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Paper No. 162.

SUPERSTRUCTURE OF THE INTERPROVINCIAL BRIDGE, OTTAWA.

By F. P. Shearwood, A.M.,Can.Soc.C.E.

The bridge recently erected at Nepean Point, Ottawa, connecting as it does two important commercial towns, as well as two provinces, naturally attracts the attention of the ordinary observer and is especially interesting to the engineer.

The bridge and approaches consist of the following structures shown in Plate 8.

1. The Southern approach including—		
Trestle at St. Patrick Street..	360'	
Skew plate girder span..	30'	
	——	390'
2. The main crossing of the Ottawa River including—		
Two plate girder spans..	59'	
Cantilever structure..	1,049'-9"	
1 Truss span	247'	
1 Truss span..	140'	
	——	1,495'-9"
3. The Northern approach including—		
Trestle to first roadway	390'	
Plate girder span over first roadway..	60'	
Trestle from first roadway to Laurier Ave ..	274'	
Skew plate girder over Laurier Ave..	75'	
	——	799'
Total		2,684'-9"

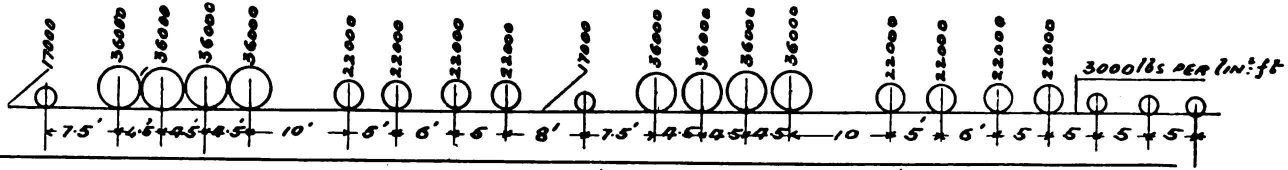
The Interprovincial Bridge Company stipulated that provision should be made for a single track steam railway, two lines of electric railway, two roadways for vehicles and two footpaths. The arrangement of these as finally agreed upon is shown on plate 12.

The approaches on the Southern end are designed to carry three steam railway tracks. The electric track on the east side of the bridge when it reaches the Southern abutment ascends by a surface track to the summit of Nepean Point Park. The Western track, descending to the level of St. Patrick street, crosses underneath the trestle which carries the steam railway tracks.

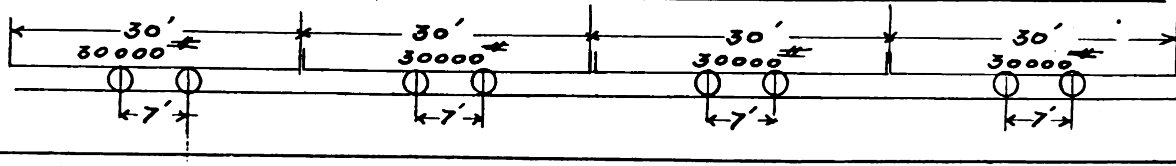
The electric track roadway and footpaths on reaching the Northern abutment descend by a 5 per cent. grade to the level of the ground at the first roadway crossing. The trestle beyond this point supports only a single track railway.

The design for the superstructure was made by the Dominion Bridge Co., Ltd., in accordance with the following loads adopted by the Interprovincial Bridge Company and approved by the Dominion Government.

RAILWAY LOAD.

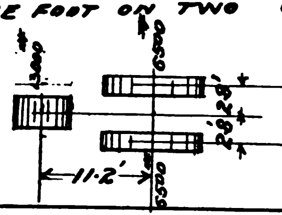


ELECTRIC R'Y LOADS



ROADWAYS = 40 POUNDS PER SQUARE FOOT ON TWO 8 FOOT ROADWAYS. FOR STRESSES IN TRUSSES

OR ROAD ROLLER OF



FOR STRESSES IN FLOOR SYSTEM

FOOT WALKS = 20 POUNDS PER SQUARE FOOT ON TWO 5 FOOT SIDE WALKS, FOR STRESSES IN TRUSSES.
OR 70 POUNDS " " " " " " " " " IN FLOOR SYSTEM.

In other respects the Dominion Government specifications of 1896 were followed.

The trusses, for the sake of stability are spaced 24 feet apart from centre to centre, the steam railway being placed in the centre and the foot walks between this and the trusses in order to utilize what would otherwise be vacant space.

The general arrangement of the suspended span trusses was to a large extent determined by the Dominion Government stipulation, that there should be a clear waterway above H. W. L. of 45 feet, and by the desire of the Interprovincial Bridge Company, that the base of rail should be kept as low as possible, in order to avoid grades in the approaches.

In order to save masonry in the main piers the shoes were placed as near as permissible to the river surface and the lower chords inclined. This was found not to be uneconomical in the steel weight, and had also the advantage of reducing the total height of the main towers.

To obviate the difficulty encountered in the suspended span, by reason of the short distance between the bottom of the steel and the base of rails, and also on account of the shoe detail used at the northern end of the anchor arms, a greater distance was taken between the centre line of the lower chord and the base of rail of anchor arms. This necessitated a slightly unsymmetrical angle of rise in the chords on either side of the towers, but on account of the long overhang of the floor beam brackets, it was thought to be unobjectionable and has proved to be unnoticeable in the structure even before the floor was laid.

The question of the wind stresses also presented an interesting aspect of the structure. A wind pressure of 30 lbs. was specified and the surface it acted upon was represented in the usual way as twice the area of the trusses and once the floor system as seen in elevation. A moving train of 10 feet in height was also taken into consideration and placed so as to give the maximum stresses in any member.

The stresses in the top laterals from the suspended span are transferred to the top lateral trusses of the cantilever and are not conveyed in the usual method by the end post bracing of the suspended span to the bottom lateral system. The object in doing this was to distribute the wind stresses more evenly between the upper and lower chords and also to obviate the difficulty of providing an efficient shear joint for a large stress at one point.

The top lateral shears are figured to pass down the heavy inclined members S 6-7 and S 8-9. To insure this result the laterals in panels 6 and 9 are omitted. The upper laterals are designed to resist tension only, but are latticed vertically for the sake of appearance. The lower laterals are designed to act both in tension and compression. This was found more economical and was adopted in order to simplify the difficulty of providing for secondary stresses induced at the pin joints. Sway bracing is used between all compression members where possible, that between the inclined members S 6-7 and S 8-9 being designed to resist the shear of the upper laterals connecting to them. The sway bracing in posts P 8 has only to transfer the shear from the laterals in panels 7 and 8. The wind pressure from the floor and train is transferred by knee braces connecting the floor beams to the lower chords.

The cambering of the suspended span was accomplished in the usual manner by lengthening the upper chords, but in the anchor and cantilever arms each member was corrected for its own alteration of length due to the dead load stresses and pin play.

The deflection due to live load at the ends of the cantilevers was compensated for by shortening the upper chords in panels 6 to 9. The bridge as finished shows between piers 2 and 3, a slight rise in the floor on a fairly regular curve. The anchor arms also have a slight, but noticeable camber.

Plate 10 shows in detail the construction of the anchor arms which were made in such a way, as to be self supporting before any of the cantilever arms were erected, as it was quite possible that the scows used to support the false work might be withdrawn before the erection of any part of the cantilever. This required a temporary strut to be placed in panel No. 7 (shown by the dotted line in Plate 9) and also that tension should be provided for at the lower chord splices and in the connection of S 3. The bottom connections of the suspended posts were reinforced to support the traveler during erection. The lower chords of the anchor and cantilever arms were constructed with three ribs for the purpose of reducing the thickness of the material and consequently undesirably long rivets. In calculating the stresses in the pins, they were considered as continuous girders, resting on three rigid supports formed by the ribs of the lower chords. The other members were assumed to be loaded in proportion to their areas.

The tie plates on the lower chords at the pin points were designed to redistribute the increments of stress received through the pin into the three ribs proportional to their areas, and also to transfer the increments of stress from the laterals. At points 2, 4 and 6, the lower laterals are connected to the chords with no tie plates occuring at the point of intersection on the upper side of the chord, and the lateral plates are strengthened to resist the bending induced by the transference of the shear from one lateral to the next.

Plate 12 shows in detail a portion of the cantilever arms and also a part of the suspended span, P 12 representing the hangers to carry the suspended span and at the lower part shows the difficulty already referred to, due to the extremely short distance between the floor and the bottom of the steel. The heavy inclined members at this point as well as at No. 12 interfered with the abutting joint of the floor beam as used at the other panel points of the bridge, and the floor beam was deepened to straddle the chord and to obtain a compression splice below it. The details at the connection of the suspended span L 13 are shown with the erection wedges in place where the pin bore on two small forgings which were removed when the centre span was connected and which bore on several shims. These shims were used as being the best way of adjustment compatible with the method used for erection and in their turn bore on stiffener angles riveted to the chord L 12.

At U 14 is situated the upper adjustable joint, and in order to resist the tension during erection two adjustable yokes engaging the pin were supported by four diaphrams. Between the diaphram and the yoke nuts, shims were placed and slotted to enable them to be easily applied when starting to erect the suspended span and removed when it was connected. The top lateral connection at this point is shown in the plan view, T R 14 being riveted to the chord U 14, is held from horizontal movement by the plates which connect the top strut T S 14 to the chord U 13, being fitted to bear against the chord 14. The top strut, T S 14, then takes the shear from the top lateral system of the suspended span and transfers it to the top lateral truss of the cantilever arm. It will be noticed that the lateral connection plates on both chords are extended to meet the tie plates in order to reinforce the ribs against bending from lateral stress.

At point U 13, a somewhat intricate connection for the laterals is shown, TR 13, necessarily being the same width as the chord U 13 while TR 12 is wider on account of other top lateral connections. The connection plates of TR 13, are riveted to the chords U 13 and TS 13. TS 13 is connected directly with the succeeding lateral TR 12. At this point it was inconvenient to intersect the centre lines of the horizontally stressed members; but the small bending is easily resisted by the wide members of the vertical trusses.

At point U 11 is seen the method of utilizing the post channels to make a stiff and efficient connection for the laterals. The top strut is placed slightly away from the pin centre in order to connect to the sway bracing which is kept on the centre line of the posts.

Plate 12 illustrates the means of transferring the wind stresses from the suspended span to the cantilever arms, P 13 and FB 13 are connected to L 13 while L 12 has slotted connection to allow for the expansion and contraction of the span.

The stringers in panel 13 are riveted to the floor beam FB 13, but those in panel 12 are only supported on brackets on which they slide to accommodate the expansion and contraction. The shear from lateral R 13 is transferred to the floor beam by 12″ channels and this is held from moving by the brackets placed on each side of the stringers S 12, which are riveted to the bottom strut BS 13, thus transferring the shears directly to R 12. The angle bracing between the stringers S 13 is to relieve the floor beam from the bending induced by the horizontal load applied on the brackets. This method of transferring the wind shears enables shears to be perfectly distributed between the two sides, and the laterals being designed to resist tension and compression, only half the total stress is resisted in each case, and the compression wind stresses in the main chords are slightly reduced.

In the cross section of the floor beam is seen the construction of the floor beam brackets for the sliding support of the stringers, and the tension at the top of the brackets, is provided for by a splice plate passing through a slot in the floor beam web and riveted to the fixed stringer.

The details of the construction on pier No. 4 are shown on Plate 12. To prevent the use of a very wide pier and the eccentric placing of the anchorage, the ends of the cantilever and fixed spans were made to rest on a common shoe. Thus the dead load of the fixed span was used directly to supply part of the anchorage required for the cantilever.

It will be observed that short pieces of channels placed endwise are inserted in the centre of the upper tier of beams of the shoe, which are to resist the horizontal stresses due to the resistance made by the rollers to the expansion and contraction of the spans and so obviate bending stresses in the webs of the eye beams.

To carry the horizontal stresses to the masonry without calling on the ribs of the shoe to do the work for which they could hardly have been made capable, a series of struts was used, which is shown in the half cross section in Plate 12. The laterals of the fixed span are connected with the bottom flanges of the floor beams, the shear being transferred by the inclineal strut to the bottom strut at the ends of which the anchor arm laterals are connected. On the lower flange of this strut, to which all the lateral shears have been transferred, a steel casting was bolted, which slides longitudinally in a casting bolted on a two webbed girder, which is firmly anchored to the masonry, and by which all side movement is resisted.

Plate 11 represents the portal bracing situated between the inclined members S 6-7, which differs only from the bracing between S 8-9 in that the main member S 8-9 is slightly wider back to back of the flange angles.

The object of this bracing as already stated is to resist the shears from the top lateral system. The top lateral connection plate connects also the top strut, upper chord, and S 6 by which the components of the stress from T R 5 are transferred direct to their proper channels and not by relying on the friction of the pin.

Owing to the necessity for providing sufficient head room over the railway tracks, the diagonals resisting the wind shear do not intersect on the centre line of S 7, and consequently this member is reinforced by four angles, riveted to the webs and tie plates, in order to resist bending. As there was a large amount of shear induced between these points, it was found inadvisable to allow the webs of S 6-7 to remain unconnected for any appreciable distance, and so the working members CS 7 and P 7, which were obliged to be connected with the pin, were passed through slots in the heavy tie plates connecting the webs. The other two, which are merely stiffening members, are riveted at this point to lug angles connected with the tie plates. The extra size of the lattice in S 7 is to provide for the wind shears. At the lower end of S 7, the diagonals are connected as low as possible. Tie plates and a diaphram are introduced to reinforce the member, and the shear is transferred by a gusset plate, which connects directly with the bottom strut shown on the Plate.

Plate 11 also shows the details in connection with the posts and the shoes on the main piers. The post P 8 has its webs placed in the opposite direction to that used in the other members of the bridge.

At the joint U 8, to reduce the bending on the pin and also the thickness of the bearing points, two diaphrams are inserted between the webs, and bearing plates are riveted to the flange angles, forming in all four points of bearing for the pin. Two of the pin plates of the diaphrams are extended beyond the pin to connect with the top strut. The floor beam at this panel point passes between the webs of P 8, resting on a diaphram riveted to the webs of the post.

To accommodate the packing of the members at pin L 8. P 8 was spread so as to bear on the pin outside of the lower chords which abut on the pin opposite each other. One pair of plates on each running past the pin to resist a possible tension from the wind force, and S 8 is made slightly wider than S 7. The ribs of the cast steel shoes do not encircle the pin, as no uplift can possibly occur at this point until the wind shall blow at a pressure of 77 lbs. per square foot on the total surface, and this is assuming that the anchorages do not assist in the resistance. The carrying of the wind force to the masonry is accomplished by all the members which have lateral stresses connecting with the cross strut BS 8. as seen in the drawing P 8. S 7 and S 8. having gusset plates riveted to them and to the upper connection plate of BS 8, the bottom laterals are riveted directly to the connection plate of BS 8, therefore, all the lateral shears are concentrated in BS 8. This is connected by gusset plates to the upper tiers of the beams under the shoes. The lower tier has two lines of separators and also is filled with concrete.

A typical floor beam at panel No. 16 is shown on Plate 12, the tension splice at the support for the cantilevered bracket is made by riveting splice plates to the flanges which pass through slots made in the post channels. The posts are reinforced at these points, the sectional area through the slot being 50 per cent. in excess of the net area required in the member.

The compression joint is made by facing the two abutting flanges which bear on the post, the two webs of which are separated by a small casting accurately fitted between them. The diaphram between the post channels is figured to transfer the greatest difference in shear between the brackets and floor beams. The two beams shown by dotted lines were placed there temporarily during erection to carry the erection traveller track. It will be noticed that the number of rivets over these beams is increased on account of the fact that the forward support of the traveller, while hoisting was sustained at these points.

The planking of the footwalks is continued between the truss members in order to take advantage of the extra width thus obtained.

The fence being next the road, and therefore liable to severe shocks, is a substantial structure 5 feet high; the rails are composed of 6" channels, the two upper ones being placed horizontally and the bottom one vertically. The posts are placed about 15 feet apart, those at the floor beams being firmly braced as shown, while those at the intermediate points are held by bracing extending out from the stringers. The fence is figured to resist a horizontal force of 2,000 lbs. applied at any point.

The anchorage at Pier No. 1, is shown on Plate 8. A steel grillage is placed 33 feet below the surface of the masonry which forms the counterweight and is composed of 2 plate girders running all the way across the pier, above which are supported several 15" eye beams built in the masonry. The main girders are supported by groups of 15" eye beams bearing on cast bolters through which the adjustable hangers pass. The four eye bars connecting the pins of the anchor arm descend through a well in the piers and are connected with the hangers by pins. Adjustment was considered advisable so that any small inaccuracy of placing the grillage could be rectified and also to put initial strain in the bars which would prevent any movement in the shoes of the anchor arm due to the considerable variation of the reactions.

The anchorage at pier No. 4 through the utilization of the dead load of the fixed span is much lighter, the eye bars at pier No. 1 being replaced by loop rods, and the counter-weight girders do not extend across the pier. In other respects the construction is similar.

The steel work at both piers is placed in wells which can be entered from below and inspected or painted. Ladder rungs are placed in the masonry to enable a workman to reach the whole length of the bars.

By giving fairly complete drawings, which should show the general construction of the bridge, it was not thought necessary to give a written description of the details, which are very similar to those used in everyday practice. The stresses are statically determined, and no ambiguity of stresses in the main members occur. Therefore, stress diagrams and other computations are omitted, since to put them in proper form for publication would entail a vast amount of labour, and would be of little interest to those conversant with the elements of bridge construction.

The principal part of the description is confined to explaining the methods and reasons for those details, which were somewhat difficult to design and were dealt with in a somewhat unusual manner. In this way it was thought that the most useful information could be presented to the members of the Society for discussion expending the time and space for its preparation to the greatest advantage and profit.

The method of erection, which is probably the most interesting feature, is not here touched upon, as it will be fully treated in a separate paper by the engineer who was in charge.

Thursday, 5th December.

E. MARCEAU, Vice-President, in the Chair.

The following donation to the Library was reported: —"Altitudes in Canada," by James White.

It was moved by Mr. W. J. Sproule, seconded by Mr. G. Janin, and carried—"That the Council is hereby recommended to obtain a list of Engineers practicing in the Province of Quebec who are not Members of this Society."

Discussion on paper by Mr. C. B. Smith on "Discharge of Sewage from Toronto Sewers in 1900," occupied the evening. (See Part I, page 128 of this volume).

Thursday, 19th December.

JOHN KENNEDY, Past President, in the Chair.

Paper No. 163.

CONSTRUCTION OF THE SUBSTRUCTURE OF THE ROYAL ALEXANDRA (INTERPROVINCIAL) BRIDGE AT OTTAWA, CANADA.

By GUY C. DUNN, M. CAN. SOC. C.E.

Since the Pontiac Pacific Junction Railway and the Ottawa and Gatineau, now the Ottawa Northern & Western Railway, have come under the control of practically the same management, it has been looked upon as a matter of absolute necessity that they should have an entrance of their own from the Province of Quebec into the City of Ottawa, in the Province of Ontario. After numerous surveys of the Ottawa River had been made, both above and below the Chaudiere Falls, it was finally decided to bring the two lines to a junction in the City of Hull and across to the Ottawa shore at Nepean Point, and construct an approach between the Rideau Canal and Major's Park, going under Dufferin Bridge, and cutting an opening through the abutment of the historical Sappers Bridge; thus making a connection with the Canada Atlantic system at the Central Station.

Several bridge surveys were made across the river at Nepean Point, but it was not until February, 1894, when a survey was made by the writer under Mr. W. Dale Harris, the then Chief Engineer of the two railways, that a line was laid down, which, with a few minor changes, was finally adopted. Owing to the heavy deposit of sawdust, slabs, etc., at the bottom of the Ottawa River, it was found necessary to employ a steam diamond drill as being the only practical means of getting a reliable profile of the bottom of the river. A short description of the manner in which this was done may be of interest.

After the centre line was marked off on the ice, every 50 feet across the river, and two lines were run parallel to this, one 100 feet up and one 100 feet down stream, borings were taken at every 50 feet on both these lines, and afterwards at intermediate points where considered necessary. In many cases, considerable difficulty was found in getting the drill through the refuse deposited by the mills, which consisted not only of sawdust, but of slabs and logs (some of the latter being of oak), and it was found necessary to abandon the diamond bit and use what is known as a blind bit, first filing the edge into rough teeth, and then sawing this through slabs, logs and sawdust until rock was reached, when the pipe would be withdrawn as gently as possible, the rough bit replaced by the diamond and boring continued into the bed rock. A core of clean limestone, 15/16 inches, was obtained at each hole, and no soil of any kind was found on the rock. The sawdust deposit ran from shore to shore, the greatest depth found being 60 ft., with 20 ft. of water above it at winter level. Numerous explosions of sawdust caused by the accumulation of gases have occurred in the Ottawa River in this vicinity, in some cases strong enough to break the ice, upset row boats, etc., but no explosions of a serious nature occurred during the construction of our works. After this survey was made, which included cross sections and contours of the heavy side hill between Nepean Point and Dufferin Bridge, nothing more was done until January, 1898, when the services of Mr. G. H. Massy, were secured by the Companies, and the final location of the piers and lay out of the bridge were decided upon.

The bridge and approaches are over a mile and a third in length, and give the Railways a magnificent entry into the city of Ottawa. They consist of the Hull approach of 500 feet of earth embankment 15 feet high, 1,000 feet of timber trestle, averaging 20 feet in height, which crosses seven streets by steel girders on concrete piers, 690 feet of single track steel trestle on concrete pedestals, and 390 feet of double roadways.

The main bridge, from pier 6 to the south abutment, is 1495′ 9″ long, consisting of one cantilever span 555′ 9″, 2 arms 347′ each, one truss 247′. one do., 140′, and two small shore spans on the south side respectively 27 and 32 feet long. From the south abutment on the Ontario side, at which point the waggon roads leave the bridge, the railway is built on rock embankment to St. Patrick St. Trestle, which is a three track steel trestle 270 feet long, the greater part being on a ten degree curve, and from the south end of the trestle to Dufferin Bridge, a distance of nearly half a mile, the track is on half rock cutting and half embankment, held in by a heavy dry masonry retaining wall, in some places 50 feet in height, and allowing for three tracks on a roadway 40 feet wide.

The contract for the bridge and approaches was let to Mr. H. J. Beemer, five of the water piers (1 to 5 inclusive) were let to Chas. H. Deans, and the contract for all the steel superstructure let to the Dominion Bridge Company, Limited, of Lachine.

The writer will avoid as much as possible the general details of construction which have been so often described, and will endeavour to deal with those characteristics of the work which may be of some interest to the profession, as being out of the ordinary run of bridge work, and in some cases peculiar to this undertaking, referring more particularly to the sinking of the caissons in the sawdust, the removal of the sawdust, the placing, sinking and filling of the caisson for pier No. 2 (which is one of the deepest concrete piers on the continent), and the successful boring from the top of the concrete in this pier to bed rock below, a distance of nearly 70 feet, and obtaining satisfactory core all the way through.

In laying out the river piers, owing to local conditions, it was considered advisable, by the Engineer in charge, not to use any base lines, but to rely entirely on intersections, and the work was laid out as follows:—A point was chosen on a wharf about 1,000 feet above the bridge and a permanent hub placed as shewn on sketch No. 13 at Point A.

The different piers were laid out on the ice, a steel ribbon over 1,000 feet in length being used, and a line was run in parallel to the centre line of the bridge, and twenty-five feet above it. The transit was sighted on the intersection of this line with the longitudinal centre line of the pier, the line produced to the shore (or as it happened in one case to a crib), and a permanent hub put in. This work, of course, had to be done quickly to avoid any movement of the ice, and checked over several times, an ordinary 6″ transit being used. The result was that all measurements on this structure came in practically exact.

Pier No. 5.—Construction was commenced early in February, 1898, the caisson for Pier No. 5 being the first to be sunk. Owing to the shallow water (21 feet), and there being only eight feet of sawdust at this point, no difficulty was experienced in cleaning off the site and sinking the caisson to the rock bottom, which was ready to receive concrete on the 26th February. The depositing of concrete was commenced on the 28th February, in the manner described later, and completed on the 2nd of March.

Pier No. 4 was the next to be built. A derrick scow having been constructed and rigged up with a powerful hoisting engine and a clam shell dredge, a channel was cut through the ice to the site, through which, with much difficulty, owing to the anchor ice freezing to its bottom, the scow was hauled to the point where the pier had been located. The sawdust at this point was 17 feet deep, and the clam shell commenced its removal on the 27th February. The contractor had the bottom cleaned off, caisson in position, and concrete commenced on the 5th March. In removing this sawdust a considerable portion was deposited on the surrounding ice, and the residents of Hull carted away most of it to use as fuel; perhaps in the future the large deposit now resting on the bottom of the Ottawa River may be utilized for some such purpose. This caisson was filled in about four days. The caissons for piers Four and Five were ordinary bottomless ones of 12″ x 12″ hemlock. Masonry was commenced on piers 1, 4 and 5 (the former being a shore pier) immediately after the completion of the concrete filling.

Pier No. 3.—On the 26th July dredging out sawdust was commenced at Pier No. 3. The depth of deposit at this pier was 20 feet, with 22 feet of water above it, the clam shell removing the sawdust very slowly, owing to the slabs getting crossways in the clam and allowing the sawdust to run out. The excavated material was deposited into scows and towed to shore, where it was dumped. During this excavation a number of large logs were hauled out and a large sized anchor with piece of chain attached, the links of which were so badly corroded that it fell apart. The excavation was made considerably larger than the area of the caisson, the sides having a slope of probably about 1 to 1. The sawdust itself formed a fairly compact mass, as the slabs tied it together and assisted to keep it from falling in. On the 12th August, the preliminary cleaning off of the foundation rock was completed and the caisson towed into place. This caisson and the one for pier No. 2 were of similar design. They were built of 12″ x 12″ hemlock, braced with 4 heavy timbers over every four courses and tied into the sides. Owing to the depth of water at these two piers (about 46 feet at pier No. 3 and 74 feet at pier No. 2, summer level), the caissons were designed in such a manner as to allow all weight necessary to sink them to be placed at the bottom, and at the outside, therefore not robbing the concrete of any of its legitimate area inside the caisson. As will be seen by the plan, the upper part of the caisson was built on the same batter as the masonry, 1 in 24, but when it reached a point about 15 feet from the bottom, the batter was sufficiently increased to allow a wall to be built from the cutting edge up all around the caisson and tied into the main wall, thereby forming a pocket capable of holding enough sinking material to lower the caisson to the desired depth. The plans for these caissons were designed by Mr. Lee Treadwell, the contractor's Engineer. After the caisson had been placed approximately on centre, sufficient sand and broken stone were deposited into the sinking pocket to lower it until cutting edge was almost touching bottom. Divers were then sent down to remove any remaining sawdust, which was sent up in a large iron bucket to the surface. This took a considerable time, the divers complaining greatly of the heat caused by the accumulation of sawdust around the caisson; the caisson was then placed exactly on centre and lowered to the bottom. The bottom edge having been scored when constructed to approximately fit the bed rock, no trouble was experienced in placing this caisson, as there was no current at this point and the bed rock at this pier as well as at piers 4 and 5 did not need further levelling. After the divers had packed any holes and crevices found around the bottom of the caisson, the Company's inspector was sent down for a final examination, and on his report being satisfactory, depositing the concrete was commenced on the 25th August, and continued night and day, until completion on the 31st day of the same month. The concrete for this pier as well as at piers 4 and 5 was composed of one of cement, one of sand and about five of broken stone. The broken stone was not screened, as after testing the stone chippings by using them instead of sand in briquettes, the result was very satisfactory, and it was decided to allow their use in the concrete.

The concrete at piers 4 and 5 was mixed by hand and that at pier 3 was mixed by a Sooysmith mixer which did excellent work and gave entire satisfaction. It is a horizontal cylindrical machine about 14 feet long, having a shaft running longitudinally through the centre, to which was attached a number of paddles. It was placed on a scow alongside the caisson. The cement, sand and stone were supplied by carriers on endless chains and the water obtained from a tap controlled by a man. The cement and sand were the first to enter and got thoroughly mixed before they reached the point where the stone and water entered almost simultaneously. Everything then got a thorough mixing and was finally ejected from the end of the cylinder into the depositing kibble. As the carriers were set at their proper proportion before the machine was started, and all worked from the same gearing, there was no measuring required ; all the inspector had to do was to see that the carriers were kept full.

Pier No. 2.—The construction of the caisson for pier No. 2 (see plan No. 15) was commenced on the Hull shore. The caisson was launched and then towed over to the quiet water below Nepean Point, where it was completed. This caisson, from top to bottom, was about 76 feet high, and as previously stated was a similar design to that of No. 3. The clam shell commenced excavating the sawdust at pier No. 2 on the 2nd September, 1898, and the process of removal was similar to that employed at Pier 4; owing, however, to there being a more swift current, a larger area had to be excavated before the caisson was placed. The sawdust at this point was 15 feet deep, with 57 feet of water over it. Two scows 80′ x 20′ each were now placed, one on each side of the caisson; a truss built from one scow to the other at each end (see plan No. 15), and the caisson suspended from them by heavy cables, sufficient ballast having been put into the sinking pocket to keep it steady. On the 16th of September they were towed into position, the current at this point running at about 3 miles an hour. Cables were then stretched from the scows to rock bolts, and to pier No. 1 on the Ontario shore, to two heavy ship anchors on the river side, and up stream to a large Chinese anchor, the cable from this anchor entering the bow of the caisson some distance below water level. Although all the anchors were bearing on sawdust debris, no dragging occurred.

The caisson was then lowered almost to the bottom and divers sent down to remove the balance of the sawdust. They found the shore slope of the rock to be very smooth and to extend some distance into the caisson. The contractor was therefore instructed to blast this section from one end of the caisson to the other. A steam drill was brought into requisition and a line of holes drilled about 3 feet deep and 5 feet apart. A diver was sent down to load them and they were fired by the battery from the top. The loose stone was then removed and the caisson placed in position, being almost to an inch on centre both ways, but owing to its extreme height it was difficult to ascertain as to its being plumb. This was, however, checked in three different ways; firstly, by a level across the caisson, and secondly, by its batter, by running a straight edge down the side. Owing to the great height of the caisson—nearly 80 courses of timber—these tests were not considered sufficient, and as a third test a plumb bob was obtained, weighing about 50 lbs., and was lowered 50 feet from the inside edge of the caisson, first on one side and then on the other. A diver was sent down with a stick, with which he measured from the sides of the caisson to the cord, marking the place on the stick; repeated trials gave the same result, and the caisson was found to be practically perpendicular. The divers were once more sent down to pack any crevices at the bottom of the caissons with bags of neat cement.

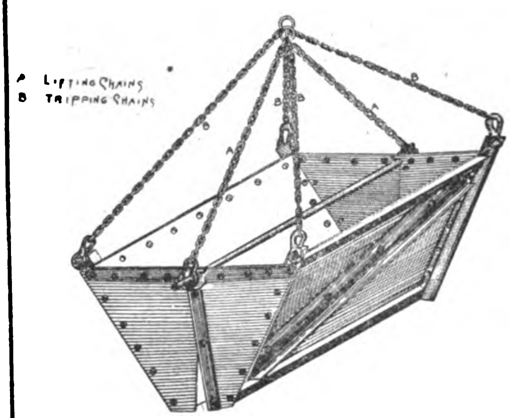
The diving at this pier was a very interesting feature of the work, and the men worked under great difficulties, owing to the immense pressure. Half an hour as a rule was the length of time they could stay down, although on one occasion one man remained down for two and a quarter hours. The water was very dark and nothing could be seen after they had descended twenty feet below the surface. After the Company's diver had made an entirely satisfactory report, the contractor received instructions to commence the deposit of the concrete, which he did on the 9th of October. The concrete for the lower twenty-five feet of this pier was mixed with the mixer and the specifications were altered to 1 of cement, 2 of sand, and about 4 of broken stone. Work was continued until the 17th of October, when 24 feet in depth or practically one-third of the concrete portion of the pier had been deposited. Just at this time an unfortunate accident happened to a large bridge under construction, killing a number of men and causing several sensational articles to be published in the local papers regarding bridge work in general and concrete in particular, and, by orders from the Dominion Government, work was suspended on this pier, the Government Engineers holding the Companies to a certain clause in their specifications, which stated that the caisson might be pumped out and the balance of the concrete deposited dry. To do this with the caisson which had been constructed was impossible, and the cost of adapting it for and obtaining a compressed air plant was prohibitive, or at least was not considered to be warranted, as the concrete and the methods of depositing were believed to be in every particular satisfactory. A test of the concrete already deposited by means of a diamond drill was then suggested, but it was not until the 10th of March, 1899, that permission was obtained from the Government to proceed with the work conditional to satisfactory core being produced through the 25 feet of concrete to the bed rock. The same drill was obtained that was used on the survey in 1894, and operations were commenced, but, owing to the depth of water which had to be drilled through, and, although a diver was sent down to steady the drill rods which were old and shaky, it was found impossible on account of the great vibration to obtain satisfactory results. A request was then made to the Government for permission to deposit the remainder of the concrete to its calculated height, conditional to our giving them a satisfactory core from top to bottom. This was finally agreed to, and concrete again deposited after first washing off the top of the old deposit as well as possible with a steam pump. Owing to the test that had to be made and on account of not being able to obtain any facts in regard to any previous borings in concrete, the proportions of the concrete in the last deposit were increased to 1 of cement, 1 of sand, and what stone it would take, and the caisson was finally filled on the 1st of April of the same year. This last deposit was mixed by hand, the weather being too cold to allow the use of the mixer. The platforms were on the Hull shore and the concrete shovelled into the kibbles, which were drawn to the pier on sleighs. The sand and water were slightly warmed, very little salt being used, and the temperature of the concrete, when placed in the kibbles, averaged 55 to 58 degrees Fah., and did not vary before being deposited under water. The concrete was allowed to set until the 19th of August.

During the deposit of the concrete in the lower portion of this caisson a diver was sent down to report as to whether the concrete was leveling itself off or not, as an opinion was expressed that it should be raked over or shoved with a hoe to the sides and into the nose at the bow, but he reported that it was of its own accord filling up to the sides of the caisson most satisfactorily, and did not require any assistance.

When the caisson was un-watered the best diamond drill to be found was secured and started in the concrete. The first bit used gave a core of 2⅛″ diameter, and satisfactory results were obtained from the start. The hole was run down 40 feet when, owing to the wall giving so much trouble and delay on account of a lot of loose stone, broken core and chippings which had scraped off, it was considered better to start a new hole than to take the time to clean this one out, and hole No. 2, which was carried through the bed rock, was commenced. No difficulty was experienced until a depth near the bottom of the pier was reached, when the vibration of the drill became so great that collars had to be attached to the tubing, and when near the bottom the bit was changed for a smaller one, giving a core of 1⅜″ dia., which was used until bed rock was reached and a piece brought up. This core was obtained in pieces from about two to six inches long and is now in the possession of the Dominion Government, who had an inspector on all the work done on this pier. In this boring the drill went through four different brands of cement, and no appreciable difference could be noticed in the core obtained as we passed from one deposit to another. The diamond drill was also run into the foundation of Pier No. 4 for about 12 feet, and excellent core obtained.

The concrete in all the piers was deposited through the water until it reached a point about 3 feet below the extreme low water mark, and after it had sufficiently set, the water was pumped out and the concrete levelled up to within two feet of low water ready for the masonry.

The concrete kibble used for depositing the concrete is shown in the sketch below and was found very satisfactory. Owing to its wedge shape it created very little disturbance in going through the water, and had a capacity of 29 cub. feet. The doors opened from the bottom, and every precaution was taken to guard against the kibble being tripped before reaching bottom. A canvas cover was used, and tied securely to each bucket before it was lowered.



CONCRETE KIBBLE
CAPACITY 29 CU. FT.

During the progress of the work on pier No. 2, the following tests were made when the first deposit of concrete was being put in. A kibble full was put down in the caisson at the usual speed to a depth of about sixty feet and then raised slowly to the surface. Owing to the flat surface of the concrete at the top of the bucket the water offered a strong resistance to motion through it and gave a very severe test for wash. On the bucket reaching the surface, very little wash was noticed and two cement barrels were filled from the top and put under water to set. Two weeks later a diamond drill was run through them in several places, and gave excellent core. When the caisson was nearly completed one more test for wash was made. A large wooden box, having a capacity of over two cub. yards, was made and sunk in the caisson on top of the concrete deposit in about eight feet of water. A kibble was then filled with concrete and let down through the ice into the stream outside the caisson to a depth of over 50 feet. It was raised with the intention of lowering it into the box, but owing to a mis-calculation, the latter had been made too small, and it was necessary to trip it above the box, letting the concrete sift through 3 feet of water; this was repeated with another bucketful, which filled the box. Owing to the severity of the test it was not thought that the sample would be of any use, but when the caisson was de-watered it was found in a very satisfactory state, and on the diamond drill being run through it, although no core was obtained, the wall stood hard and firm.

The following brands of Portland cement were used in this pier, viz., Star, Hercules, Alsen and Mannheimer, a sample of each being tested by McGill College, and continuous tests being made by ourselves all through the progress of the work. The sand used was good, clean river sand, which was obtained from under the surface of the water near the Hull shore, about two miles below the bridge.

The Company had a number of inspectors on the work day and night, their chief duties being to check quantities used in the concrete and superintend the mixing of the same; to see that the concrete bucket was lowered very gently until it was under the surface of the water; and to also see that it was not tripped until it reached bottom. The Government also had an inspector on all the work on No. 2 pier, and on most of the other important work. During the winter of 1898-1899, grave fears were entertained for the safety of caisson No. 2, as it had then only 24 feet of concrete at the bottom, and there remained over 50 feet standing up in the river, a hollow box, exposed to local ice shoves and to the steady pressure of the anchor ice which at this point we found to be over 30 feet deep. To as far as possible counteract any pressure, the contractor was instructed to put extra bracing inside the top of the caisson and to keep the surface ice out for a distance of several feet around the caisson. This he did, and no ill effects were experienced; but had the balance of the concrete not been deposited in April, the spring ice floating out would most assuredly have destroyed the caisson. The filling up was only completed on the 1st of April. On the 19th of the same month the ice was moving out of the river, and one block from the bay at the foot of the locks with an area of over 30,000 square feet of surface ice about two feet thick, and anchor ice below that anywhere from 10 to 20 feet thick struck the top of the caisson and rested there for several days; efforts were made to blast it, but dynamite had no effect, and, when it finally broke away, it was found that a few of the top timbers and some of the bracing of the caisson were slightly injured, but otherwise no harm was done. This in itself was a severe test on the pier. Another severe test received by this pier was during the erection of the superstructure; the south half of the cantilever span was swinging out a distance of over 270 feet for upwards of three months and was during that time exposed to some gales blowing over 60 miles per hour.

All the upper portions of the piers are solid masonry, no concrete backing being used, and were built under the usual specifications for first class masonry, the bridge seats and copings being hammer dressed, and the remainder rock face. The limestone used for piers Nos. 1, 2 and 3 came from Eganville, Ont., except the copings of two or three, which were obtained from Crookston, as were the copings for piers 4 and 5. The balance of these latter two piers were built of stone from Rockland, Ont. The stone for pier No. 6 was brought from the Terrebonne quarries. Concrete was used for all the trestle pedestals, also for the abutments of all bridges over streets in Hull.

From the south end of the bridge to Central Station, three tracks were laid of 75 lbs. steel rails, with crushed stone ballast, the two outside ones now being operated by an electric service running from Ottawa to Aylmer across the bridge on the highway portion, and the centre one is used by the trains of the Ottawa Northern and Western Railway, and in a week will also carry the trains of the Pontiac Pacific Junction Railway. To make a connection with the tracks of the Canada Atlantic Railway at Central Station. as the writer previously stated, it was necessary to cut out a portion of the abutment of the Sappers Bridge, which is a stone arch over the Rideau Canal, and was built by the Royal Engineers in 1827; the abutment was 24 feet thick, the walls being anywhere from two to 4 feet thick and on the south side the top of the wall was about 2 feet thicker than the bottom. The lime used had deteriorated until it apparently had no consistency, but the masonry held together in a most remarkable way. Earth filling had been chiefly used between the walls.

The superstructure of the main bridge is being dealt with in a paper by a member of our Society, and the writer will refrain from touching on it, except to state that the bridge is free to vehicles and pedestrians forever and that the Company keeps the waggon roads in repair for thirty years. Before being opened to the public the bridge and approaches were inspected and found entirely satisfactory by the following officials: R. C. Douglas, Bridge Engineer, and E. V. Johnson, Inspecting Engineer for the Dominion Government; Louis A. Vallée, Director of Railways for the Province of Quebec; Robert McCallum, Inspecting Engineer for the Province of Ontario; and Newton J. Ker. City Engineer of Ottawa, Ontario.

The first locomotive crossed the bridge on the 12th December, 1900. The roadway portion was opened to the public on the 5th March. 1901, and the first passenger train to cross was the Ottawa Northern & Western Railway express, on the 22nd April, 1901. This undertaking as a whole is a monument to the energy of Mr. H. J. Beemer, the original promoter and, later contractor. who, practically unaided, and with seemingly unsurmountable obstacles in his way, has finally brought the work to completion. The permanent Engineers' staff was as follows:

Guy C. Dunn, Chief Engineer.

F. A. Hibbard, Resident Engineer.

A. W. H. Stimpson, Ass't. Engineer and Draughtsman.

C. E. Fouse, Inspector Superstructure (Pittsburgh Testing Laboratory).

The following is a summary of a few of the quantities:

	Sawdust.	Concrete
Pier No. 2................	1,000 cu. yds.	2,579 cu. yds.
Pier No. 3................	800 "	1,462 "
Pier No. 4................	370 "	728 "
Pier No. 5................	300 "	394 "

DISCUSSION.

Mr. C. E..W. Dodwell remarked that the Alexandra Bridge at Ottawa, of which the substructure was described in Mr. Dunn's paper, would rank as one of the notable bridges of the country in length, cost and importance, if not in boldness of design and difficulty of construction. The railway companies, to whose enterprise and far-sightedness its projection was due, were to be congratulated on its completion. The only distinctive feature of especial interest that distinguished this work from many others of a mainly similar character was the remarkable depth of sawdust through which the pier foundations were carried to rock bottom. This, while probably greater than in any other river in Canada, owing to the magnitude and extent of the lumbering industries of the Ottawa, was not peculiar to that stream. In the Maritime Provinces there was more or less sawdust in every stream big enough to drive a mill or float a log, and for many years (in some cases nearly a hundred) not only sawdust, slabs and the refuse from sawmills, but, in Nova Scotia at any rate, the pulverized tailings from quartz crushers, had been thrown, not only with impunity, but with an absolute disregard of consequences, into streams that formerly teemed with trout, salmon and other fish. In the La Have River, where he had made a survey four or five years ago with a view of some dredging for the widening of the ship channel, there was found sawdust of a thickness of nearly 20 feet in depth for several miles. The result of this wholesale, reckless pollution of the streams was that in the most beautiful of them trout and salmon were now rarely found. It might perhaps be urged in defence of this time-honoured mode of disposing of mill refuse that the lumber interests of the country were of more importance and value than the river fisheries; but when the sawdust and slabs could so easily, and with such an insignificant additional outlay, have been burned or otherwise so disposed of as not to be a nuisance and positive detriment, it was a great pity that proper legislative restrictions were not made and enforced in the earlier days of the lumbering industry of the country. At this date most of the sawmills in Nova Scotia and, he believed, in New Brunswick also, burned their refuse either as fuel or in specially constructed furnaces or incinerators; but the mischief to the streams was done, and the lordly salmon sought purer and sweeter spawning grounds. It was to be hoped that some day an inventive genius would discover a hidden value in sawdust. For such there would await a princely fortune. The mode of excavating the sawdust for the pier foundations seemed to have been simple and effective, and the nature of the work to be done peculiarly suited to the clam-shell form of bridge. It was fortunate for the contractor that between the saw-dust and the rock there was not found a stratum of gravel or clay. The form of kibble for depositing the concrete did not appear to him to be an improvement on that adopted at the Canadian Pacific bridge over the St. Lawrence at Lachine, which was a square iron box, holding 2 cubic yards, with a closing top hinged in two leaves and a similar bottom tripping by means of a simple latch. This construction caused the minimum disturbance to the concrete, and its operation was everything that could be desired. The author's paper had the same defect that characterized nearly every paper of a similar nature that had ever been published in the Society's Transactions, namely, the conspicuous omission of all mention of cost and prices. It was comprehensible that there might be instances in which, for business or other reasons, there would be objections to the publication of the details of the cost of certain works, but, in many cases, authors of papers would not find these objections insurmountable, and they should consider the tremendously added value that would attach to their papers by making the subject of cost a prominent feature. He hoped that in his reply to the discussion the author would add an appendix to his paper giving particulars both of cost and quantities.

Mr. G. H. Massy observed that, so far as he was aware, the first instance in which bottomless caissons filled with concrete were used was in the construction of some of the bridges on the Intercolonial Railway about thirty years ago. Since then, this class of foundation was adopted in the construction of the Chaudiere Bridge at Ottawa in 1879, on the Lachine Bridge in 1886, and at the International Bridge at Sault Ste. Marie in 1889, together with many other cases too numerous to mention, thus giving a continuous practical test of this class of work extending over thirty years, and in every case, so far as he was aware, the result had been satisfactory. As in all work which depended upon the excellence of the concrete, the greatest care was required in the choice of materials, proportions, mixing and depositing. Allowance had also to be made for loss of cement due to the washing action of the water during the process of depositing, especially where there was any current; and also, it should be remembered, that once the concrete was deposited it must be neither rammed, leveled nor otherwise disturbed, as the least agitation separated the cement. Ramming would probably add one-third to the strength of concrete, but it must be dispensed with in this class of work. Much had been written and said about concrete, but still it was an open question as to what the proper proportions should be for certain classes of work. The strongest concrete was probably produced when the mortar was rich in cement and no more mortar used than was sufficient to fill the voids in the stone. Another source of danger to be guarded against was the deteriorating effects of water forced through very porous concrete, which he was inclined to think might cause trouble. More experiments were required on these points. It would be generally admitted that machine mixing when well done was superior to mixing by hand; but with some continuous mixers, especially when starting and stopping, the concrete produced was either too wet or too dry, or had not the proper proportion of ingredients. The author appeared to be fortunate in securing the services of such a good continuous mixer as that used in the Alexandra Bridge.

The AUTHOR, replying to the discussions on his paper, agreed with Mr. Massy in every particular, unless, perhaps, as to concrete losing one-third of its strength by not being rammed. In reply to Mr. Dodwell's criticism, he observed that from the experience he had had in depositing concrete he considered the V-shaped kibble, as used on the substructure of the Interprovincial Bridge, an improvement (especially in deep waterwork) on the square bucket usually adopted, as, on account of being wedge-shaped, it cut through the water with much less disturbance than the square bottom, and when opened, while resting on the bottom, the concrete was deposited on the foundation rock without having to pass through a foot and a half or two feet of water, as necessitated by the square bucket. As regards the omission of costs and prices in his paper, he fully appreciated the additional value of a paper in which such figures could be given; but the engineer in charge of work was placed in such a delicate position of trust, both in the interests of the company he was working for and the contractor who was doing the work, that, without the joint permission of both parties concerned, it was impossible that such figures could be given.

Paper No. 164.

ERECTION OF THE ALEXANDRA BRIDGE.

By H. D. Bush, M. Can. Soc. C.E.

This bridge crossing the Ottawa River between Ottawa, in the Province of Ontario, and Hull, in the Province of Quebec, was called, during construction, the Interprovincial Bridge, at Ottawa.

During the visit of the Duke and Duchess of York to Canada, in 1901, the bridge was formally opened, and named after the present English Queen.

The method of building the substructure and the design of the superstructure have already been described in the papers of Guy C. Dunn, Member, and F. P. Shearwood, Asso. Member, of this Society.

The profile shown on Plate 16 gives the numbering of the piers from 1 on the Ottawa to 6 on the Hull shore. The spans will be designated by the numbers of the piers they connect, as 2-3 for the cantilever span, etc.

Somewhat unusual conditions were found here. From the Ottawa shore the bed rock slopes abruptly to a depth of seventy feet in a distance of about 200 feet. From this point to the Hull shore the bed rock is covered with a deposit of saw-dust, mill refuse, etc., in one place to a depth of 50 feet.

The general method of erection was decided on by the engineers of the Dominion Bridge Co., Ltd., when the contract for the superstructure was awarded. A central cantilever span of 555 feet 9 inches was designed, and it was planned to erect the two cantilever anchor arms each 247 feet and one other span of the same length, on falsework, to be supported on four scows carrying timber trusses for distributing the load, the scows being connected by the trusses, so that the whole structure could be floated together from span to span.

The writer's connection with the work began in July, 1899. At that time the scows were being built at Lachine, the drawings for same having been made immediately after the contract was let. The writer then, under the general direction of Mr. Phelps Johnson, M. Can. Soc. C.E., Manager of the Dominion Bridge Co., Ltd., made designs for the remaining features of the erection plant, timber, trusses, derricks, traveler, etc., and, later, went to Ottawa, remaining there during the construction of the bridge.

The bridge was built for what is now called the Ottawa, Northern & Western Railway Co., and is arranged to carry one steam railway track between trusses 24 feet centre to centre. The spaces on each side of the track between the trusses are used for foot walks. Outside the trusses, on each side, is a roadway 21 feet wide, supported on cantilever floor beam brackets, carrying an electric railway track close to the trusses, and leaving room for the vehicles outside of the same. This makes a total width of bridge of 66 feet.

The metal weight of the cantilever structure alone was approximately 5,000,000 lbs.

The outer floor beam brackets and stringers were not placed in position on any span until that span had been fully connected and become self-sustaining. The weight of metal in one of the 247 foot spans, as erected on the falsework, exclusive of the roadways, pier members, etc., was 910,000 lbs. The weight, exclusive of traveler, supported by the scows during erection, was about 1,400,000 lbs., made up as follows:—

Metal work..	910,000 lbs.	
Howe Truss and Falsework on same..	308,000 lbs.	
Blocking..	42,000 lbs.	
I-beams and blocking under Howe Truss..	140,000 lbs.	1,400,000 lbs.

As there were four scows employed, this gave a load of 350,000 lbs. per scow. In addition to this, each scow in turn had to support the weight of the traveler (except as it might be partly distributed by the Howe truss), amounting to about 140,000 lbs.

The maximum load for each scow was taken at 450,000 lbs., or 112,500 lbs. at each of the four points of bearing on the scows.

The scows were especially designed for the concentrated load to be placed on them during erection. Each scow contained two longitudinal steel trusses, which were 22 feet 6 inches apart between centres, 6 feet 3 inches high, and divided into panels of 6 feet 3 inches.

Opposite panel points of the bottom, chords were connected with 15″ —42″ rolled I-beams, under which were 4 inch by 12 inch longitudinal timbers, to which the 3 inch bottom planks were spiked.

Timber posts above the floor beams supported timber deck beams and planking.

The construction of the scows is shown by the drawing, plate No. 16.

The scows were 100 feet long, 26 feet wide and 8 feet deep outside measurements.

Each scow was estimated to weigh 150,000 lbs., and, when empty, to have a draft of 13⅜ inches.

The estimated displacement of one scow was as follows:—

			Less weight of scow.	Net. capacity for load.
	Lbs.	Lbs.	Lbs.	Lbs.
For 2 feet draft	277,000	277,000	150,000	127,000
For 3 feet draft add	149,500	426,500	"	276,500
For 4 feet draft "	154,750	581,250	"	431,250
For 5 feet draft "	158,500	739,750	"	589,750
For 6 feet draft "	161,000	900,750	"	750,750

The maximum estimated load of 450,000 lbs. per scow, would therefore, correspond to a draft of 4 feet 1½ inches, and the load of 350,000 lbs. (not including the traveler), a draft of about 3 feet 6 inches.

The contractors for the superstructure had been given to understand that there was very little change in the level of the Ottawa River at this point during the months of October to March, when it was proposed to erect spans 6-5, 5-4 and 4-3. In fact, the writer was instructed to work on the assumption that the average height of water would be at elev. 94 above the bridge datum, and that it might fall to 93 or rise to 95.

During the year 1899 it was difficult to get early delivery of steel from the rolling mills. For this reason the manufacture of the bridge was so delayed that the erection of the steelwork, starting at pier 6, could not be begun until December, 1899. The erection of span 5-4, the first one on which the floating falsework was used, began January 12, instead of at least two months earlier, as originally planned. This delay gave rise to unexpected difficulties in moving the scows through the ice, as will be described later.

It was also learned that there was more variation in the level of the river than had been expected. From the 13th to the 17th of December the river rose from elevation 94.5 to elevation 98.1. This occurrence, three weeks after the writer's arrival at Ottawa, prompted him to examine the records of water levels. Mr. A. T. Phillips, M. Can. Soc. C.E., kindly gave access to the records, in the office of the Rideau Canal, of the gauge at Lock No. 1, in the bay just above the Ottawa end of the bridge. The elevation of the bottom of this gauge is 85.92 feet above the bridge datum. The readings of the gauge from 1884 to 1899 were copied and a table made, adding each reading to 85.92 giving the height of water above the bridge datum. From this table the chart on Plate No. 18 was prepared. This chart has been made complete to December 31, 1901, so as to include the extremely low water in the fall of that year, and it is here given, not only for its connection with the bridge erection, but in the belief that it will be found of value to engineers called upon to study the flow of the Ottawa River with reference to power development.

It will be seen from this chart that a sharp rise in November and December is a common occurrence, but that outside of these months the variation in height in any one year in either September, October, January or February is about 3 feet.

It was proposed to take care of most of the variation in the water level by pumping water into or out of the scows, starting work with water enough in them to give 5 feet draft. Pumping in more if the river rose, and pumping out if the river fell, and, in any case, pumping out water to correspond to the weight of metal added as erection progressed.

There should have been about 2 feet of removable blocking between scows and truss for erection of spans 5-4 and 4-3. Span 5-4 could not have been placed on the piers at the time of the December rise, for instance, without this, although in January it was not needed.

Two upright boilers, of about 20 H.P. each, were set up on one of the inner scows, and 2 inches steam pipe run from the same to the other scows, with branches to six steam syphons: 4 (1 on each scow) used for pumping water out of the scows, and 2 (1 suspended between each pair of scows, with spouts running to either scow) for pumping water into the scows. The syphons had 6 inch suction pipes, and were used because they happened to be in stock in the Dominion Co.'s erection plant. The steam pipes were protected with cellular asbestos covering and enclosed in a wooden box.

The trusses over the scows were of the Howe Truss type, 20 feet high. The panels of the bridge were each 30 feet 10½ inches. The Howe Truss panels were one-half of this, or 15 feet 5¼ inches. The angle blocks were of oak, with 10 inch faces. The chords were made 33 inches wide of 3 inch by 12 inch plank, dressed to exact thickness, in 8 continuous leaves (4 spliced in each panel, making the planks 30 feet 10½ inches long), and three packing and splicing pieces, also 3 inches by 12 inches in each panel, 15 feet long, between the ends of which were spaces, through which passed the rods. There were three of these rods at each panel point, and they were all 1⅝ inches, except at the ends, where they were 1½ inches square. The planks were well bolted together with 28¾ inch bolts per panel. The braces were composed of two pieces, 10 inches by 11 inches, and the counters of 1 piece 10 inches by 11 inches.

The general arrangement of Howe Truss and scows is shown in plate No. 16. The alternate top chord panel points of each Howe Truss were assumed loaded with 90,000 lbs. each. The trusses were figured to carry this load if any one of the scows sunk by accidental dropping of material from above, assuming, however, that the extreme ends of the trusses were supported. The concrete foundations of the piers provided a good offset outside the stonework, on which timber bents were placed. Blocking was kept on these bents under the ends of the Howe Truss as a safeguard, and to increase the stability of the structure against tilting by wind.

The loads being brought over the scows at panel points 30 feet 10½ inches apart, and the steel trusses in the scows being 22 feet 6 inches C to C, five 20 inch I-beams, 32 feet long, were placed across the scows under each truss to prevent bending stresses in the chords. These were clamped together with wooden blocks and bolts to avoid punching. Oak blocks, 8 inches by 10 inches, were placed between these beams, and bottom chords of Howe Truss close to truss rods.

On top of the Howe Trusses were 7 bents of falsework, 4-20 feet high, and 3-15 feet, 10 feet and 5 feet high respectively, to fit under the bottom chords of anchor arm spans. Temporary bents were placed on top of the short bents to bring the top of falsework level for span 5-4.

The falsework bents were each supported on two 20 inch beams extending across from truss to truss, placed on the top chords close to bearing plates of truss rods.

After the scows had been launched at Lachine, the Howe Trusses and top falsework and the traveler to be used in erecting the bridge were framed in the shop yard and loaded on the scows, together with five 12 ton stiff-leg derricks and the I-beams, anchors, chains, etc., to be used. Five scows had been built, the fifth one to be used as a derrick scow. The scows with their loads left Lachine in November, 1899, just before the close of navigation. The material was unloaded at the Hull end of the bridge.

The scows were placed in position between piers 5-4, and the Howe Truss and top falsework erected on the same with the derrick scow. Three of the 12 ton derricks were set up along the Hull approach, one with a 72 foot boom, close to pier 6, to lift material up to load on lorries on the bridge track.

Arrangements had been made to carry the steelwork from Lachine to Hull over the Canadian Pacific Railway. From the Hull station, about 1½ miles from the bridge site, the cars were brought down at night over the tracks of the Hull Electric Railway Co., using an electric locomotive. Much of the material, on account of its length, had to be loaded on two cars, and it may be of interest to note that the cars passed over one curve of 80 feet radius in the Hull Electric Co.'s tracks, and one of 100 feet radius in the Dominion Bridge Co.'s spur track without difficulty.

Steel began to arrive at Hull, December 10, 1899, and the erection of span 6-5 began December 20, 1899. This span (6-5) was erected on ordinary falsework, two bents on the ground and two bents supported on 61 feet plate girders belonging to the Hull approach to the bridge, which were placed to span from an old crib wharf to a bent set on the concrete foundation of pier 5.—This span was erected by a simple movable bent. In all the spans the vertical posts, after being bolted to the deep floor beams, "stood alone," which fact greatly simplified the erection.

As soon as span 6-5 was completed, January 3, 1900, the erection of the traveler was begun. This consisted of a rectangular "inside" tower supporting top trusses, which overhung the tower at each side in the plane of the bridge trusses, and also overhung one and one-half panel lengths, or 46 feet 3¾ inches in front of the tower for the cantilever work.

The tower was erected on span 6-5, and the two top trusses put together complete on the ground, one on each side of the bridge, and hoisted up one at a time, as shown in Photo No. 1, January 10, 1900.

The traveler tower was made 18 feet 6 inches wide and 28 feet long, C to C of posts. This width just gave clearance on each side inside the bridge trusses. The length of the tower was made less than the bridge panel length, so that, with centre of forward posts at a panel point, top lateral and sway bracing could be bolted in place just behind the traveler.

The rear posts were 12 inches by 12 inches. The forward posts were each made up of three leaves of 7 inch by 12 inch timber bolted together to break joints. The two outer leaves were 63 feet high. The centre one extended up 30 feet higher, supporting a 7 inch by 12 inch cross timber, 22 feet long, and, over that, a 15 inch 50 lbs. I-beam, 26 feet long, to which the tackles for lifting the top trusses were attached.

The tower was braced on four sides by timber horizontal struts and diagonal adjustable rods, except in the bottom panels of the transverse bracing.

About 18 feet above the track there was a working platform, which extended 20 feet back of the rear posts. Just above this platform, between forward posts, the timber strut of the wind bracing was replaced by a 14 inch by 14 inch cross timber, intended as a beam to hold the snatch blocks through which the lines from the erecting tackles led to the hoisting engines. From the centre of this beam plank braces to the bottom of the posts completed the transverse wind bracing. A similar, but lighter construction, was used between rear posts. This arrangement left a clear space for a central track, on which material was brought forward as required.

The various features of construction, and the assumed wind pressures and resulting stresses are shown on Plate No. 17.

Two 24 inch I-beams were placed across the traveler over forward and rear posts, those in front resting on the outer 7 inches by

12 inch sticks. These beams projected on each side far enough to give support to the top trusses, which were placed 24 feet apart, centre to centre.

The anchor rods, from the back of the top trusses, were fastened to the sills of the traveler. The weight of the booms, overhanging in front, together with tackle, etc., was only slightly overbalanced by the weight of the rear portion of the traveler, including the empty engine platform. The estimated weight of the foot of each rear post was 3,000 lbs., and at the foot of each forward post 57,000 lbs. The weight of the boiler, engine, etc., gave sufficient excess of weight on rear posts to make the traveler safe when moving. The traveler ran on eight 24 inch double flanged wheels, two under each corner, the weight on each forward wheel being approximately 30,000 lbs. Double lines of rails, on each side of the bridge, were supported by ties laid on double stringers of 20 inch I-beams belonging to the outer roadways. These were bolted between the floor beam webs, and removed when convenient after the traveler had passed over them.

When the traveler was in use, short anchor rods fastened rear ends of sills down to the floor beam underneath, and iron wedges were placed under forward truck castings to prevent excessive loading on forward wheels and axles.

A study of all the possible combinations of members, during the assembling of the cantilever spans, was made to determine the maximum loads on overhanging beams before top trusses were designed. It was found that an anchorage re-action of 73,000 lbs. would be required at the rear end of each top truss.

The two top trusses were braced horizontally with timber struts and diagonal rods, the cross struts arranged to give support for tackles in addition to that provided by two inch U bolts.

There were two engines, placed tandem, on the working platform, each having two 7 inch by 12 inch cylinders, and operating two shafts with a spool at each end, or eight spools for the two engines. A 20 horse power upright boiler furnished steam.

The heaviest single bridge members weighed 12 tons each. The tackles for lifting these were of 2 inch diameter Manilla rope, rove in 16 inch triple blocks.

The traveler, though designed especially for cantilever work, handled the three spans on the falsework very well, and was especially convenient in laying the floor system ahead of its travel.

In order to load the falsework gradually, the traveler advanced from pier to pier assembling the floor system, lower chords and vertical posts, and then returned to its starting point and went forward once more assembling the top chords and completing the span; the top lateral and sway bracing being handled by a swinging boom projecting behind.

Span 5-4 was finished January 30, 1900. The picture, No. 2, taken January 27, shows the span nearly complete, and also shows open water (where the ice had been cut), just upstream of the scows.

A small ice-cutting plant had been bought and put in use for a few days previous to this, and sufficient ice cut and removed to make room for the first movement of the scows about 80 ft. upstream. Up to this date there had been very little extremely cold weather, so that the ice was only 10 or 12 inches thick and the water free from frazil. It was believed that what ice might form in this space before the scows actually started could easily be broken as they were moved. Beginning with the night of January 27, the temperature fell and remained near 0 Fahrenheit for several days. The ice took quickly above the scows, beginning above pier 4 and building out toward the Hull shore. Just above and back of pier 5 the water remained open, and the writer noticed a change in the usual conditions there on February 2, when the scows were first moved. Previous to this there had either been no current at this point or a slight eddy, with chips, etc., drifting upstream; now there was a marked current down stream, showing that the channel farther out must be obstructed, and, of course, with frazil. Moreover, the water was seen to be full of crystals of frazil. This meant more difficulty in moving the falsework than had been anticipated; but if the enormous difficulties could have been foreseen the start would not have been made.

About a mile above the bridge is situate the Chaudiere, or Big Kettle Fall, of the Ottawa River, with perhaps 1,000 feet of open water below, and occasional short stretches of open water, including several lesser falls and rapids for two or three miles above.

This open water is known as an excellent frazil factory. The water used for power in Ottawa and Hull, though taken from near the sides of the river, is often full of frazil, which clogs up the racks and wheels. The water from the central channel of the river, passing through the Chaudiere itself, would naturally contain a still greater quantity of frazil.

These floating ice crystals, which form when the atmospheric temperature in falling approaches or passes below zero Fahrenheit over water which is too much agitated for the surface to freeze solidly, will be called "frazil" in this paper.

As the scows were first to be moved directly upstream or endways, it was expected that they would move quite easily. The writer's diary states that, on February 2:—"Scows were moved only 2 feet. Frazil very deep." This was the first day's experience with frazil. It was found to have other dimensions than depth. On

February 8 there was rain, followed by three rather warm days. By February 11 the river had risen about one foot, and the frazil seemed less dense. On that day, the scows moving broadside across stream advanced 26 feet. This was the record day. Some days only four, five or six feet would be gained. Photo No. 3, taken February 6, shows the scows moved about 80 feet upstream as a result of five days' work.

The method of working, which developed after a few days, was substantially as follows:—

A few men were kept at work night and day with saws, keeping a narrow channel open all around the scows. The surface ice was cut each day for a width of 15 or 20 feet in front of each scow in the direction in which it was desired to move them. This ice was cut with saws, and the blocks pulled out on light skids and drawn away by horses. Large hoes were made by fastening steel snow shovel blades at right angles to long wooden handles. With these the frazil crystals were pulled from in front of the scows upon the uncut ice, and, as soon as a good sized pile was formed, this was scooped up on wooden drag scrapers and drawn away with teams. The frazil would keep rising to the surface for a time, but, generally after a few hours', or, perhaps, half a day's work, there would apparently be about two feet in depth of clear water in front of the scows, about equal to their draft. Orders would then be given to move the falsework, but more frazil would rise and fill this clear space as soon as the scows started.

To some extent the idea still prevails that frazil is heavier than other forms of ice and readily sinks in water. The old theory of the formation of anchor ice by the freezing to each other, and to the bed of a stream, of surface formed needles of ice, has been shown to be incorrect by the work of Dr. Barnes, of McGill University.* The explanation, given by Dr. Barnes, of the formation of anchor ice, as caused by the radiation of heat from the bed of a stream directly through the open water and atmosphere above into space, must, it seems to the writer, be accepted, and result in more clearly distinguishing between two forms of ice that have often been confounded.

The frazil in the Ottawa River showed no tendency to unite by regelation, and none to sink in water. Its tendency to rise is mentioned above, and shows clearly in the annexed photographs.

The crystals of frazil drawn out on the surface ice turned immediately white in the cold air, but remained as separate from each

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*Transactions Royal Society of Canada, Vol. III., June 23, 1897, Vol. V., 1899.

other as particles of coarse salt, the water draining out from between them before it had time to freeze.

A pike pole could be thrust down into the undisturbed beds of frazil more easily than into clear water, as no effort was required to hold it plumb. When released the pole showed no tendency to float or rise up, the friction of the frazil crystals holding it steadily in position. There was just enough cohesion in the masses of tightly packed frazil and, perhaps, adhesion to the bottom of the river, so that with great care about 2 feet in depth at the surface could be scooped off without bringing up the lower layers. The commotion caused by the slight moving of the scows brought new masses of frazil to the surface and above the surface, which, rolling up in front of the scows, quickly formed a barrier which stopped all progress.

The traveler tackles were used to pull the falsework ahead. These were fastened to various scows; some of the lines were run to the engine on the traveler overhead, some to the engines on derrick scow, which was frozen in near pier 5, and two of the fall lines were pulled by teams of horses and the men. The scows would generally resist the combined pull of all the tackles for a few seconds and then, if they moved at all, jump forward a few inches and then move more slowly until the masses of frazil in front brought them to a standstill.

The tackles, which were designed, with a large factor of safety, to lift 10 and 12 tons, were often broken either in the rope, the blocks, or the chains fastening the blocks to the "dead-men" under the ice. So that it was estimated that a pull of 150 tons was exerted to move the scows, often with no other result than a breakage.

It is not believed that the frazil was frozen to the bottom of the scows, as once or twice ropes were pulled under them from end to end.

The mixture of frazil and water, on which the scows floated about as they would if left stranded on a soft mud flat by an outgoing tide, offered a similar if not as great a resistance to pulling the scows over its surface as the soft mud would have done.

It is almost incredible that the amount of frazil first encountered under and around the scows between piers 4 and 5 could have been manufactured and placed there in the few days intervening between January 27 and February 2. It is probable, however, that the part of the channel between piers 3 and 4 had been filled up during January, and that, because of this, the increased current near pier 5 was caused, and this increased current in turn quickly packed the frazil under the surface ice between piers 4 and 5.

The small photographs shown on following pages give some idea of the difficulties encountered in trying to move the floating falsework over the beds of frazil, and they also show some of the characteristics of frazil. View No. 13 shows the space of open water in advance of one of the intermediate scows when they were moving across stream, and shows the frazil rolling up in front of the scow just as it started to move. View No. 14 shows the frazil rolling up in front of the forward scow just as it started to move, with considerable comparatively clear water still left forward of the frazil. The edge of the solid surface ice, on which the men stood to work, is shown to be irregularly cut, and not so many feet away from the scow at its farther end. The next view, No. 15, shows the frazil completely filling the narrower space between the scow and the solid ice, and nearly filling the wider space in the foreground. View No. 16 is taken immediately after a move of the scows, at a time when the edge of the solid ice happened to be parallel to the scow for the full width of the cutting. Here the frazil is seen completely filling the space between scow and solid ice. In both views 15 and 16 it will be seen that the frazil has been forced up above the level of the top of the solid ice.

View No. 17 shows piles of frazil and a workman standing away from the ropes while the strain of pulling the scows forward is on them. View No. 18 shows piles of frazil being shovelled by workmen. It is quite evident that the crystals are not frozen together.

The new position between piers 3 and 4 was reached in the afternoon of February 23rd, but, in the meantime, one end panel of Howe Truss bottom chord had been pulled off and all the scows moved from the correct position under the trusses. To have repaired the damage and replaced the scows in their former position, necessitating moving each one through the frazil, would have taken three or four days' time, or to about February 27th. Counting from Feb'y. 2nd to 27th, including the Sundays and nights to 10 p.m., on which work was done, this would be equivalent to at least twenty-six full days' work for moving the falsework through the frazil with a force of about 50 men and 12 to 16 horses. The actual cost was about $3,500.00, including the expense of moving three of the scows 15 feet each through the frazil to new positions under the truss.

Before the scows had reached their new position the plans for carrying on the work had been changed. The Ottawa River occasionally breaks up at this point by the middle of March. The shoes on pier 4, as described in Mr. Shearwood's paper, had been designed with two pins each—the lower pin for the end of the cantilever anchor arm, the upper one being the end pin of span 4-5. This arrangement utilized the weight of half the latter span as anchorage for the cantilever and saved in the pier anchorage; but it made it dangerous to start the erection of span 3-4 so late in the season.

when a sudden rise in the river might, with floating falsework, have wrecked two spans. If the work could have been started two months earlier than it was, the scows would have been moved the first time through clear water in a few hours. Or, if there had been only surface ice to contend with, this could have been cut and the scows moved in three or four days. Spans 3-4 could then have been finished and the floating falsework taken across to span 1-2 for work there during the spring high water, as originally planned. It was now decided to rearrange the falsework for span 1-2, and to erect part of the material intended for span 3-4, working leisurely until the river broke up, and then move the falsework and partly erected span across the river. In order that when erecting span 1-2 the scows should be as far as possible from the rocky shore in front of and just below pier 1, three of them were moved, one Howe truss panel length, or 15 feet 5¼ inches toward pier 3, and vertical posts placed under the top falsework bents, extending down to the I-beams on the scows. This is shown on the profile view, Plate 16, with falsework reversed from its position at 3-4. Even with this new arrangement (which had been intended for span 1-2), it had been found necessary to blast considerable rock to clear the inshore scow. This work had been laid out and finished in January. Without working under water, the rock could only be taken down to elevation 94. Hence, with the scows drawing 5 feet the one next to pier 1 would still ground, with water at elevation 99.

The top falsework was now cut down 5 feet shorter, and 5 feet of blocking put under the Howe trusses on the scows. A "Jacking rig" had been added to the Howe trusses, which is shown in Plate 16.

By means of this, aided by pumping water into and then out of each scow, the trusses had been jacked up for this blocking, just as it was intended later to jack them down. About 3 feet were cut off the Howe truss chords at the end next to pier 3, and the falsework moved in that direction so as to clear the double shoe on pier 4. The erection of what should have been span 4-3 began March 11 and progressed until April 2, when as much material was assembled as it was thought safe to bring across the river.

It happened that the break up in the Ottawa River came late in 1900. The photo No. 4 taken April 2, shows the partly erected span and solid ice and piles of frazil still around the scows, and it is possible that span 4-3 might have been erected without accident. Had such an attempt, however, been made in 1898 or 1900 it would have certainly resulted in a wreck. In 1898, the rise began March 10th, and culminated March 19th.

The erection men were now put at work on the trestle approaches. The river began rising soon after this, and the ice went out April 15. On the 19th the derrick scow was towed across the river, and, on the 21st, three tugs took the floating falsework across. This was first pulled down stream and turned end for end, then towed upstream and across to just above its new position, and then dropped into place between piers 1 and 2. The photo No. 5 shows the false-work, with part of span and traveler, as it crossed the river. Photo-No. 6 shows the falsework between piers 1 and 2, with the metal work above the top of pier 2.

The water was now at elevation 101. One of the 12 ton stiff-leg derricks had been set up just back of pier 1. This lifted the material off the derrick scow, as the latter brought it over from Hull, and landed it on the track on span 1-2. This span was connected May 21, when the work of jacking down began with a small force. About 10 inches of blocking at a time was taken out from over each scow, water being pumped into the scow to help the jacks and then pumped out again.

The river rose this year only to 105.5 (the extreme high water mark is 115.4), and was again down to elevation 101 when the span was landed on the masonry, May 29th. The span is shown resting on the piers in photo No. 7, taken May 31st.

In the meantime there had been exciting episodes connected with the great Ottawa-Hull fire. On the afternoon of the fire square piles of blazing boards came floating down the river, but the up-stream wind held them back, so that what fire remained when they reached the scows was easily extinguished by throwing on water from buckets. There was a great deal of debris in the river after the fire, and one long and heavy boom floated down and tied itself all round the scows one Sunday morning, when it was difficult to get tugs to pull it away.

The falsework was held in place by chains and anchors and by pier harnesses made of 14 inches by 14 inches upright timbers fastened to the piers by a system of rods and timbers running completely around the stone work. These are shown in photo No. 4. The uprights were spaced about 27 feet apart in the clear so that the Howe truss chords could move up and down between them. The chords were kept wedged against the harness timbers, the watchman loosening and re-adjusting the wedges occasionally as the water level changed.

On June 2 the unloaded falsework was moved back to between piers 3 and 4. The traveler remained at work on the cantilever erection, finishing this to centre of suspended span on July 10th. The progress of erection to June 23rd is shown in photo No. 8. On July 11th the work of takihg down the traveler began. The top trusses were lowered to the derrick scows *complete*, and after that the tower in pieces. This work was finished at noon of the 16th, in 4½ working days.

The erection of the traveler over pier 4, at the end of span 5-4, began on the 17th and was practically finished on the 21st. On Monday, July 23rd, engines and tackles were raised, and erection of span started in the afternoon of the 24th. Photo No. 9 shows span 5-4 finished and cantilever erection started August 30th, 1900.

There is nothing of special interest to describe in the rest of the work except the method of making the final connection in the centre of the cantilever span. No wedges had been arranged in the trusses, as it was known that the floating falsework would be on hand in case of need. There were adjustments for length in the chords, at U13 for tension and L13 for compression.* Shim plates were inserted at these points to give the length of half spans, which, it was thought, would enable connections to be made at what would be the average temperature at the expected time of connecting, about October 1. The temperature at this time was lower, and the central opening was found to be about one inch greater than had been calculated on. On Saturday, October 6, the floating falsework, with enough water pumped into the scows to give about 4 feet draft, was brought out under the suspended span. Blocking was inserted between the falsework and the panel points of the span, and the water partly pumped out of the scows on Saturday night. On Sunday morning the pumping was finished and the weight of the span lifted. The adjusting yokes at U13 were loosened, and the shim plates removed at both U13 and L13. The half spans were then jacked together and the last pins driven about 11 a.m., October 7th. Water was then again pumped into the scows, and on Monday, October 8th, they were towed to moorings on the Hull shore, where the work of dismantling the top falsework and Howe trusses began, the material being piled up on the scows and taken on board the latter back to the shop at Lachine.

The progress of the cantilever erection to September 18th is shown in photo No. 10. Photo No. 11 shows the falsework under the suspended span while the last pin was being driven, October 7th.

Concerning the cost of the work, a few items only can be given.

The falsework scows cost about $2,400 each, and were readily sold at two-thirds their cost. The cost of moving them through the frazil has already been given, $3,500. This was an unusual and unexpected expense. The Howe trusses were easily taken apart, and the material in them was of considerable value for other work. A suitable falsework span, at least 200 feet long, for use between piers 1 and 2, and which would, necessarily, have been erected on shore and floated into position, would probably have cost nearly as much

*See Plate 15 Shearwood's paper.

as the falsework used for the three spans. The floating falsework, if it could have been moved before the appearance of frazil, would at least have saved the cost of the heavy bents that would otherwise have been required for spans 3-4 and 4-5.

The superstructure was designed in the office of the Dominion Bridge Co., Ltd., Phelps Johnson and G. H. Duggan, Members Can. Soc. C.E., respectively Manager and Chief Engineer, and F. P. Shearwood, Asso. Mem., Assistant Engineer, in charge of computations and drawings. Jas. Finley was in direct charge of men employed on erection.