with bags of concrete; this was necessary in order to exclude any current from washing over the concrete and running the current.

When this was finished the concrete; was prepared by mixing Portland cement and sand in the proposition of one to one, to this was added as much broken stone as would make the whole into a mass of stone, whose interstices were filled with mortar, the whole thoroughly mixed. The stone was broken to pass through a 2½ inch ring. The proportions were about 3 of broken stone, 1 of cement, and 1 of land. This concrete was lowered into place by means of an iron box holding 2½ yards, the box was constructed of iron ¼ inch thick, with a floor hinged about 2' 6" from the bottom, and opening at the centre by turning a lever; this floor was allowed to fall, permitting the concrete to slip through, but being still protected from the action of the water by the sides of the box; by this means with two gangs by day and two at night 80 yards could be placed in 24 hours.

When the concreting was finished the caisson was left for 2 or 3 days until the concrete had set, when the water was pumped out the concrete levelled off and the masonry commenced.

Very little pumping was required to keep the caisson dry.

The anchors were never removed until the masonry was above water level.

In sinking the caissons it was necessary to take into account that water might get between the concrete and the rock, and thus place the caisson in the same position as a tub when being sunk in the river, with its edge above water and then baled out, in danger of rising and floating away bodily.

Over the foundations of Nos. 6 and 7 piers there was a considerable deposit of gravel, this was partially removed before the caisson was brought down by means of a large rake worked from two scows anchored over the foundation. The rake was hauled up stream along the sides of the scows by men, then dropped and pulled down stream by a horse and windlers.

The head of the rake was formed of an iron bar about 2½ 2½, 5 ft. long on which steel teeth 8 in. to 2½ in. were fastened, and the whole attached to a long handle. This arrangement removed a quantity of loose stones and gravel, the remainder was removed when the caisson was in place by means of a "Hayward excavator."

The next foundation commenced was for No. 8 pier. The surface gravel was removed by the rake and the caisson placed.

The rock here was covered with 4½ feet of hard pan, so tough and hard that the Hayward excavator could make little impression on it. An ordinary clam shell dredge was tried, but without success; recourse was then had to dynamite, and holes were drilled to a depth of 2½ feet at different places and charged, small quantities of hard pan were loosened in this way by each explosion.

Three weeks were occupied at this work with little effect. When a long iron bar was made with a chisel edge of steel at one end and a ring at the other. The bar was about 25 feet long and weighed 1,700 lbs., this bar was hoisted up vertically some 10 or 15 feet by an ordinary pile driving engine, and allowed to drop with its full weight, and by this means the remainder of the hard pan was loosened and removed by the excavator.

From the experience gained at No. 8, it was decided to procure a dredge from the remaining foundations, and, accordingly, dredges No. 5 and 6 were hired from the Harbor Commissioners; these worked in a most satisfactory manner, notwithstanding the hard, tough character of the material to be excavated. Nos. 9, 10, 11 and 12 caissons were brought down and placed without much difficulty.

Some of these were only partially built at Lachine, the remaining courses of timber added when the caisson was near the foundation for which it was intended, the water being shallow just above the site of several of them.

At No. 14 the foundation was covered with 14 feet of hard pan, requiring the constant employment of No. 6 dredge from June 22nd until August 6th.

From the foundation to the surface of the water there were about 33 feet with a current of 4 miles per hour.

Previous to dredging a guard crib was sunk in front of this foundation. The crib was 8 feet wide at bow, 26 at the stern, and 26 feet long.

This crib was sunk with its lower end 3 feet above the bow of the caisson (when in place), just far enough above to clear it, thus forming an eddy in which the dredge could work with little difficulty from the current. This crib was placed in position in a similar manner to the caissons, with the exception that one of its anchor chains was secured to an iron bolt on shore.

This caisson was so deep and required so much loading that rails were used as well as stone to sink it. Some of the rails were placed along the outside near the bottom, and the remainder rested on the cross timbers inside.

At this and several of the other foundations the electric light was used at night and also in the daytime under water, to assist the divers in clearing the foundations and placing the bags of concrete round the edges of the caisson. No. 13 pier was always looked on as the most difficult.

It stands in 28 feet of water and at the swiftest part of the current, and on it is to rest the cantilion spans 408 feet each.

It was of the greatest importance that the foundation should be first class in every way, so as to avoid any possibility of settlement when the weight of superstructure came on it. The pier is much larger than any of the others, and the placing of the caisson required much care.

A guard crib was also placed in front of this, similar to that used at No. 14, but a little larger, being 30 feet wide at the stern.

This crib was brought down when about half built in a manner similar to that used for bringing down the caissons, being placed between two scows and supported by cross timbers. No. 13 pier stands directly in the centre of the main channel, the current here being so strong as to sweep off all loose material, leaving the bottom bare rock, and thus affording little chance for anchorage.

Accordingly a "dead man" was placed on a projecting point on the south shore, about 1,700 feet above No. 13 pier, this "dead man" consisted of a 16 in. pine log, let into a trench excavated purposely in the limestone, both ends of the log were well loaded down with stones, and round the centre the 1¼ wire rope was lapped and secured, the other end of this rope was rolled in a coil on the deck of a scow anchored about 400 feet above the site of No. 13 pier, the scows attached to the crib carried 3 four ton anchors and 2 one ton anchors, these large anchors were dropped as the crib floated down, and as it passed the scow the end of the 1¼ wire rope was taken on board and secured to the "snubbing posts." Thus, the crib had 3 4 ton anchors, and this wire rope, two of the anchor lines passed through the front timbers of the crib a few feet from the bottom, thence up to above water level, then over another cross timber, and round the snubbing posts, and the other two lines passed directly above water over the front timbers and around the posts.

As the line from the "dead man" passed diagonally across the steamboat channel it was necessary to load it down so as to avoid any risk of accidents to passing vessels; for this purpose 3 heavy pile hammers were used, tied together and dropped over the line at the centre of the channel. The breaking strain of the 1¼ inch rope would be about 30 tons.

The crib was thus lowered, so that her stern remained about 10 feet above the position of the bow of the caisson when in place.

The crib was completed here and sunk, so when the caisson was floated down and dropped behind the crib, it required to be forced *down stream* to get it into place, so strong was the eddy formed by the protection crib.

The bottom here was bare rock perfectly clear, so that when the caisson was sent concreting commenced at once.

I may mention that it was in connection with this pier that the greatest loss of plant was sustained by the contractors. No. 5 dredge was brought over to try the nature of the bottom before the protection crib was sunk. A scow was brought alongside and secured to the dredge, the action of the current on this scow swung the dredge round, and after swinging for a time broke away from her anchor and dropped swiftly down stream, till meeting with a more shallow part of the river, the "spuds" come in contact with the bottom, and the dredge went over on her side, where she now remains, the men on board having a narrow escape from drowning. As soon as the piers were finished the caissons were well protected from the action of the current by rip rap to within a few feet of low water level.

As some curiosity was felt as to the power required to hold No. 13 caisson in the heavy current, some experiments were made with two models one 4 times the size of the other. The models were held in the current, and the strain on the line holding them measured, by observing the strain in currents of different speeds we arrived at the conclusion that the force varied as the lineal dimensions of the caisson, and as the square of the velocity of the current from which calculated the holding strain on the large caisson in the main channel to be from 60 to 100 tons, being subject to serious increase of strain due to shearing from side to side.

G. H. MASSY,
Engineer in charge of St. Lawrence Bridge.