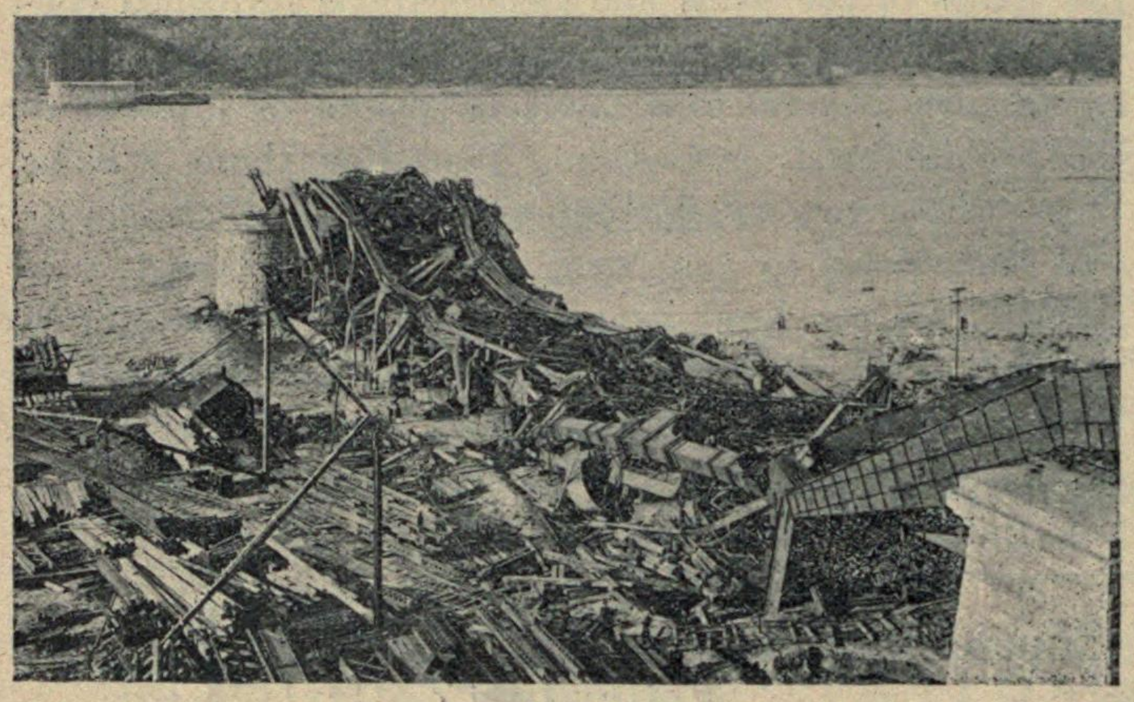
Progress of Quebec Bridge Construction

Detailed Account of Methods Employed by the Contractors—Plant and Machinery Required for Substructure — An Interesting Comparison

Prepared expressly for this Journal by our Montreal Representative

The north shore site of the new Quebec bridge is at present the scene of great activity. Approaching the site of operations from the St. Louis road, which leads from Quebec City, the railway yards are encountered. Here the contractors, Messrs. M. P. & J. T. Davis, have a large staff of workmen employed in laying extensive tracks and sidings for service in handling and storing supplies when the work of constructing the bridge proper begins. Further on another gang of men are engaged in



The old structure after the disaster

widening the approach to the bridge, for the centre of the new structure has been shifted slightly to the west.

From the crest of the hill a general view of the works is obtained. Across the river lies the wreckage of the former bridge, a grim reminder of the disaster of 1907. This debris can be seen exceptionally well at low tide.

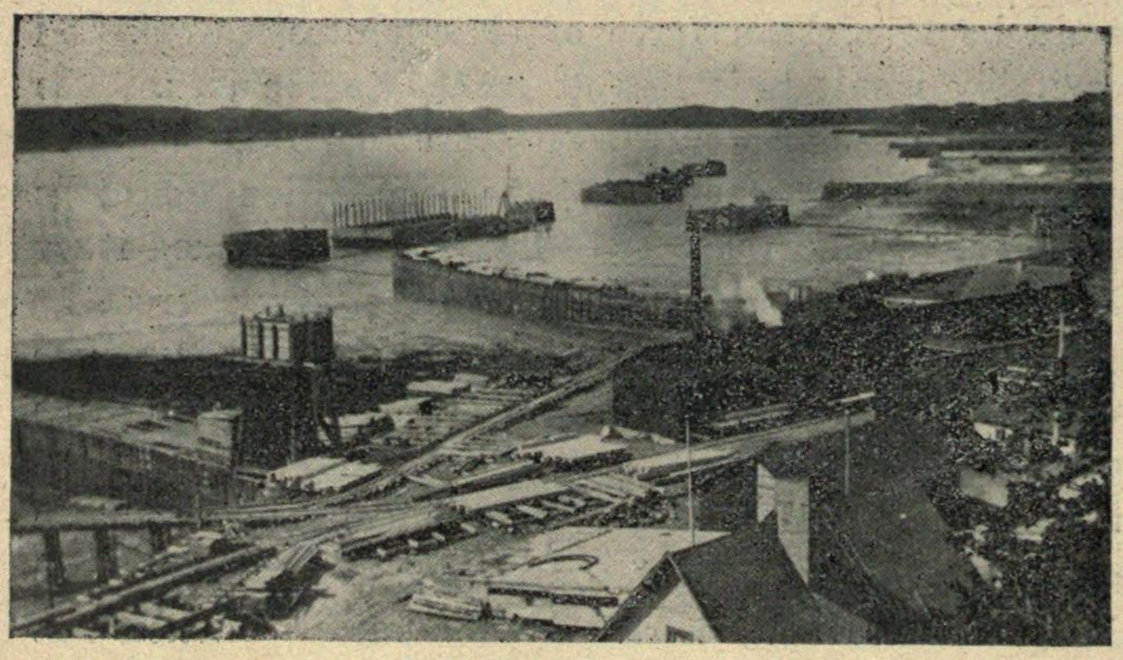
The Big Caisson—Interest centres around the work of Messrs. M. P. & J. T. Davis, who have contracted to construct the substructure for the new bridge. Their present work consists of sinking into place the enormous caisson which is to form the footing for the north main pier. The amount of plant that must necessarily be placed in position, the enormous work involved before the actual work of sinking the caisson can be commenced, are features that cannot fail to impress the onlooker.

The big caisson was built at Sillery, a small village about two miles to the west and on the same shore. Here again it was necessary to make elaborate preparations for construction and launching. Work was first commenced early in April of the present year and a large shed, approximately 200 feet by 70 feet, was erected to ensure steady progress, regardless of weather conditions. For a short period the contractors were delayed pending alterations to the plans, but on July 8th work was well advanced and the launching from the ways was successfully accomplished. To aid in this latter work, concrete piers had been constructed to better control the movement of the caisson until it reached the water.

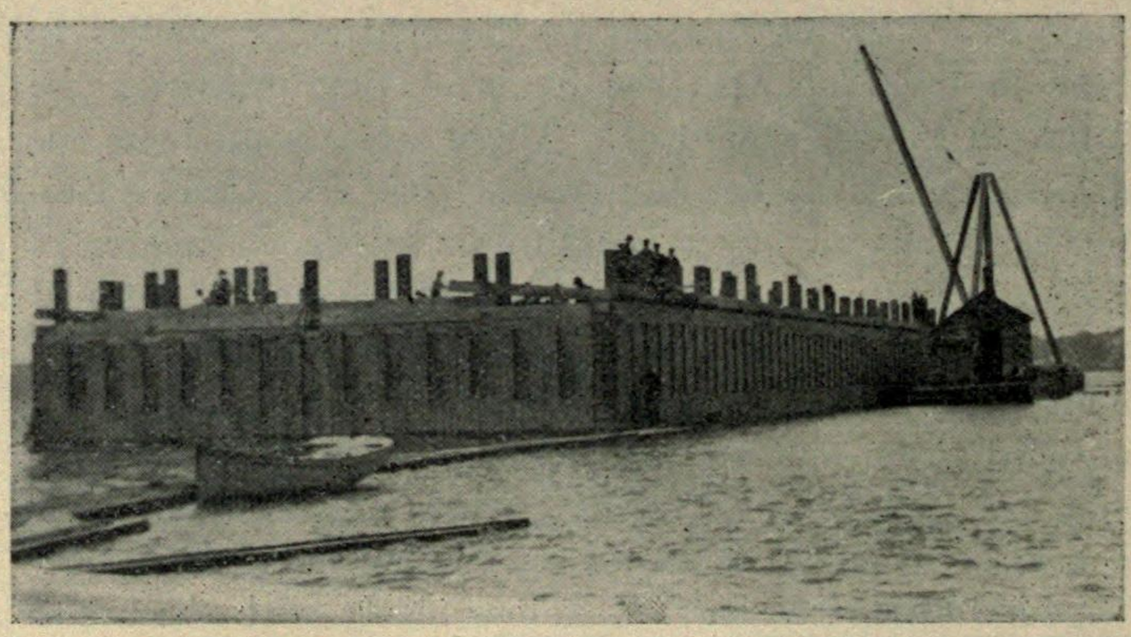
On August 1st the caisson was towed out and placed in position. Taking advantage of the period between tides, the caisson was floated in between two rows of piles, with a small clearance of two feet at each end. A staging was afterwards erected, closing off the entrance-way. Both up and down stream the caisson is securely anchored by cables attached to heavy oak beams weighted in position by rocks. The number of cables will be augmented as the caisson goes down and the pressure increases. When launched the big structure drew only five and a half feet of water, the floor having been false-bottomed to give this effect.

The site of the new north caisson is five feet south of the existing caisson and is to be sunk to an elevation four feet, or much lower than the old one. The centre line of the new north main pier will be 57 feet off shore from the centre line of the old pier and will be also 15 feet west of the centre of the old north pier, to accommodate the shift of the new south pier. The anchor pier and abutment will also shift the same distance to the west, but details of these have not yet been settled.

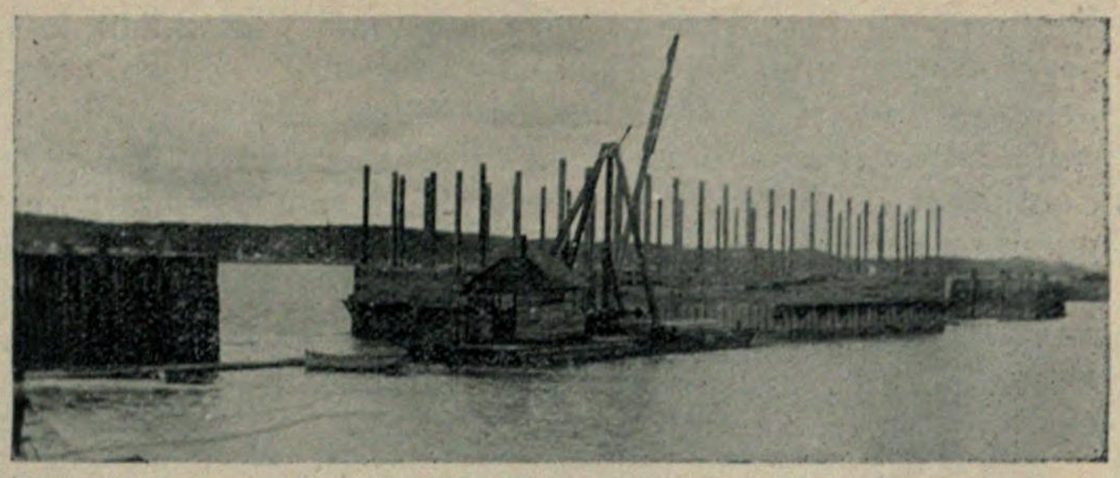
Caisson Construction—The caisson for the north main pier embodies several unique features in caisson work. In giving this important work to Messrs. Davis, the Board of Engineers left the design to the contractors, stipulating only that it should be most modern in every respect and that the final plans should be subject to the Board's approval. Caisson work is not new to



General view of M. P. & J. T. Davis' plant at Sillery.



The big caisson just after being launched at Sillery



Big caisson at Sillery ready to be towed out into position

Messrs. Davis, and it may be said that in planning this structure the experience of years was available. The dimensions of the caisson on the cutting edge will be 180 feet 6 inches by 55 feet 6 inches. In the main wall construction, 12 feet by 12 feet, Georgia pine timber is being employed, while for the cutting edge, 30 feet by 30 feet, British Columbia fir has been adopted. The wall seams are being well caulked with oakum, pitch and tar to render them water tight. The heavy square timber forming the walls will be kept in place by thickly interspersed drift bolts. In order to minimize friction in sinking caisson the walls will be cased with two layers of 3-inch tongued and grooved sheeting, laid vertically.

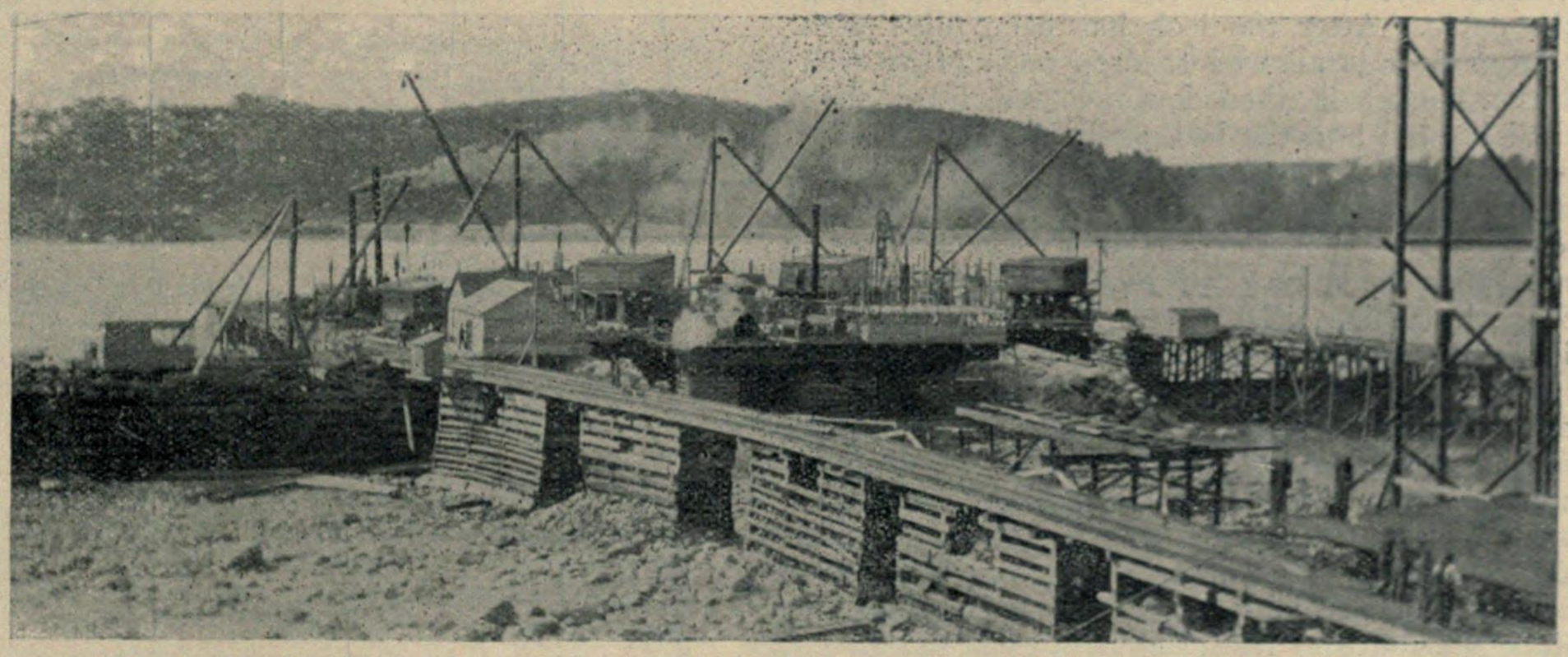
The working chamber, which is both air and water tight, is divided by eight bulkheads and has a comfortable working height of eight feet. The roof or deck of the working chamber consists of two rows of 12-inch by 12-inch pine timber, separated by two layers of 3-inch tongued and grooved planking. The whole is well supported and knee braces are placed at frequent intervals.

For the cutting edge the usual steel shoe has been discarded and is in this construction replaced by a wearing timber consisting of a solid piece of oak, 12-inch by 6-inch and which is easily replaceable. It is estimated by the contractors that this arrangement will be more serviceable, since the usual steel shoe, once it becomes twisted or broken, is no longer useful and cannot be replaced, whereas the wooden timber can be renewed without difficulty, as required.

By a remarkable coincidence the seven-ton girders which were to have formed, in the old bridge, the floor beams for the railway section of the bridge, were found to be of just sufficient length (55 feet) to be of service in supporting the walls of the caisson.

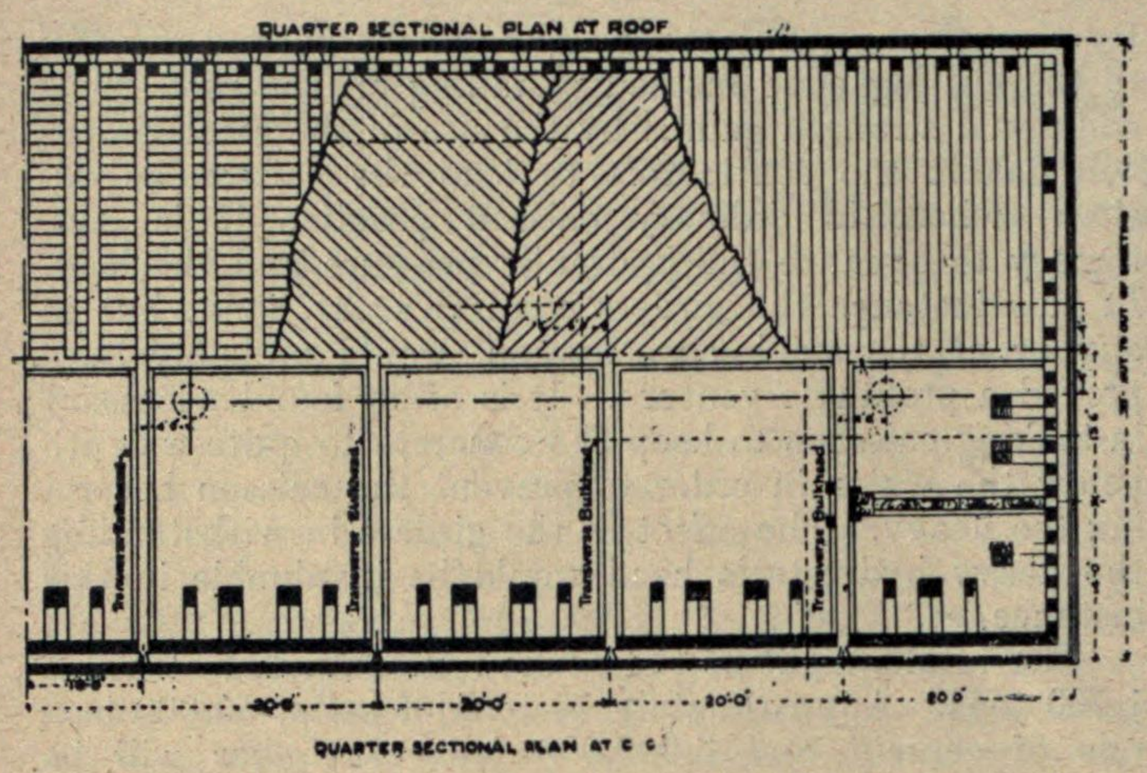
The first row of 17 girders has already been placed in position about 15 feet above the deck of the caisson. By this arrangement the weight will be carried directly to the cutting edge instead of falling on the roof. The additional strength gained by the use of the steel girders will enable the contractors to load the caisson as desired, where in ordinary caisson practice it is customary to equalize the hydraulic pressure and the load. In this instance the girders were close at hand, but in any event the steel construction would probably have proved a profitable venture. It is often found necessary in sinking caissons to keep the concrete to quite a depth below the water in order to prevent the caisson becoming too heavy. The effect of the girders in withstanding the heavy hydrostatic head would be invaluable in this instance.

The total weight of the caisson is estimated at about 1,700 tons. Approximately 70 tons of bolts, 50,000 barrels of cement and 3,000,000 feet of timber will be required for its construction. The method of excavating material for the working chamber will be along the usual lines employed in caisson work. The contractors, to facilitate operations, employed a dipper dredge on the site of the caisson, and dredged the bed to a considerable depth. When the cutting edge reaches the river bed the lighter material will be blown out, all the chambers being piped This operation consists of simply allowing the compressed air in the chamber to escape, carrying with it the material, which has been shoved up against the valve. Jets of steam can also be blown into the chamber under high pressure to loosen the sand and gravel. Sinking pumps will be employed to remove



View of contractors' plant from east of elevator

General view of construction work showing steam dredge in operation. (Inset shows where larger view was taken and also sheds containing boilers, air compressors, etc.)



Showing the deck or roof construction of caisson. Note extensive knee bracing

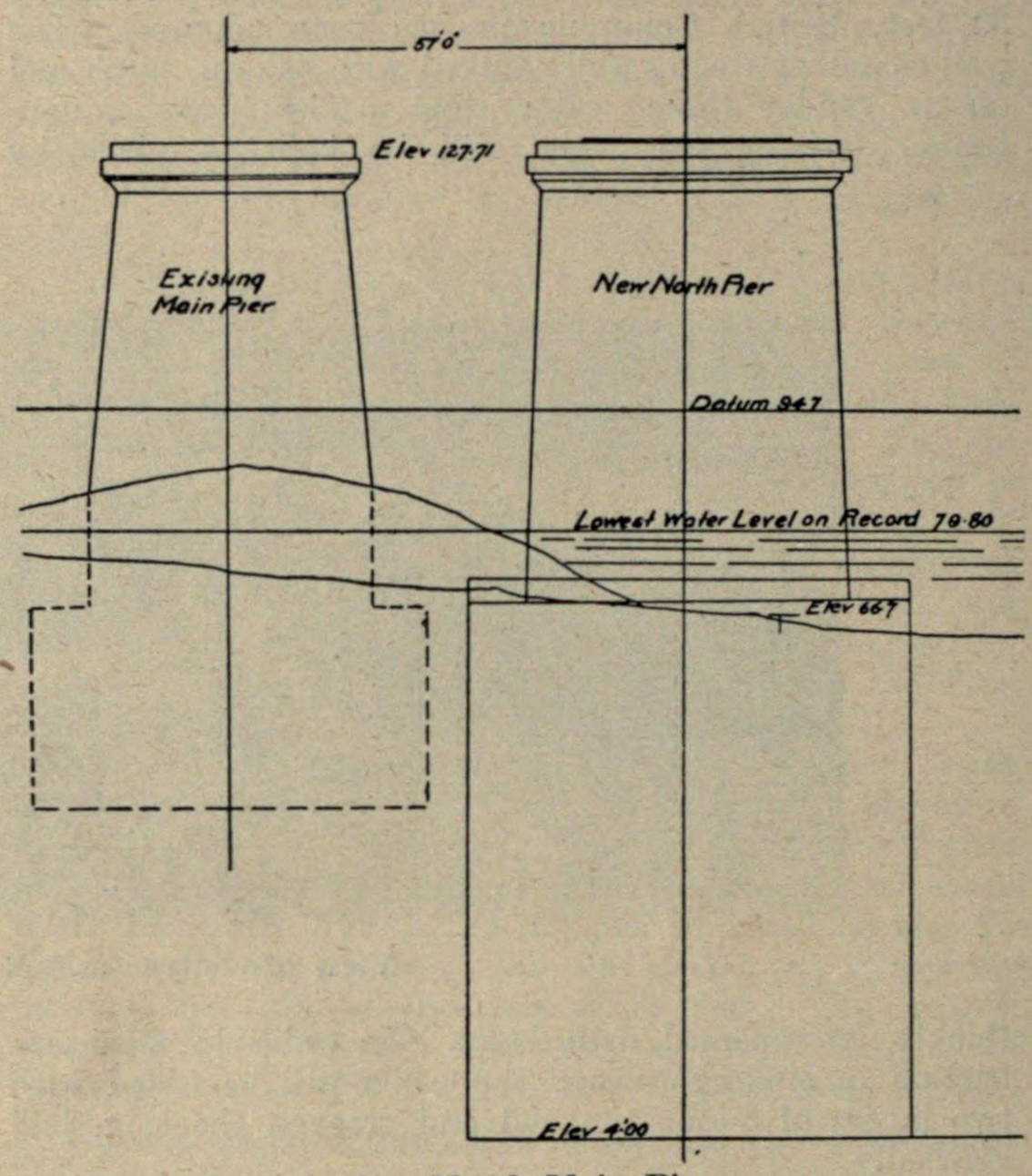
some of the material while the heavier excavations will be taken out by buckets through air locks. This latter operation takes place as follows: The bucket is lowered by the derrick into the lock, the upper door closing against the cable. After the lock has been filled with air the bottom door is allowed to drop open of its own weight. The bucket is then lowered and filled with material and hoisted into the lock again. Then the lower door is swung up by levers from the outside and the air in lock allowed to escape, permitting the top doors to be opened.

Messrs. Davis have now on hand a large staff of "sand-hogs," by which title the excavators are known. At the lower depths these men will be working at a pressure of about 48 pounds. Two 40-minute shifts in the 24 hours complete a day's work at these depths, for which the men receive liberal pay.

The work of concreting the cofferdam has now been placed under way and from this time on the contractors figure that rapid progress will be made in sinking the caisson. Once the river bed is reached the pneumatic work will be started and the caisson is expected to go down at the rate of one foot to eighteen inches per day. Work will be carried on continually, night and day, until the big structure is sunk to the required depth of approximately 70 feet.

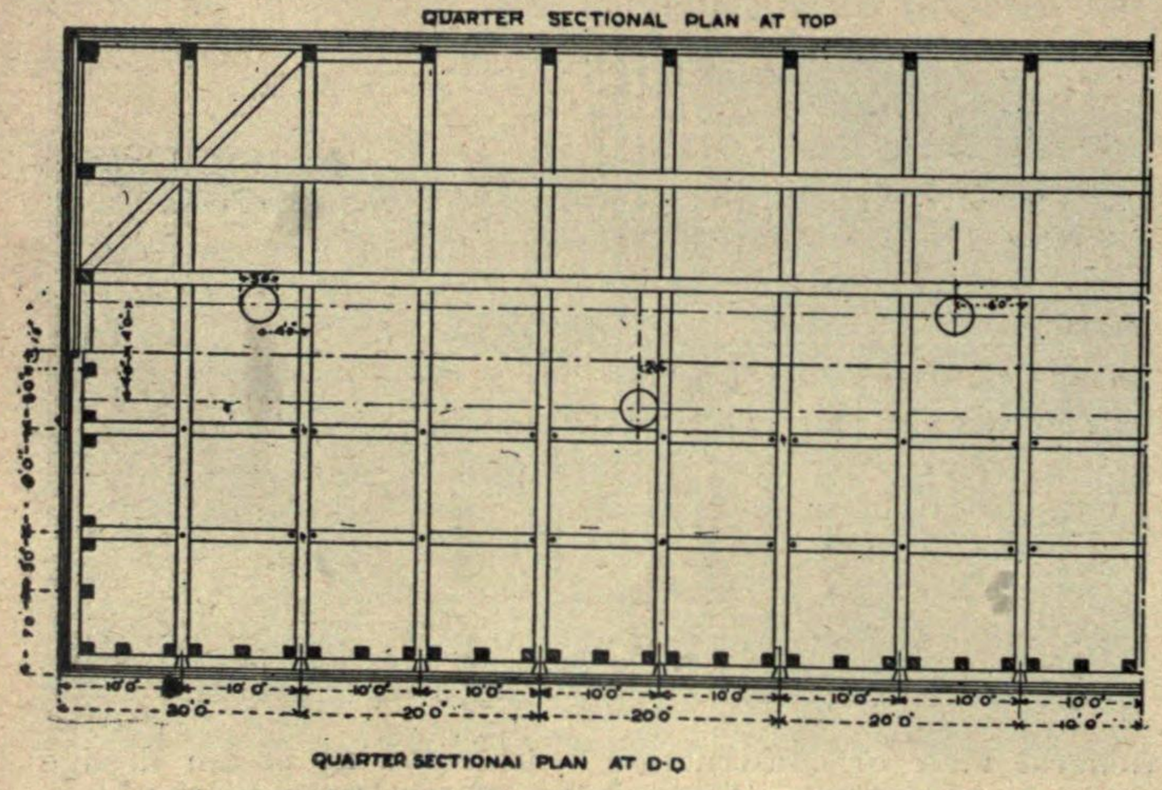
Plant—The machinery and plant required by Messrs. Davis in carrying out their substructure contract is extensive. At the foot of the hill is located the power and boiler house. Here are situated the four large Ingersoll-Seargent air compressors with a capacity of 2,240 feet per minute, under 100 pounds pressure. These compressors are driven by a battery of six 125 h.p. boilers, supplied by the John MacDougall Caledonian Iron Works Company, Limited. This air is chiefly for service in the pneumatic caisson work and is carried out to the staging through a 12-inch pipe and fed into the caisson as required. This compressed air pipe is surrounded by a water jacket in order to cool the air and thus render the work of the men more comfortable.

On the top of the hill, a trestle work has been erected. This will enable the dump cars to empty their loads of gravel and rocks into the chutes which have been prepared to receive them. From the hill, the materials to form the concrete are led below by a natural gravity system. The rock passes through to the rock crushers, two in number, supplied by Allis-Chalmers-Bullock, Limited, which are separately steam driven, and from

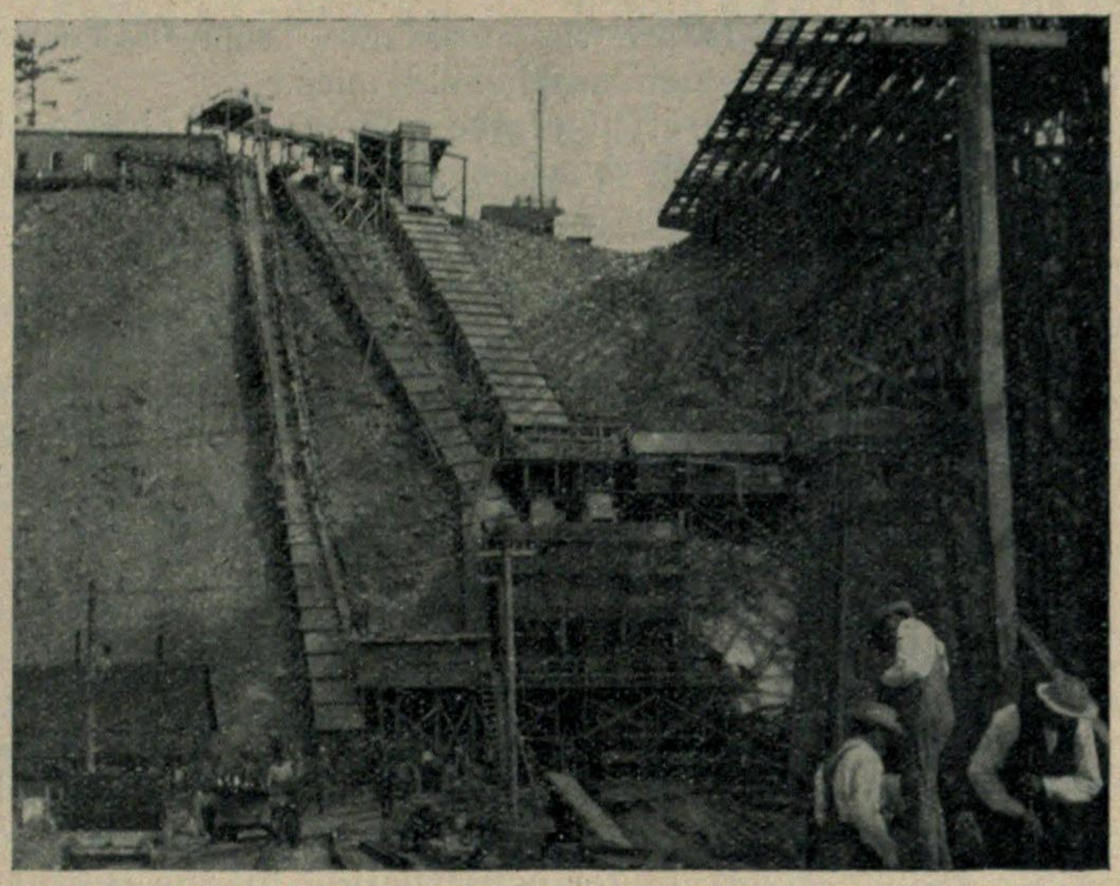


New North Main Pier

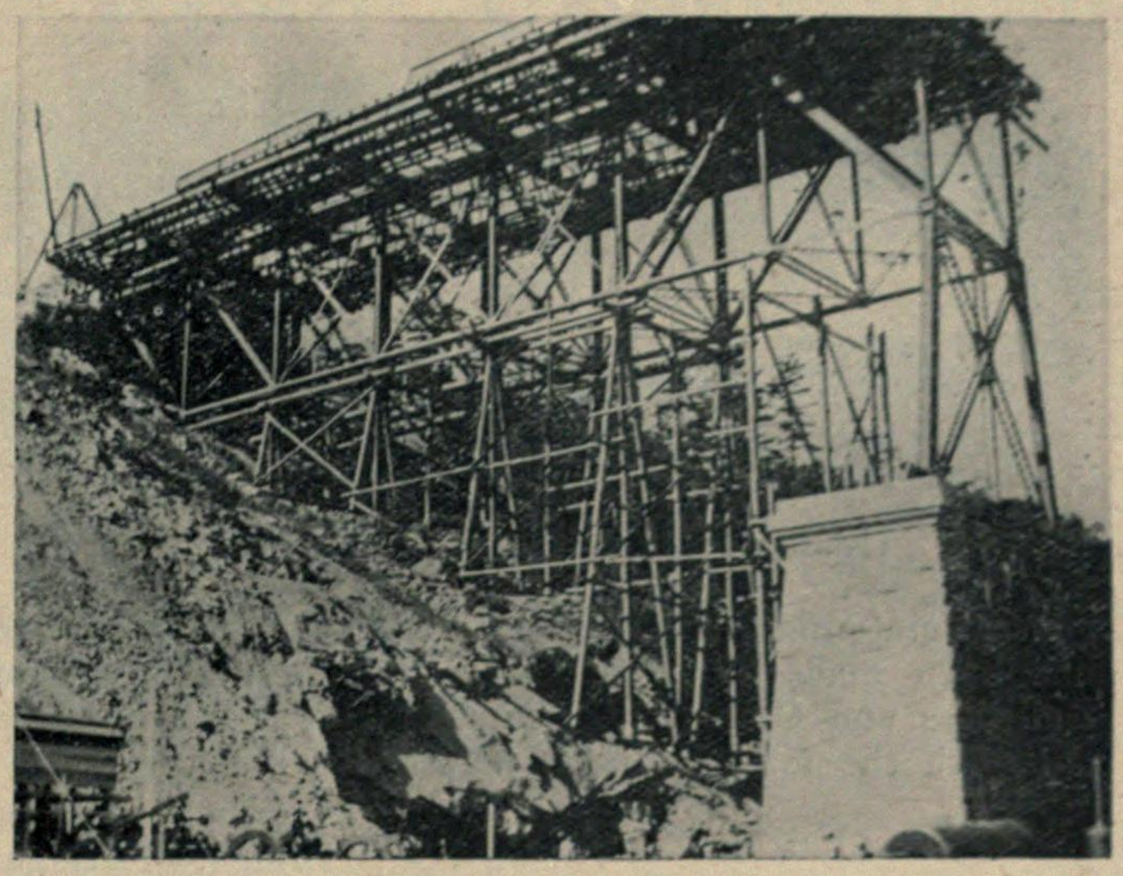
there is fed to the two concrete mixers. The rock bin, it may be mentioned, has a storage capacity sufficient for a 24-hour run, thus minimizing danger of cessation of work. Gravel and concrete are also delivered to the mixers through chutes at the top of the hill and from the mixers a railway carries the concrete to the side of the caisson. The anchor pier of the old bridge, a splendid piece of masonry, is being pulled down by the contractors and the granite obtained from this source will be used in the cofferdam construction. Six derricks, three on the north and three on the south staging, placed so that they will operate equally well at either high or low tide, have been installed to hoist the various materials as required. Messrs. Davis have also installed an electric lighting plant and the whole works will shortly be illuminated by numerous arc lamps. Since the work is to be carried on night and day without ceasing, the necessity for the lighting plant will be appreciated. For the accommodation of the engineers a commodious boarding house has been erected at the foot of the hill, and close to the work. Here the wants of



Showing the lay out of square timbers forming roof of caisson



View of concrete plant from trestle

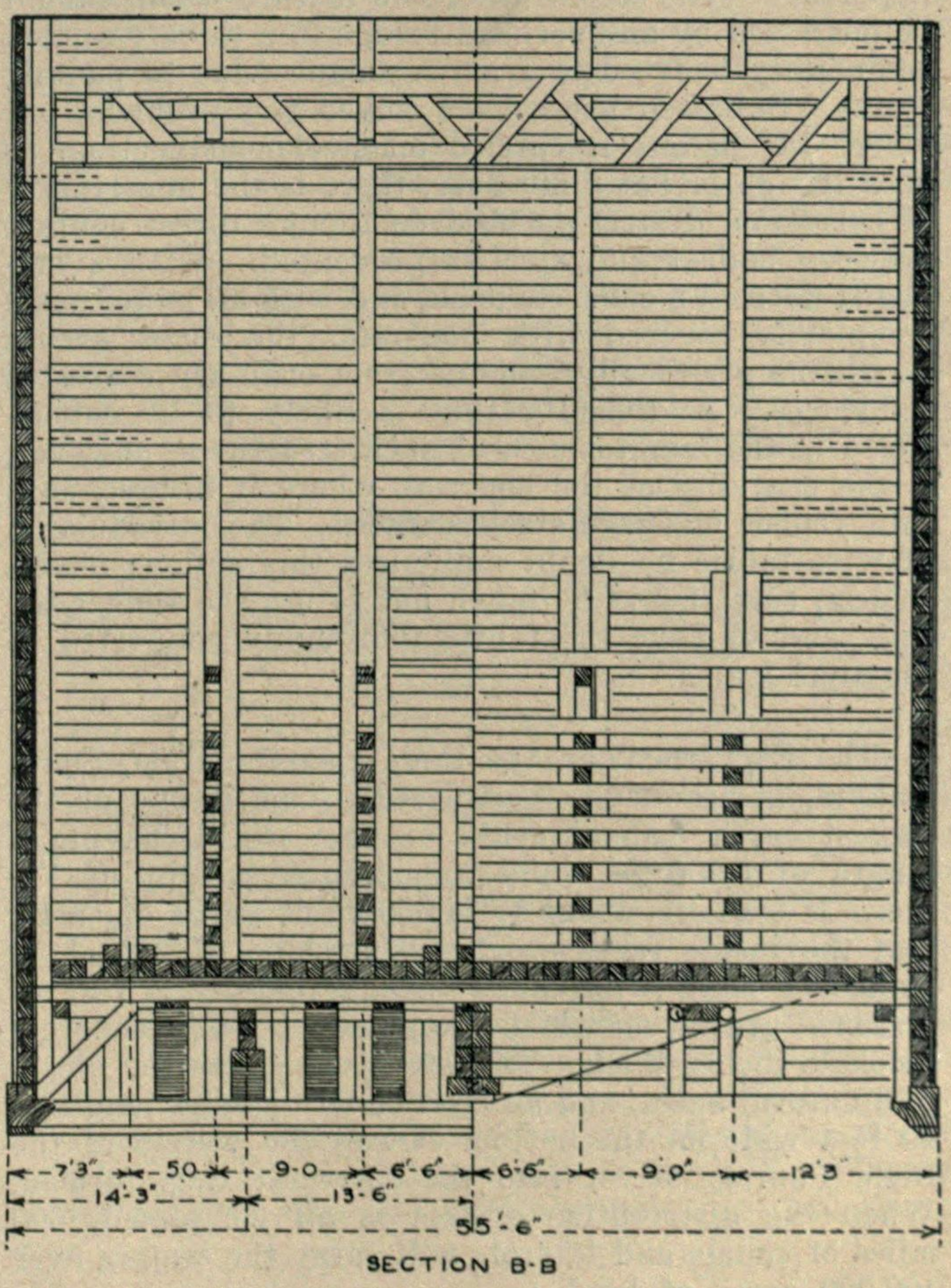


Extent of construction of old bridge on north shore. All the steel will be removed and the granite forming anchor pier will be used in construction of new caisson

the men are considerately looked after while the cuisine provided is of the best.

Mr. M. P. Davis personally takes an active interest in the work of superintending construction with Mr. C. A. D'Abbedie, Mem. Can. Soc. C. E., who is the engineer in charge. Mr. Wm. J. Galbraith is also actively connected with the caisson construction.

Office of Quebec Bridge Commission—The Board of Engineers have erected at the crest of the hill a combined office and rooming building where the Government's staff of engineers are established. Mr. J. D. Wilkins, the resident engineer for the commission, is a man of considerable experience in general engineering practice. Previous to his present position he was commissioner in charge of construction on the famous Queensborough (Blackwell's Island) Bridge. He was also connected with the erection of the Williamsburg Bridge and for a number of years was identified with the engineering interests of the New York Central Railway lines. At the present time Mr. Wilkin's department is engaged in testing the concrete to be used in construction of the large caisson and in generally supervising the progress of the work on behalf of the Bridge Commissioners. Attached to this office also are Messrs. Atkinson and H E. Bates.



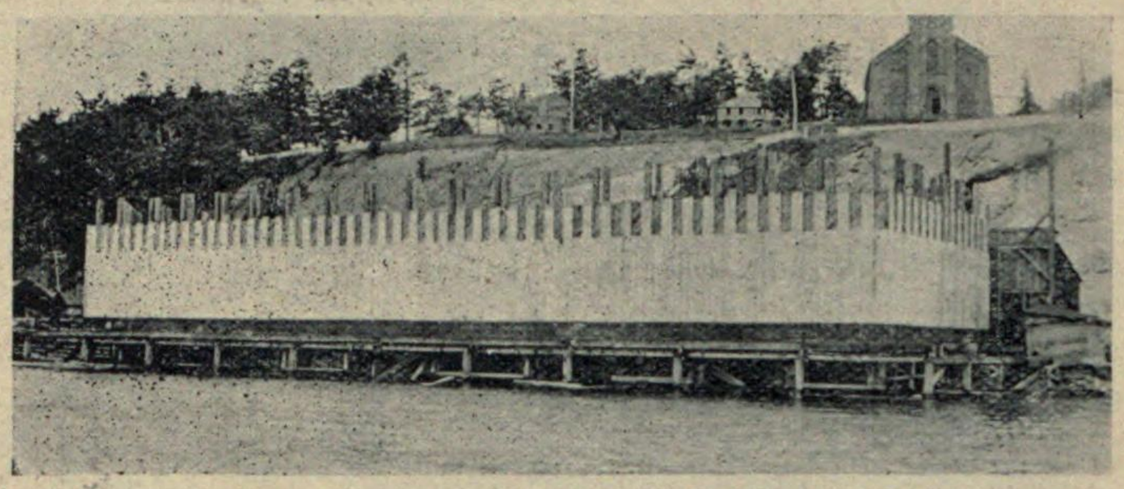
SECTION B-B

Side elevation of caisson with sheeting removed

Koenig & Company's Operations—The work of removing the debris of the Quebec bridge has been carried on continually for several months by Messrs. Koenig & Company, of Quebec, and a big pile of wreckage has been taken out and piled on the shore. During the spring two bodies of victims were recovered. In the early operations an oxy-acetylene flame under heavy pressure was used to advantage in cutting up the twisted debris. Latterly the contractors have resorted with considerable success to dynamite to assist them in their work. Heavy charges of dynamite have sometimes to be used. For instance, it required a charge containing 50 pounds to blow the big shoe plate from the anchor pier. The work of dynamiting is not carried on without danger, but a bomb-proof shelter, consisting of heavy timbers, has been provided for the workmen. In some instances fairly large pieces of steel, blown across the river to the north shore, have been picked up by the contractors at work on the caisson. In the operation the sticks of dynamite are simply laid against the wreckage. Good results have been achieved by this method of procedure.

Phoenix Bridge Company's Contracts—The Phoenix Bridge Company, the contractors for the construction of the old bridge, are at present employed on the north shore removing their falsework which had been erected to a considerable distance past the completed approach span. They have about fifty men employed and with the assistance of three derricks are making excellent progress. As fast as the false work is taken down it is loaded on cars and shipped back to the company's plant at Phoenixville, Pa. This company also have the contract for taking down the intact approach spans on both sides of the river.

A Comparison With the Famous Forth Bridge—A



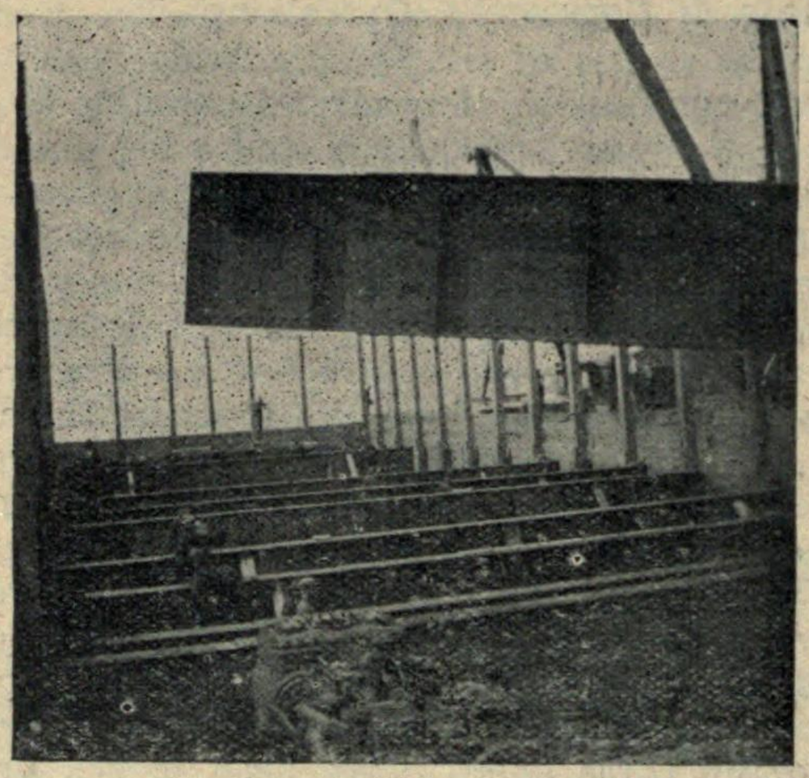
Caisson ready to launch at high tide

general statement in reference to the new Quebec bridge has been made by Hon. G. P. Graham, Minister of Railways and Canals. A comparison is made throughout with the famous bridge across the Forth:

	Quebec Bridge.	Forth Bridge.
Total length of cantilevers .....feet	2,930	5.349.5
Number of channel spans	1	2
Length of longest channel span..feet	1,758	1,710
Load per lineal foot bridge is designed to carry exclusive of its own Weight .....pounds	13,340	4,480
Total weight of bridge .....tons	72,000	57,000
Weight per lineal foot for cantilever only ..... pounds	49,150	21,360
Greatest depth of piers below high water ..... feet	93	87

Roadways on Quebec bridge: 2 railway tracks, 2 street railway tracks, 2 highways, 2 sidewalks; on Forth Bridge: 2 railway tracks.

The weight per lineal foot of steel in the Quebec bridge is 2.30 times as great as that of the Forth bridge.



Swinging a girder into position. This construction enables the contractors to load the caisson up to any point required

The load for which the Quebec bridge is designed is 2.98 times as great as that for which the Forth bridge was designed.

The Forth bridge has 4.77 pounds of carbon steel for every pound of live load it is designed to carry.

The Quebec bridge has 3.69 pounds of nickel steel for every pound of live load it is designed to carry.

The prescribed test load for the Quebec bridge is 4⅓ times heavier than that used for the Forth bridge.

Test pieces of the compression chord of the old Quebec bridge broke at 26,850 pounds per square inch.

Test pieces of similar chords for the new bridge broke at 56,800 pounds per square inch.

The new chords are therefore more than twice as strong per square inch as the old ones.

The maximum section of the compression chords of the old bridge was 843 square inches; in the new bridge the maximum section is 2,037 square inches.

According to the tests the old chords would break under a pressure of 22,634,000 pounds, and the new ones under a pressure of 115,701,000 pounds.

The new chords are therefore more than five times as strong as the old ones, although the live load of the new bridge is only about twice as heavy as the live load of the old bridge.

Problem of Steel Bridge Corrosion

Encasing Steel Arch Ribs in concrete, as used in the Buffalo grade crossing improvement, illustrates one phase of the effort to solve the problem of steel bridge corrosion, says the Engineering Record. The plate girder arches, under construction by the Buffalo Grade Crossing Commission to carry railroad tracks over highways, possess the additional merit of satisfactorily meeting two other requirements which are often overlooked in grade crossing eliminations. In the first place the arch presents by far the most pleasing appearance of any bridge type that could be used in such a location. It should be borne in mind, however, that to secure the best architectural treatment the clearance under the structure should not be too small. Frequently, in fixing the clear headroom underneath the bridge, the minimum is used without giving proper consideration to the effect which this will have on the finished structure. It is, of course, realized that this matter is intimately connected with the question of cost, but in many locations appearance is of prime importance. The second desirable feature which should be possessed by an overhead bridge in a thickly settled community is freedom from resonance due to passing trains. Ballasted floors have solved this problem, but where the ballast is carried on steel construction, as on a trough or flat plate floor, there is the uncertainty of corrosion of steel parts, even though direct contact between ballast and steel is prevented. With a ballasted floor on a concrete deck, and with all metal parts completely covered with concrete, the steel arches should be practically immune from ordinary corrosive influences. A difficulty that is likely to be experienced in the maintenance of such structures, however, is the cracking of the concrete where it is used as a thin veneer on large steel surfaces. The introduction of wire fabric no doubt minimizes this action; nevertheless, care should be taken not to use the veneer too thin, and to have the fabric thoroughly connected to the steel frame.

The Earthwork on the Belle Fourche Dam, South Dakota, is practically completed. This is one of the largest earth embankments in the world, having a length of 6,200 feet and a maximum height of 115 feet. It contains about 1,674,000 cubic yards of earth, and the inside face, which has a slope of 2 to 1, is protected from wind and wave action by 2 feet of screened gravel, on which are placed 4 x 6-ft. concrete blocks 8 inches thick. This structure closes the outlet to a natural basin, and an inlet canal 6½ miles long and 40 feet wide on the bottom carries the waters of the Belle Fourche River into the reservoir thus formed. When the distribution system is all completed, 600 miles of canals and laterals will carry the waters over 100,000 acres of land.

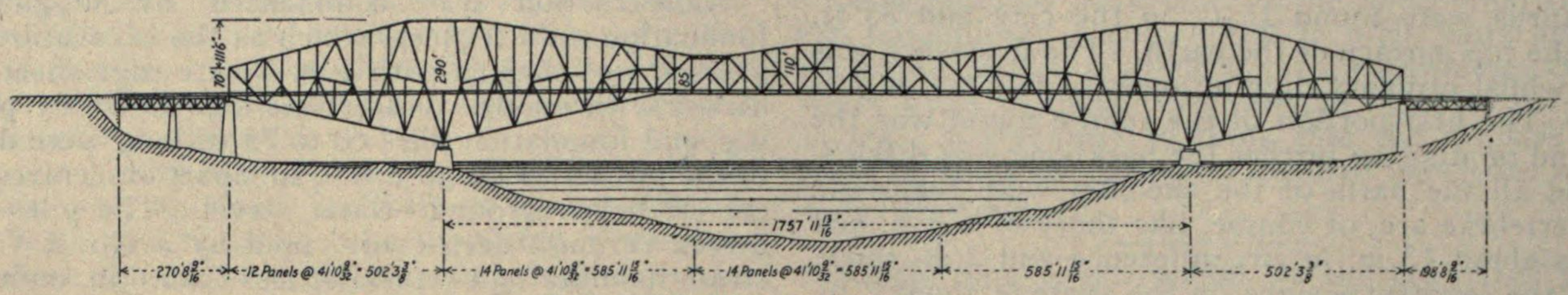


FIG. 1. OFFICIAL DESIGN V, BOARD OF ENGINEERS.

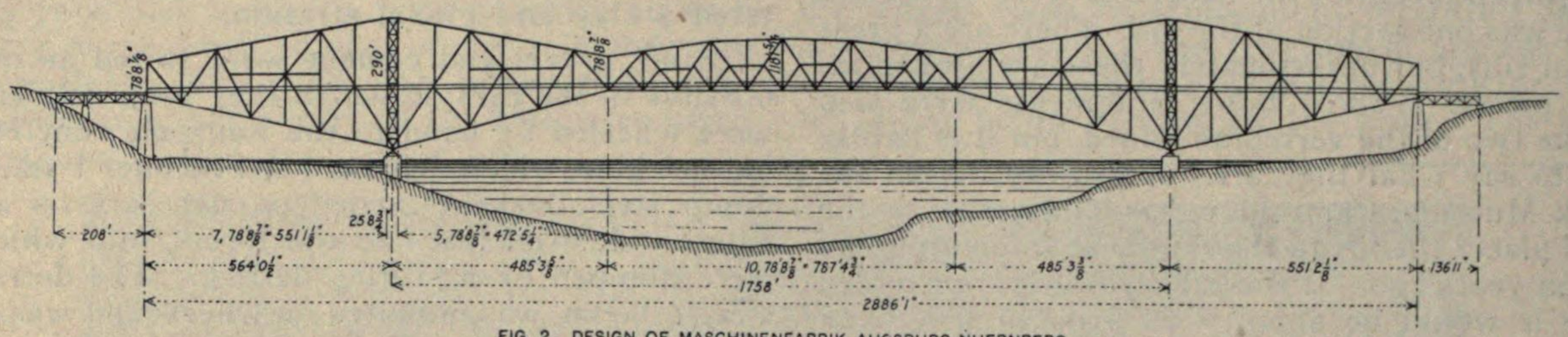


FIG. 2. DESIGN OF MASCHINENFABRIK AUGSBURG-NUERNBERG.

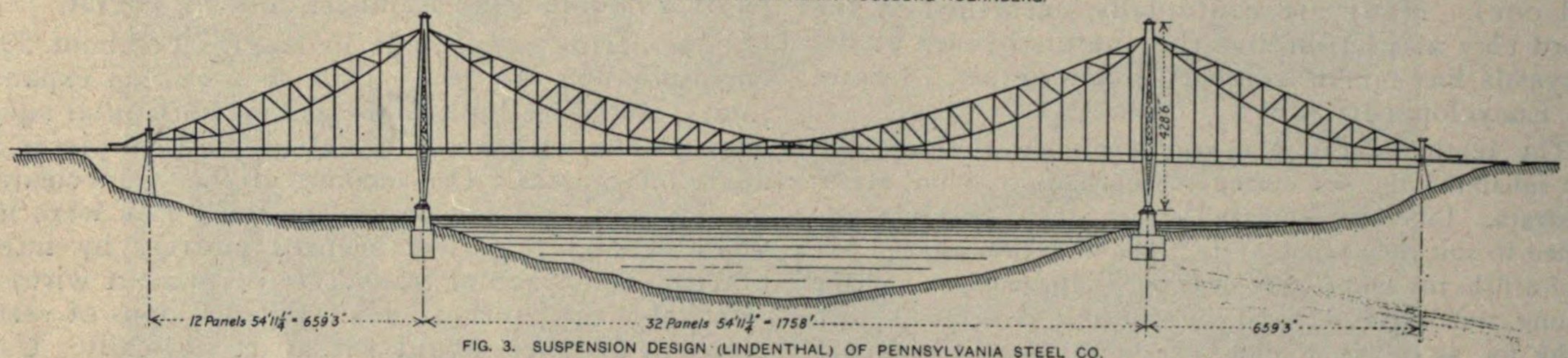


FIG. 3. SUSPENSION DESIGN (LINDENTHAL) OF PENNSYLVANIA STEEL CO.

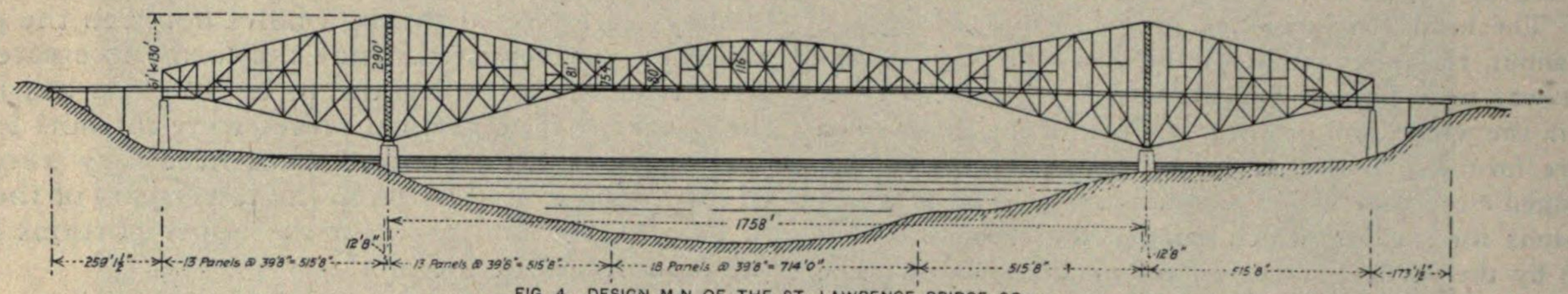


FIG. 4. DESIGN M-N OF THE ST. LAWRENCE BRIDGE CO.

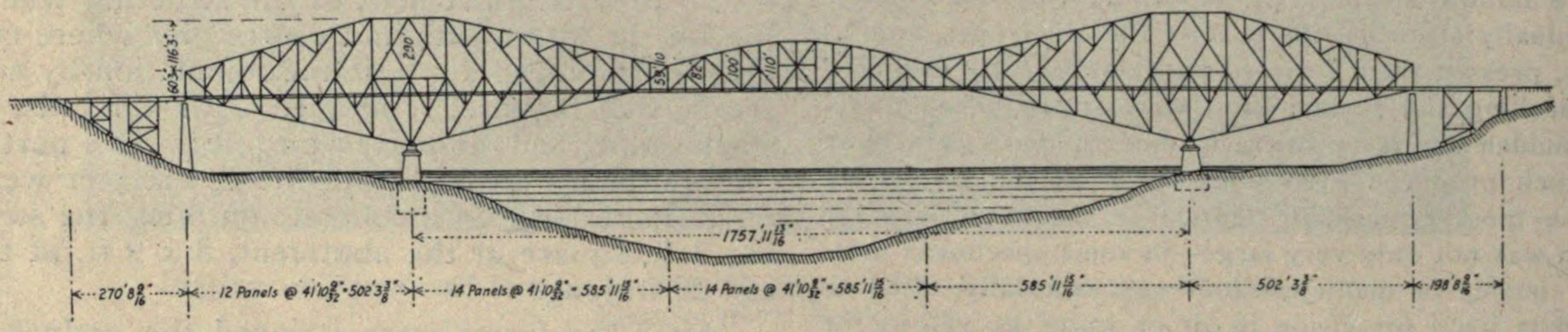


FIG. 5. DESIGN A-B-X OF THE ST. LAWRENCE BRIDGE CO.

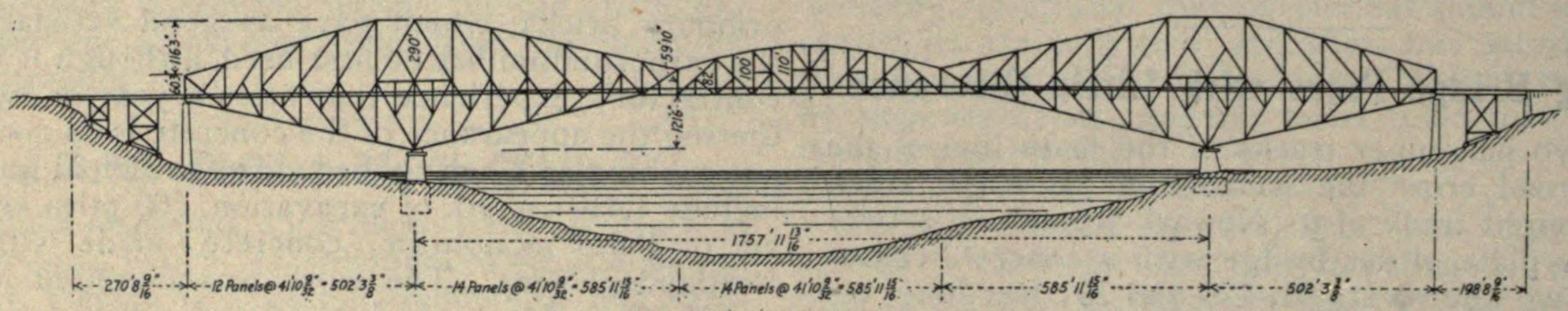


FIG. 6. DESIGN C-Y OF THE ST. LAWRENCE BRIDGE CO.

OUTLINE DIAGRAMS OF SIX COMPETING DESIGNS FOR THE NEW QUEBEC BRIDGE OVER THE ST. LAWRENCE RIVER.

Designs Submitted for the Quebec Bridge

Together with the Accepted Design of the St. Lawrence Bridge Company, of Montreal—Interesting Features of the Various Plans

The diagrams of the accepted design upon which the contract for the reconstruction of the Quebec bridge was awarded to the St. Lawrence Bridge Company, of Montreal, and also six of the competing designs are reproduced herewith from an official drawing.

The St. Lawrence Bridge Company, as is now well known, is a combination of the Dominion Bridge Company, Montreal, and the Canadian Bridge Company, Walkerville. The contract price is about $8,650,000; this sum and the contract price for the substructure make a total of about $12,000,000. It is expected the bridge will be finished by 1915. In addition to the St. Lawrence Bridge Vompany, three other firms tendered on this work, namely, the Maschinenfabrik Augsburg-Nurnberg Aktien Gesellschaft, of Gustavsburg, Germany; British Empire Bridge Company, of Montreal, and the Pennsylvania Steel Company, of Steelton, Pa. Tenders were based on the plans and specifications prepared by the Board of Engineers in charge of the work, but contractors were granted the privilege of preparing plans of their own, if they should so desire, and submitting tenders thereon. Three of the above firms availed themselves of this privilege; the St. Lawrence Bridge Company, in fact, submitted seven different plans with tenders, in addition to tendering on the Board's plans.

The official plan was for a cantilever bridge with anchor arms and cantilever arms of the same length, and the erection to be by cantilevering out the suspended span. Five modifications of this design were also prepared by the Board, a tender on any of the six propositions being considered a tender on the Board's design. Two of these schemes were based on erecting the suspended span by cantilevering out, while the remaining four were based on erecting the suspended span at an adjacent site and floating it into position.

The Maschinenfabrik Augsburg-Nurnberg Aktien Gesellschaft tendered on three of the designs of the Board. It also submitted a tender on a design of its own, fig. 2. The principal features of this design are the large panels, the small number of members in the web system and the length of the suspended span. The material proposed was a chrome nickel steel. Built up riveted members were to be used for tension members throughout.

The British Empire Bridge Company submitted six tenders on the Board's design only. It proposed two schemes of erection in connection with the floating in of the suspended span; one floating the span in on high falsework, the other by floating in a light temporary span to be used as staging upon which the suspended span is erected.

The Pennsylvania Steel Company submitted ten tenders on the Board's design and one tender on an eyebar suspension span designed by Mr. Gustav Lindenthal, fig. 3. This company submitted prices on two schemes of erection of the suspended span. In one scheme the suspended span is floated in on high falsework, while in the other the entire span is lifted directly from the pontoons by a special lifting device designed and patented by the company.

The St. Lawrence Bridge Company submitted a tender on each of the Board's designs and, in addition, seven tenders on designs of its own. In general elevation and outline the designs submitted by this firm conform to that of the Board's design. Two of these designs are of the single intersection Warren type, fig. 4, the remaining five being variations of the single intersection K web system type, figs. 5 and 6. The variations in these different tenders were due mainly to variation in the details of the members, as well as the proportion of nickel and carbon steel used in the construction.

The design approved by the majority of the Board, as well as the additional experts appointed by the government, was one submitted by the successful contractors, it being the opinion of the engineers that this design contained several features, particularly in respect to erection, that rendered it preferable to the designs prepared by the Board.

The design fig. 7, is to have the K web system in the cantilever and anchor arms, the suspended span being a modified Pratt. All members in the anchor arm and those immediately over the main pier, as well as the floor system, are carbon steel, the cantilever arms and suspended span being of nickel steel. The top chords are composed of built-up riveted members extending over one full truss panel or two floor panels.

The suspended span is 640 fe. long, 110 ft. deep at the centre and 70 ft. at each end. The cantilever arms are 580 ft. long, 70 ft. deep at the end and 310 ft. high over the main post. The anchor arms are 515

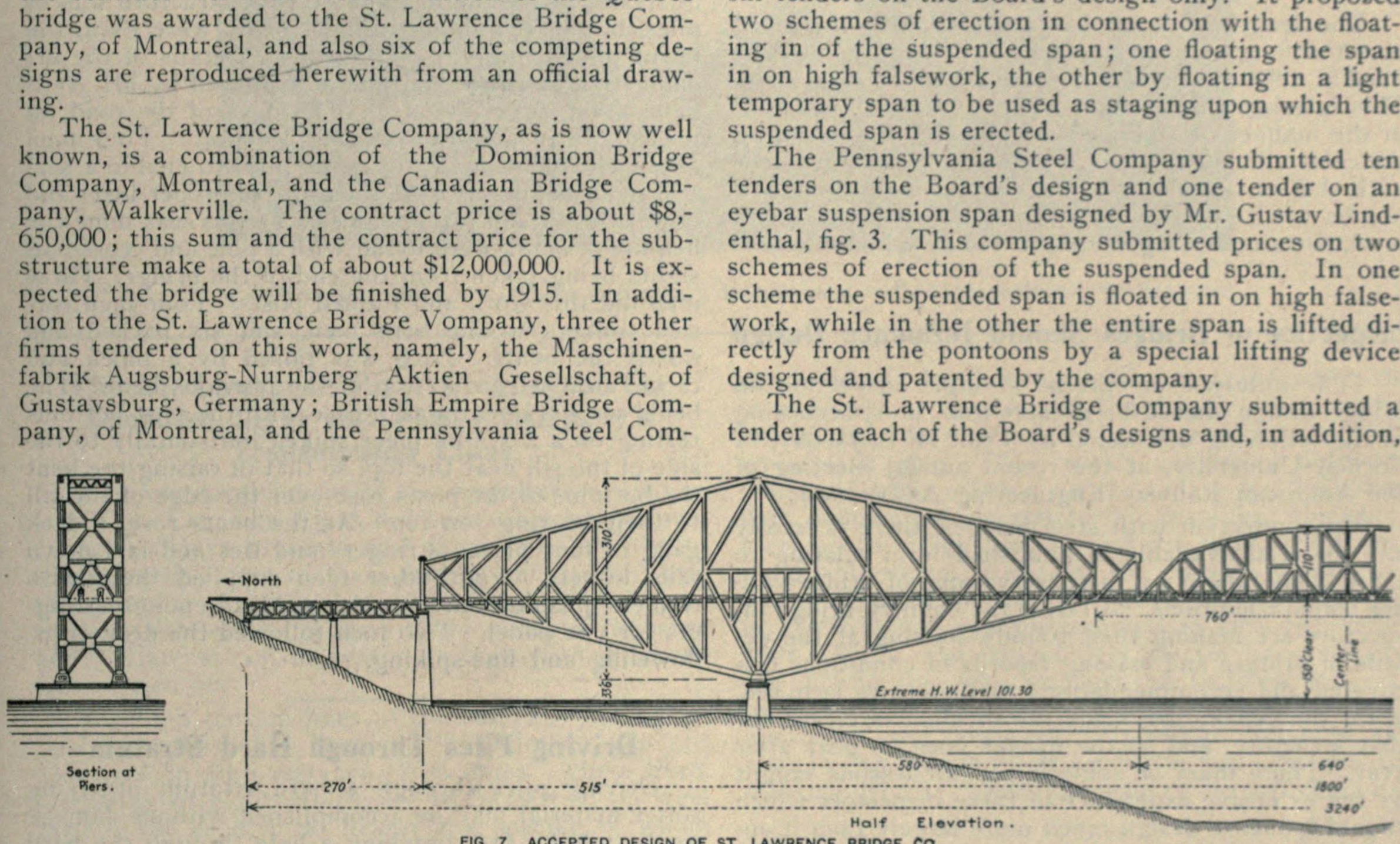


FIG. 7. ACCEPTED DESIGN OF ST. LAWRENCE BRIDGE CO.

ft. long, as at present designed. The trusses are 88 ft. apart and there is a clear headroom of 150 ft. above extreme high water. The total length is about 3,228 ft.

The bridge will be designed to accommodate two railway tracks and two sidewalks for foot passengers, the government having decided that no accommodation will be provided for highway traffic. The train load allowed for on each track will be equivalent to two E60 engines followed by a train load of 5,000 lbs. per lineal foot of track.

The length of span has been slightly increased over that originally proposed by the Board, being now fixed at 1,800 ft., being the same as the original span. This increase was brought about by a rearrangement in the manner of sinking the caissons, thus allowing the centre line of the new bridge to remain coincident with that of the old bridge. The old main piers will not be used, but will be taken down to lower water level, the stone being reused in the new piers.

Inspection of Bridges Should Influence Design

The influence of current bridge inspection on bridge design should be greater than it is, according to the following discussion by Prof. H. S. Jacoby, of Cornell University, at the recent annual meeting of the American Railway Engineering Association:

"In connection with steel bridges, there is hardly any material available in published form relating to the lessons taught by the observations of bridges under traffic conditions. All over the country bridge inspectors are making their rounds, looking at the details of bridges and making records of conditions discovered and recommendations as to repairs required. After the repairs are made the incident is closed for that structure, and so the matter goes on year after year. There must be some important lessons taught by the extensive experience of these inspectors which should influence design much more largely than it apparently does.

"One reason is that the maintenance department is entirely separate from the bridge department, in which the designs of new structures are developed. There are doubtless also other influences at work. Designers and draughtsmen have but little opportunity to become familiar with these matters by direct observation. It seems that the railway does not get the full benefit of the experience of the maintenance department, thus leading to the continued construction of some faulty details because the designers do not learn (except incidentally) of the actual behavior of bridges previously designed by them.

"For example, certain designs of brackets on end floor beams perform their duty in an excellent manner under heavy modern live loads, and under adverse conditions of adjacent track, while others show marked defects. Yet the defective designs are built over and over again on the roads in which the maintenance-of-way department has discovered their weakness.

"This condition is not confined to steel bridges. I am convinced that some railways are losing at least two or three years of service in their Howe trusses because of the lesser relative efficiency of the splices in the lower chords. This is an indication that there are details in timber framing which are not receiving sufficient study by designers, although similar timber structures have been used for many years. This is probably true because the conditions under which failure occurs are not brought to the attention of designers."

An Expeditious Piece of Work

Rapid reconstruction of a burned trestle was accomplished on the Duluth, South Shore & Atlantic Railway by systematic organization of a gang of about 30 men, the time required being 32 hours for 518 feet of trestle 28 feet high. The original structure was of piles, but in rebuilding, framed bents were used, the burnt piles being cut off for sills. Details of the organization and procedure were furnished by Mr. William Noon, superintendent of bridges of the road, to the "Railway and Engineering Review." Four men ahead cleared around the burnt piles to enable a second gang of three to cut them off at proper level and dowel the sills in place. As fast as this was done the heights of bents were found with a pole and cross-bar, sights being taken from the end of the bridge. Three men did this work and framed posts. Four men carried timbers to the bent men, and six packed and raised the bents. Each was raised by a block and tackle attached to the top of the previous bent. The bents were framed in each case with the post bottoms resting on a 2 x 4-in. piece spiked horizontally to the side of the sill near the top, so that in raising the bent the bottoms of the posts rose over the edge of the sill to their bearings on top. As the bents rose, a deck gang of four placed stringers and ties and laid down rails loosely. Four other men supplied them with timbers, pushing out at each truckload enough stringers for one panel. Two men followed the deck crew, doweling and line-spiking.

Driving Piles Through Hard Stratum

Driving piles through a hard stratum overlying softer material may be accomplished without damage to the pile by first breaking a hole through the hard material before final driving is started. A method of doing this is suggested by Mr. F. E. Schall, bridge engineer, Lehigh Valley Railroad, in discussing the recommendation that the hard stratum be removed, as made by the committee on wooden bridges and trestles of the American Railway Engineering Association. This method was adopted in a case where 55-ft. piles had to be driven through a hard embankment under track with a pile-driver having leads of only 40 feet. A 12-in. wrought-iron, double-strength pipe, 25 feet long, was fitted with a steel point and cap and was driven 20 feet into the embankment. It was then withdrawn, the pile dropped into the hole and driven to the proper depth.

The Trent Valley Canal is now open from Orillia to the Trent River, a distance of about 160 miles. The canal was begun before Confederation and has involved an expenditure, up to 1911, of $7,873,501. The route utilizes nearly twenty lakes and numerous rivers, and when completed will form an inland waterway from the Bay of Quinte to Georgian Bay and the Great Lakes. The section from Rice Lake to Lake Ontario, 71 miles, is under contract, at an estimated cost of $6,759,000. It is the most expensive section of the whole canal, and follows the general course of the Trent river. On this section there are to be eighteen locks, with a total fall of 369 feet.

Progress of Quebec Bridge Construction

The Practical Problems of the Work and How they have been Solved to Date—Criticism of the Accepted Design

Special to the Contract Record

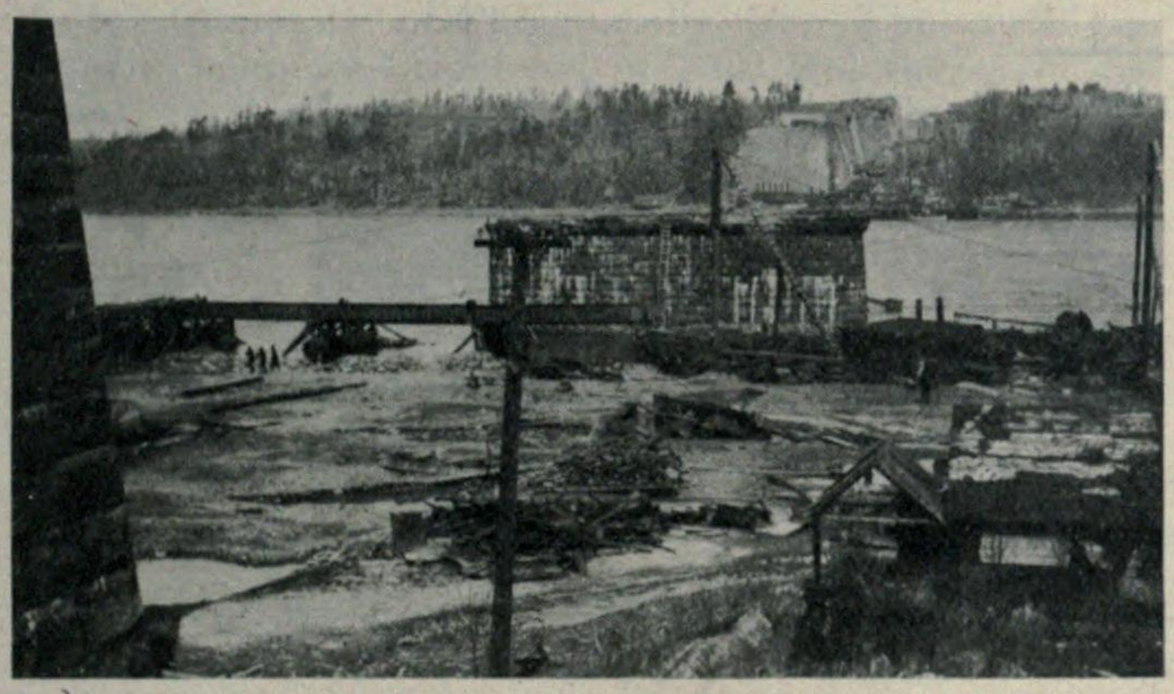
The work on the foundations for the new Quebec bridge is in full swing and is being pushed energetically by the contractors, Messrs. M. P. & J. T. Davis. As stated in the Contract Record of May 3, 1911, the new span is to be 1,800 feet in length. The axis of the bridge remains as in the original structure. The new north main pier will be 65 feet farther out into the river than the old pier, while the new south main pier will be correspondingly 65 feet nearer the south shore. Owing to the change in length of the anchor arms, the location of the north anchor pier will be 50 feet south of the existing pier and an intermediate pier will be built between it and the abutment, which remains in the same position as originally. The new south anchor pier will be 80 feet south of the original one.

Owing to the severe climate of Quebec the work for 1910 was stopped in November and the only work done during the winter was the widening of the rock cut on the north side which necessitated a removal of 20,000 cubic yards of solid rock. About the middle of March work was begun at Sillery on the two new caissons for the north main pier, and as soon as the river was free from ice, in April, work was commenced at the bridge site on both the north and south sides.

On account of the difficulties encountered in the sinking of the north caisson in 1910, the masonry plans have been changed by the board of engineers. A huge caisson, 180 ft. 6 ins. x 55 ft. 6 ins, was built early in 1910, as described in the Contract Record of Sept. 7, 1910. This caisson was put in place and about 8 feet of concrete deposited on the deck where the caisson became strained and developed leaks which caused the work to be stopped. The concrete was blasted out and the caisson towed to the dry dock at Levis and repaired. This caisson remained in the dry dock all the winter. After the additional repairs now being made are completed, the caisson will be sunk for the south main pier. It will be towed to the bridge site and put in place, and will remain there all summer, while two new caissons building at present will be sunk this season for the foundation of the north main pier.

These caissons are identical, each 85 feet x 60 feet in dimensions, and will be placed end to end, 10 feet apart, one each side of the bridge centre line. They are built of 12 in. x 12 in. Georgia pine and are up to the standard of modern practice in caisson foundations. The cutting edge is British Columbia fir, 30 x 30 ins., and instead of a steel shoe it will rest on an oak wearing timber 12 in. x 6 in. This wearing timber can be replaced when injured much more readily than a steel shoe which becomes badly twisted by blasting. The corners of the caisson are protected by steel shoes.

The working chamber of the caisson is 8 feet in height and is divided into four large compartments by solid bulkheads with doors for intercommunication.



View from south side showing old south main pier; in the background the plant on north shore.

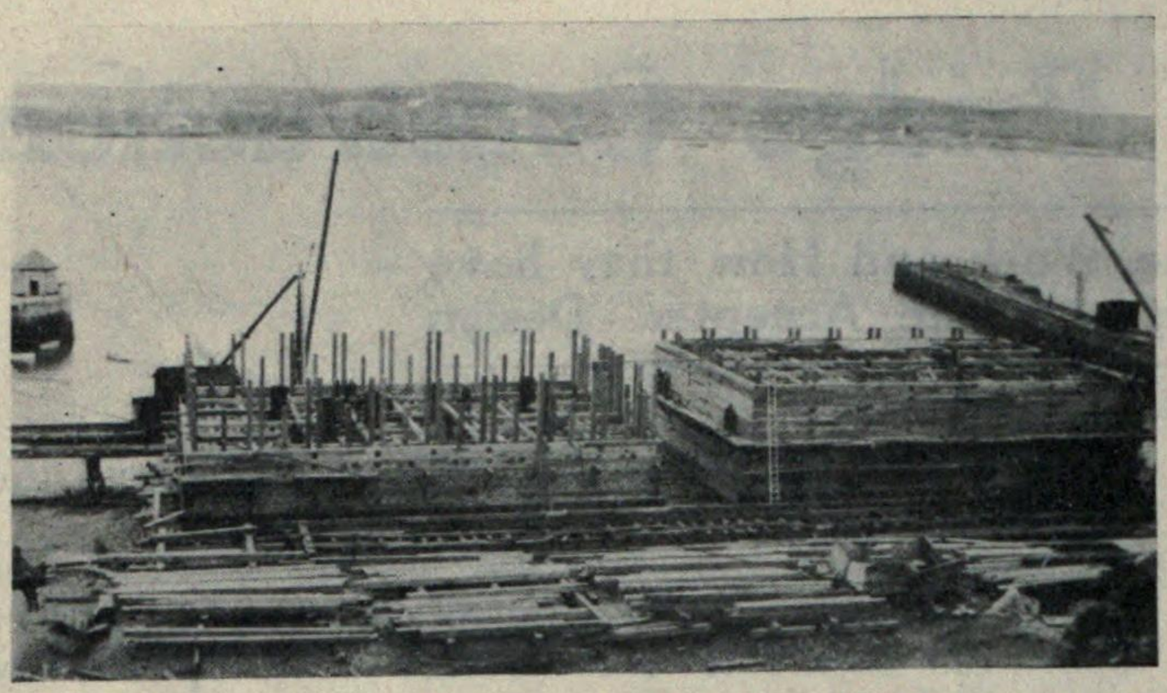
Plant at north shore. Anchor pier in background.

Each compartment is subdivided again by a truss or skeleton bulkhead of timber with diagonal truss rods. The roof of the air chamber is 3 feet thick, well caulked and braced to the walls by 12 in. x 12. in knee braces.

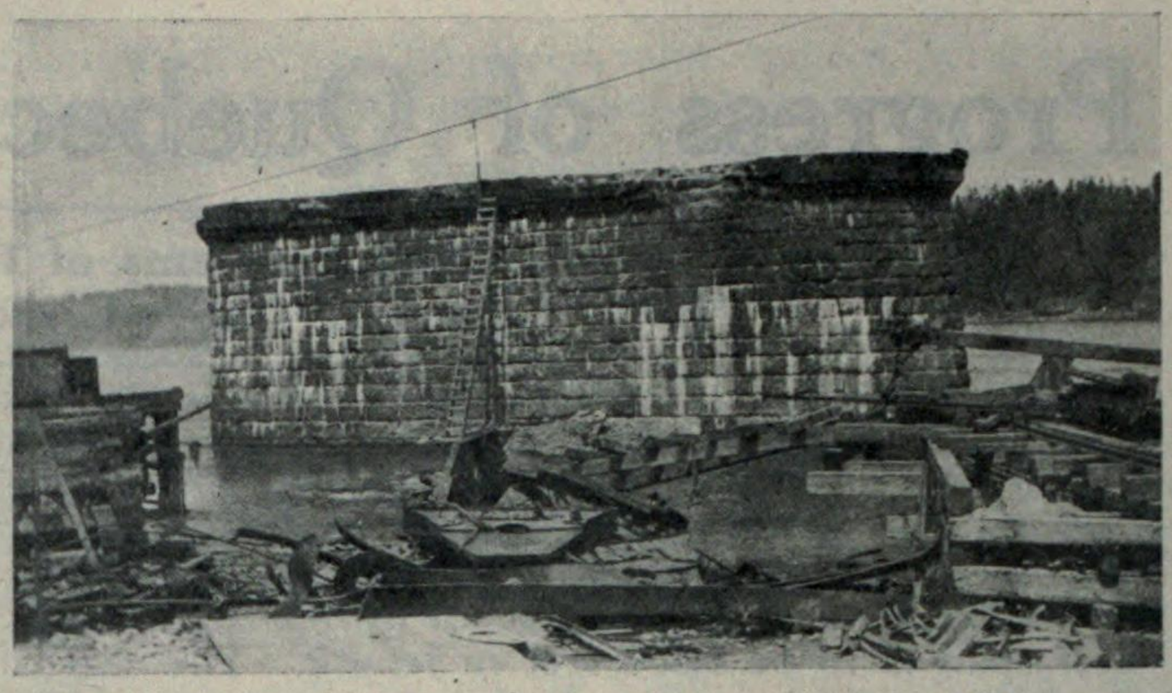
Above the deck is the crib, consisting of three longitudinal rows of timber and seven rows of transverse timbers, all 12 in. x 12 in. The caisson is stresgthened by six truss rods of 2½" of steel running diagonally from the wall under the longitudinal bulkhead and up to the other wall. The walls of the caisson are caulked and then sheathed with 6 ins. of spruce to protect the caulking. These caissons are being built at Sillery and will be launched on the high tides about this date.

Bridge Site

At the bridge site, on the north side, preparations are being made for the caissons. The air compressor plant has been overhauled and put in shape for the sinking of the caissons. A great part of the pile platforms was removed in the autumn to prevent damage by the ice. This is now being replaced. The work on these platforms is being pushed at top speed. Two pile drivers are being worked day and night. The



Pointe a Pizeau. Two caissons for north main pier.



South main pier.—Note coping broken by falling steel.

contractor has installed an electric plant to light the work at night. The platforms will completely surround both caissons and will carry the material tracks and derricks for handling the concrete. Six stiff leg derricks are being erected, three on the south and three on the north side of the caisson.

The swift current and great rise of the tide necessitate great precautions and the caisson will be anchored by steel cables to "dead men" placed about 900 feet up and down stream respectively.

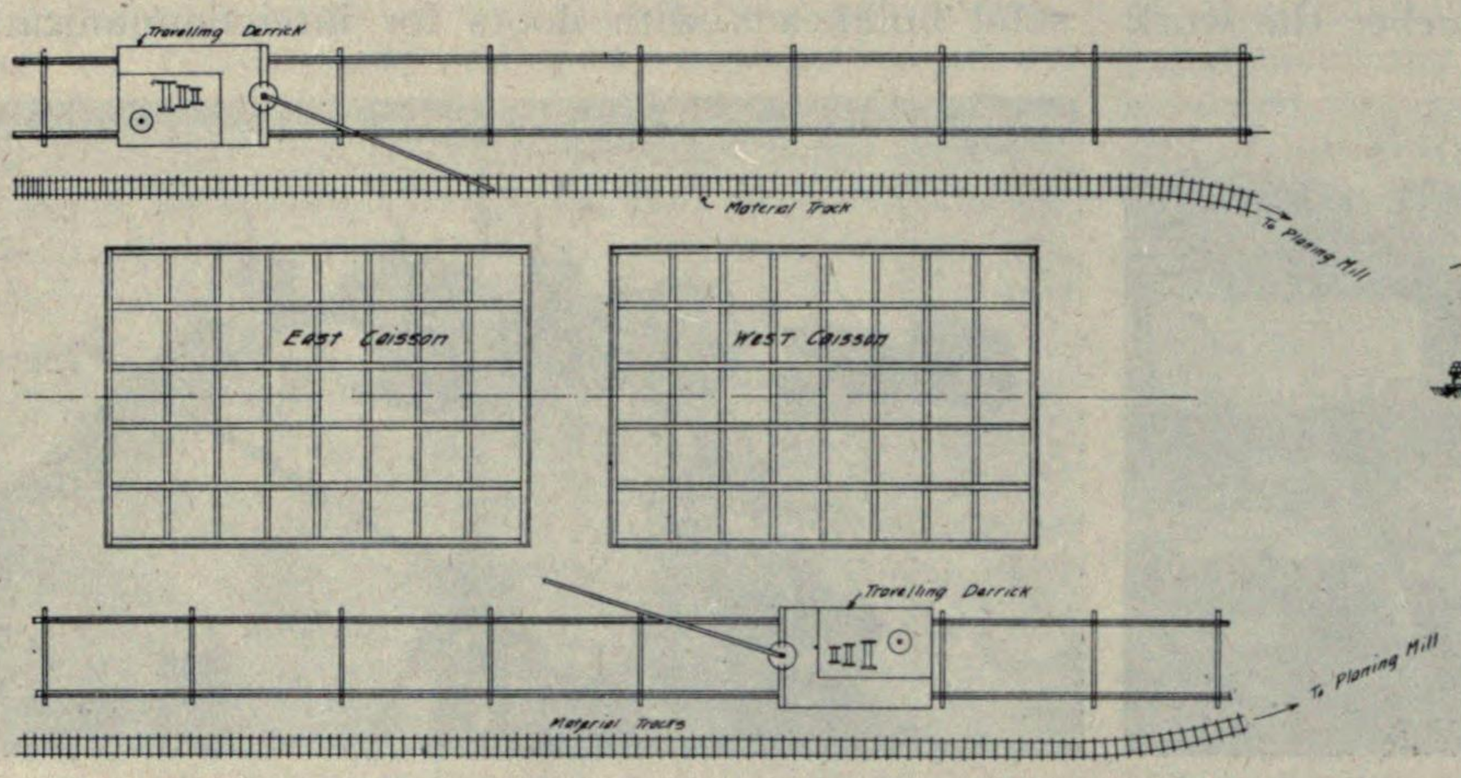
The concrete plant is at the foot of the cliff and consists of two Gates stone crushers and three concrete mixers—two Ransomes and one Smith mixer.

The stone and sand are brought by cars to the top of the cliff and shot down to the concrete plant by chutes. The cement will be lowered by a gravity elevator, the full car hauling up the empty one. The contractor has also installed an elevator for other material, this being operated by a 3-drum hoist.

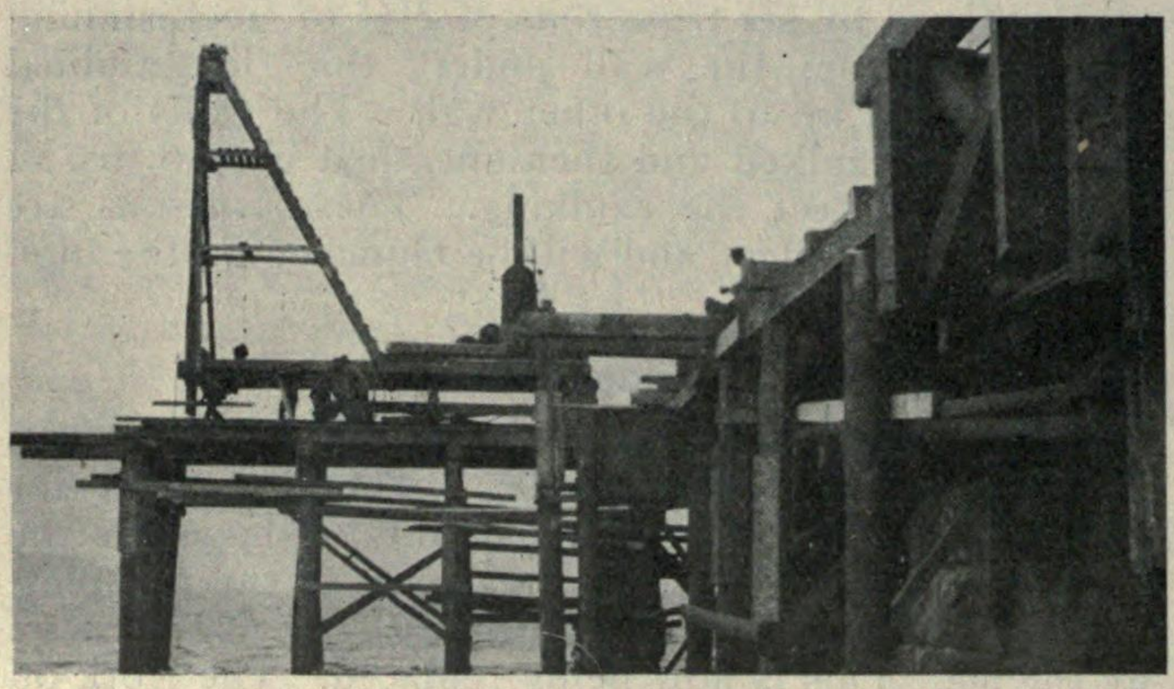
The old anchor pier, which is to be replaced by a larger structure has been taken down and the stone is being re-cut for the new pier.

South Side

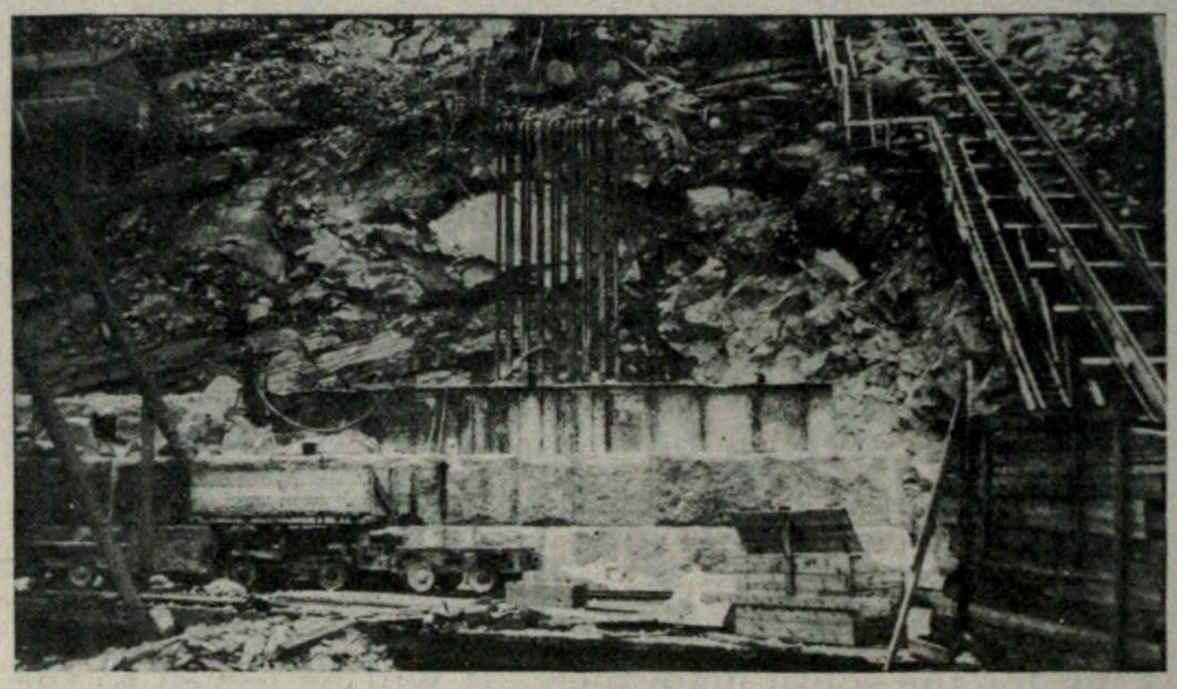
The south side of the river is also the scene of activity, the work here being carried on by night, as well as day, to take advantage of every low tide. The resting place of the huge caisson is being levelled and large rock filled cuts are being erected to form a protection from the swift current. The south main pier has not yet been removed and it will give additional protection to the caisson. It is expected that the sinking of this caisson will be started this sum-



Sketch showing method of handling material in construction of north caissons.



Driving piles at north main pier to make platform for new caisson.—Remains of old main pier to right.

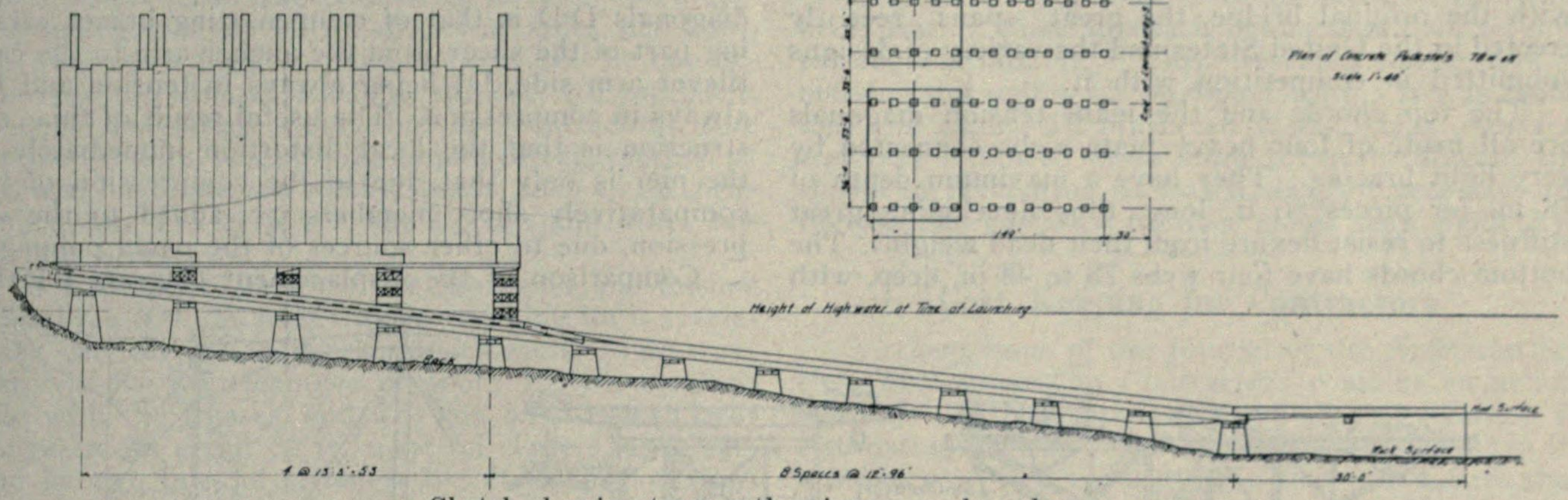


Removing north anchor pier, showing anchor girders and eye bars.

mer. It will be carried deep enough to be proof against any movement from the ice.

Phoenix Bridge Company

When the ill-fated bridge fell in 1907, the two approach spans remained standing. The contract for

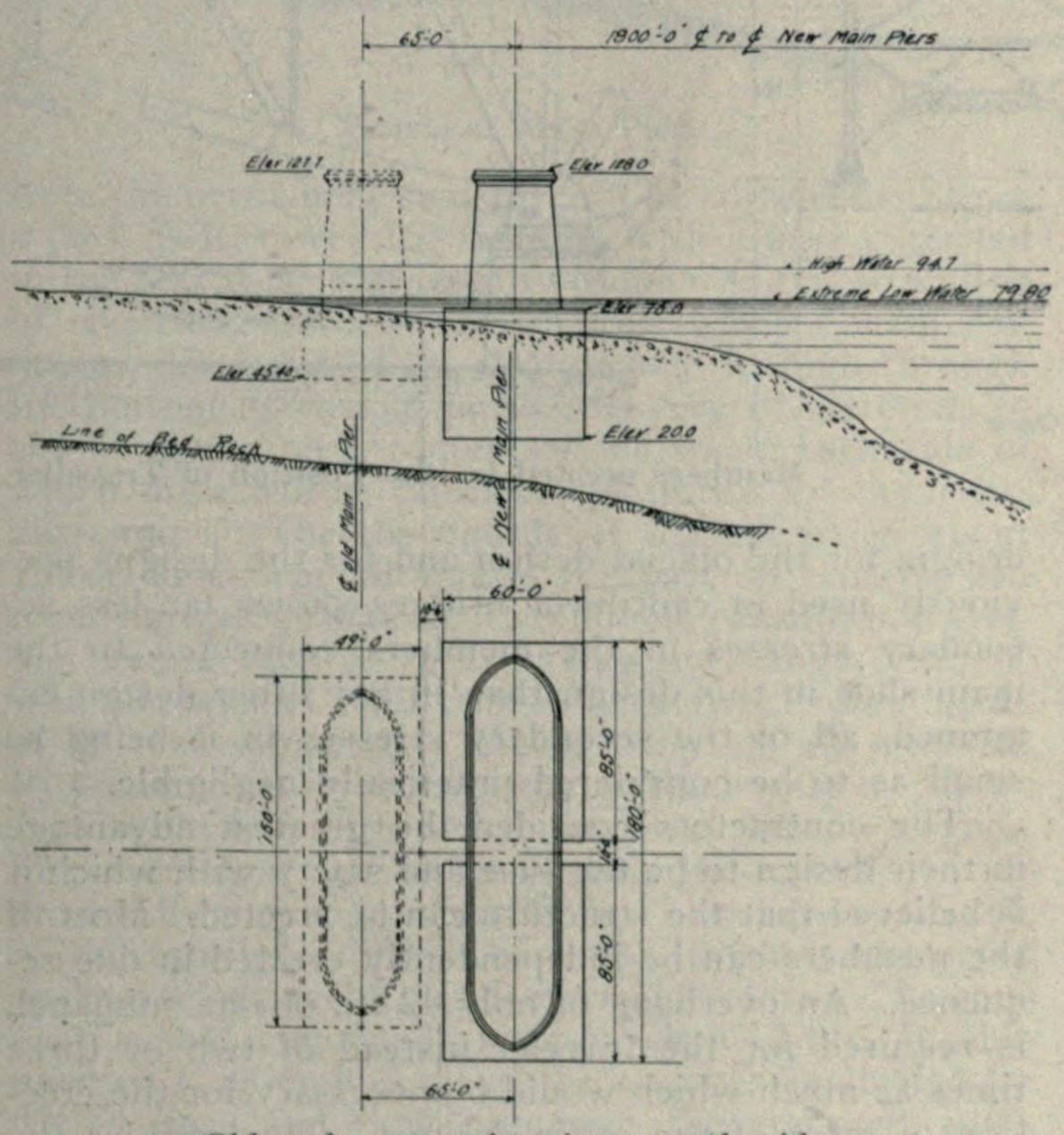


Sketch showing two north caissons on launchways.

removing them was let to their builder, the Phoenix Bridge Company, of Phoenixville, Pa. The north approach span was removed in 1910 and the plant removed to the south side when work was stopped for the winter. At present the Phoenix Bridge Company are removing the south approach span.

Koenig & Co.

The contract for the removal of the debris of the old bridge is being handled by Koenig & Company,



Old and new main piers, north side.

of Quebec, and is nearly completed. The huge members are cut into smaller sections by use of the oxy-acetylene torch or else they are blown apart by dynamite and removed by derricks. The debris is stored east of the bridge centre line and has been sold to the Dominion Steel Company of Sydney, N. S., who will shortly begin to remove it.

The contractors for the new masonry are the same as for the old, viz: Messrs. M. P. & J. T. Davis, whose chief engineer is Mr. Walter Retner, of New York. Mr. Retner has had wide experience in caisson work. Among other work he handled the caissons for the Manhattan bridge. Mr. M. P. Davis is also very active in his direction of the work.

At present Messrs. Davis have about 600 men employed on the work. They have an extensive plant of boilers, enginer, air compressors, hoists, scows, etc.

The supervision of the entire bridge is in the hands of the board of engineers for the Quebec bridge, of which Mr. C. N. Monsarrat is chief engineer and chairman, with Ralph Modjeski, of Chicago, and C. C. Schneider, of New York, consulting engineers.

Mr. J. D. Wilkens is resident engineer in charge of the work. The engineering staff occupy offices on the north shore, overlooking the river, and only a few hundred feet from the bridge.

The Accepted Design for the Quebec Bridge

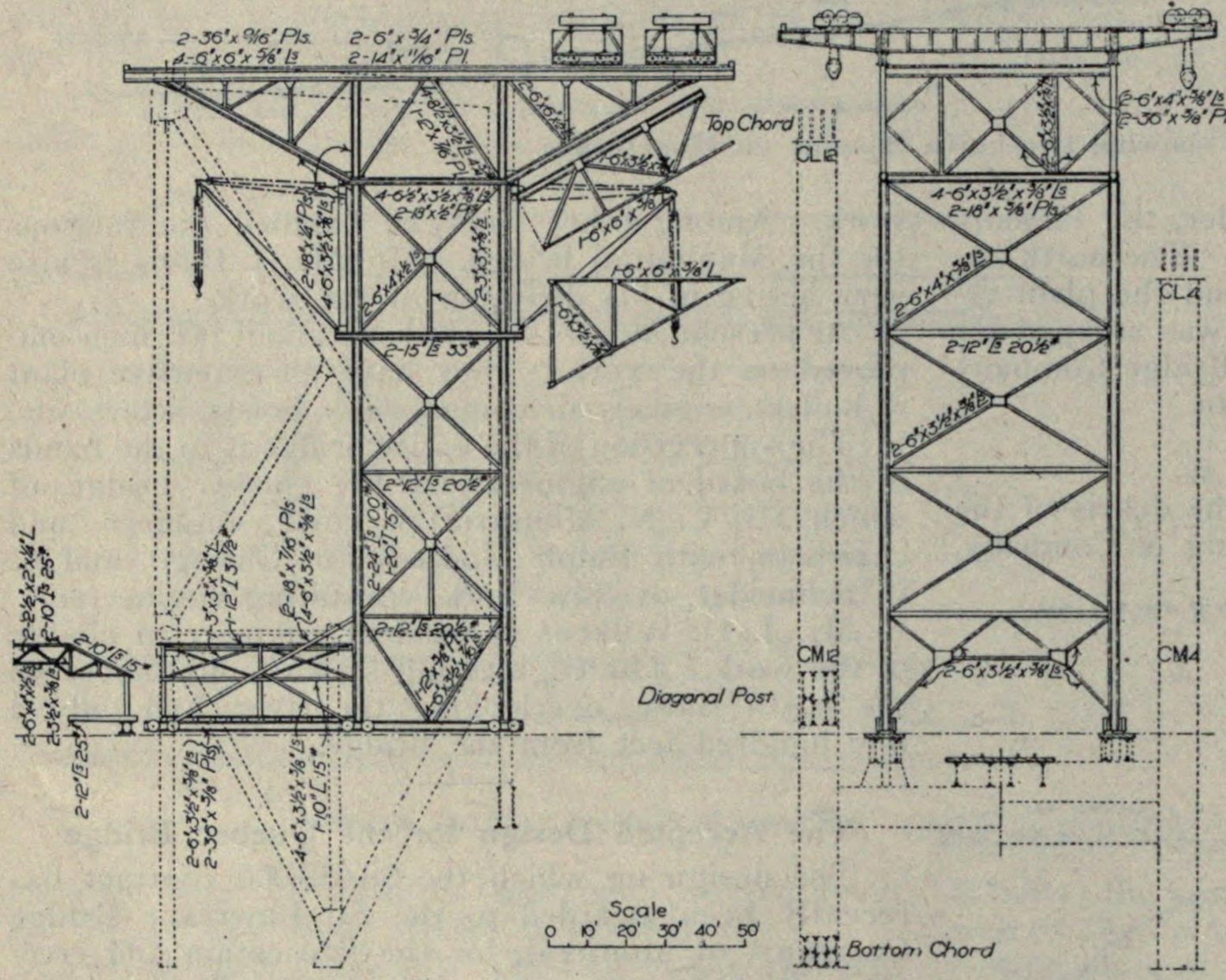
The design on which the $8,650,000 contract has recently been awarded to the St. Lawrence Bridge Company, of Montreal, for the fabrication and erection of the superstructure of the Quebec Bridge is for a very much heavier, stronger and more costly structure than the original bridge design of the Board of Engineers, and from the designs submitted by other bidders, says the Engineering Record. It restores the length of the main span to 1,800 feet, increases the length of the suspended centre span to 640 feet, involves the construction of an entirely new substructure, and the dead weight is considerably reduced by the use of nickel steel for all principal members between the main piers, while greater mass and counterweight in the anchor arm has been secured by the use of carbon steel there. Eyebars have been eliminated in favor of rivetted tension members in the cantilever arm, but some of these have been provided with pin connections to facilitate erection. Many details of connections that were carefully developed in the official design have been retained or modified in the contract design, but the arrangement of the web members in the cantilever and anchor trusses is entirely different from that design or from that in any American bridge, and is considered statically determinate with a minimum of secondary stresses and

with no redundant members in the cantilever arms. The conspicuous omission of the members usually provided to connect the top chords of the centre spans and cantilever arms emphasizes the structural independence of the stresses. Modifications have been made in the original specifications and the present design has been carefully revised by the commission. The consulting engineers and the contractors have had the advantage of a careful study in connection with the original bridge, the great spans recently erected in the United States and the variety of designs submitted in competition with it.

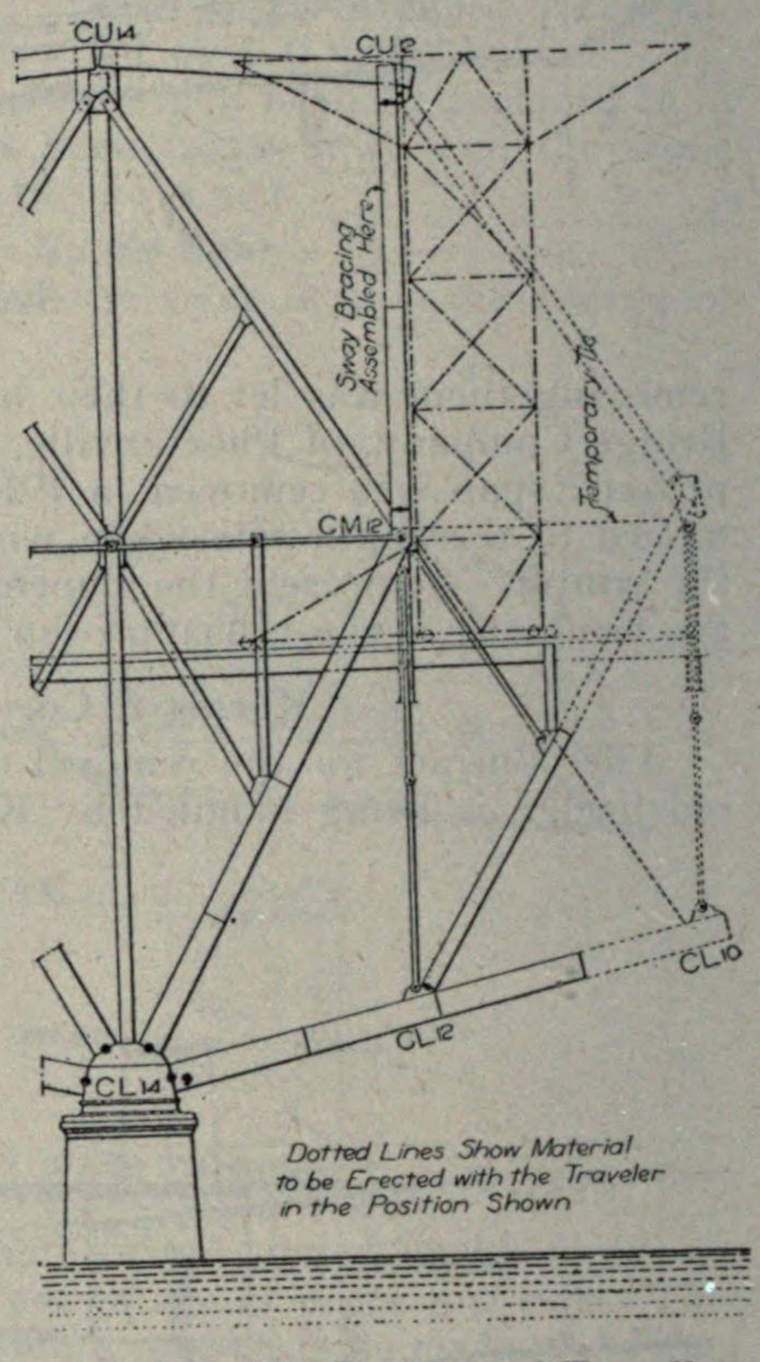
The top chords and the main tension diagonals are all made of four heavy plate webs connected by very light bracing. They have a maximum depth of 78 in. for pieces 86 ft. long, thus developing great stiffness to resist flexure from their dead weight. The bottom chords have four webs 78 to 48 in. deep, with

In the cantilever and anchor arm trusses all members carry both dead and live loads excepting the four secondary ones marked X in the pier panels. All shear transmitted to points BB is taken directly down the inclined posts CC to the pier bearings, and the horizontal thrust at the points BB is taken by the tension subcord EE. Because of the shorter length of the anchor arm, the shear there will always be greater than on the cantilever arm, and the function of the diagonals D D is that of compensating braces carrying part of the shear from the anchor arm to the cantilever arm side, D1 being always in tension and D2 always in compression. The useful result of this construction is that the local distortion immediately at the pier is only that due to the compression of the comparatively short members c c, added to the depression, due to other sources of the panel point g g.

Comparison of the displacement diagram for this



Elevation of the Inside Traveller.



Members erected in One Position of Traveller.

full length longitudinal plate diaphragms. Both top and bottom chords are made in full panel sections of a maximum length of 86 ft. and will be fully spliced with joints made and completely riveted as the erection progresses. The web members are pin-connected to gusset plates projecting beyond the top and bottom chords so that neither of the latter have pin holes through them. The bottom chords have half-hole pin bearings on the main pedestals at the river piers, and the principal compression members in the truss webs have similar bearings at both ends. None of the compression members have forked ends, the maximum members will have a shop length of about 43 feet and a weight of about 300,000 lb., but it is believed that they can be fabricated without special difficulty.

In each panel the shear, being divided between two principal web members, is reduced to a moderate amount except in the main diagonals meeting on the river piers, and the chord connections providing for a moderate increment of stress at each panel point do not present special difficulties.

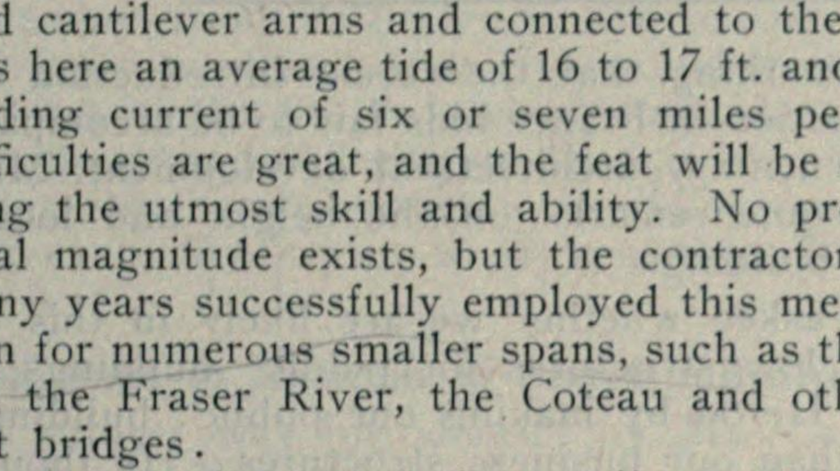
design, for the official design and for the designs previously used in cantilever bridges shows far less secondary stresses in the members connected to the main shoe in this design than in any other design examined, all of the secondary stresses in it being so small as to be considered practically negligible.

The contractors consider the greatest advantage in their design to be the ease and safety with which it is believed that the structure can be erected. Most of the members can be independently erected in due sequence. An overhang of only 42 ft., or one subpanel, is required for the traveler instead of two or three times as much which would be necessary for the erection of most of the other designs. This enables the length of the traveler to be sufficiently reduced to enable it to clear the sway-bracing at the first panel point from the end, thus permitting that bracing to be always connected up close to the traveler and maintaining the stability of the trusses as fast as they are extended. It is intended to complete the erection of

the anchor arms before commencing that of the cantilevers.

The most difficult and critical part of the work will be the placing of the 5,000-ton, 640-ft. suspended canter span which it is proposed to erect by ordinary methods at the proper height on shore falsework, which will be floated with it to position between the finished cantilever arms and connected to them. As there is here an average tide of 16 to 17 ft. and a corresponding current of six or seven miles per hour, the difficulties are great, and the feat will be one demanding the utmost skill and ability. No precedent of equal magnitude exists, but the contractors have for many years successfully employed this method of erection for numerous smaller spans, such as the Miramichi, the Fraser River, the Coteau and other important bridges.

It is proposed to erect the cantilever and anchor arms by a 600-ton steel traveler running on a special track carried on the regular floor-beams. The traveler will have a clearance of about 10 feet on each side with the trusses, and will run on two standard-gauge tracks about 54 ft. apart on centers, each carried by two lines of stringers 6½ ft. deep, borrowed



Panels at Main Pier.

from the permanent structure. The traveler will have a 36 x 54-ft. tower 160 ft. high, with a base extended in the rear to a total length of about 85 ft. It will be of riveted construction, with four vertical main columns. There will be a clearance 20 ft. high through the bottom extension for the delivery of materials to the overhang on a center service track, each side of which there will be cantilever platforms for the hoisting engine. The top chords of the overhang, about 150 ft. long over all and 54 ft. apart on centers, will form runway girders for two double cantilever traveling cranes, each of them having overhangs of 25 ft. which command both trusses with two trolley hoists of 60 tons capacity. This will enable all principal truss members to be erected simultaneously in pairs.

The facility with which the most difficult portion of the erection can be handled by this traveler is indicated by the diagram of the first two panels, C10-14, of the cantilever arm, where the traveler, supported on the semi-panel C12-13 clears all of the C12 connection and commands semi-panels C13-14. In this position it assembles all of the members indicated by dotted lines and thus completes the erection sufficiently to enable it to advance to C14 and erect the next sub-panel and so on.

Discoloration of retaining walls built in trench and temporarily backfilled along the face was avoided by using cinders, in the Bloomfield, N. J., improvements of the Delaware, Lackawanna & Western Railroad. The walls were built in advance of the general excavation for depressed tracks, and on account of their great extent and height, it was necessary to pull the trench sheeting for re-use, the trench being filled front and back. If the original material, a reddish, sandy clay, were used or were permitted to run in against the wall face, there was danger of serious discoloration of the surface. In addition, this material was of a character such that it would stick to the wall, necessitating close approach of the steam shovel dipper in loosening it. This presented the danger of marring the wall with the dipper teeth. It was found that the cinder fill preserved a dry, clean surface, and that it flowed away from the wall toward the shovel in excavating so that it was not necessary for the teeth to approach the face closer than about 2 ft.

Cost Keeping for Contractors

A recent issue of the Journal of the American Society of Engineering Contractors contains an article entitled "Cost Keeping and Its Value in Relation to Estimating on New Work," which is significant in its substance as well as its title in that it indicates that the contractor of to-day is looking upon his business as not merely that of a good "boss," getting a maximum amount of work out of each laborer at the minimum wage, but that he is advancing it to be a profession, the laws of which should be studied and mastered if success is to be attained.

Even more significant of this than the paper itself was the discussion, in which several contractors stated their belief in this idea of contracting. One contractor whose work is largely reinforced concrete stated: "I keep a clerk on all of my work, and he has nothing to do but one thing, keep the time and keep track of the materials and their disposition. He check up materials, and that relieves the foreman of that duty. . . . It is a small job that does not pay for the clerk to keep time and check materials. I think that is as necessary as any other part of the work. If there is a bag of cement that goes over to a certain footing it is charged to that footing, and so on for other sections of the work. And all it costs to know that is the salary of the man who is taking notes of them."

Another speaker summed up the advantages to contractors of cost keeping as follows: "The old-fashioned contractor who did not keep cost records never knew whether he had made or lost money on his job until it was completed; and if he had made money he did not know on what items he had made it. He had made money on the whole job, and that is all he knew. And he used those same figures on the next job, if it was similar to the previous one; whereas, if he had kept a cost system he would have been able to bid more intelligently on work by reducing the price on some of the items where he had made more money than was necessary, and increasing the price for those items on which he had figured too low before."

The author of the article, Berton M. Laughead, described in brief what is included in such cost keeping as follows: "In order to successfully make estimates that will enable a contractor to make safe bids, it is absolutely necessary that he keep daily records, in detail, of every branch of his work, so that on completion, he will be able from such records to compile a final cost sheet that will show him the total cost and the cost per yard of his work."

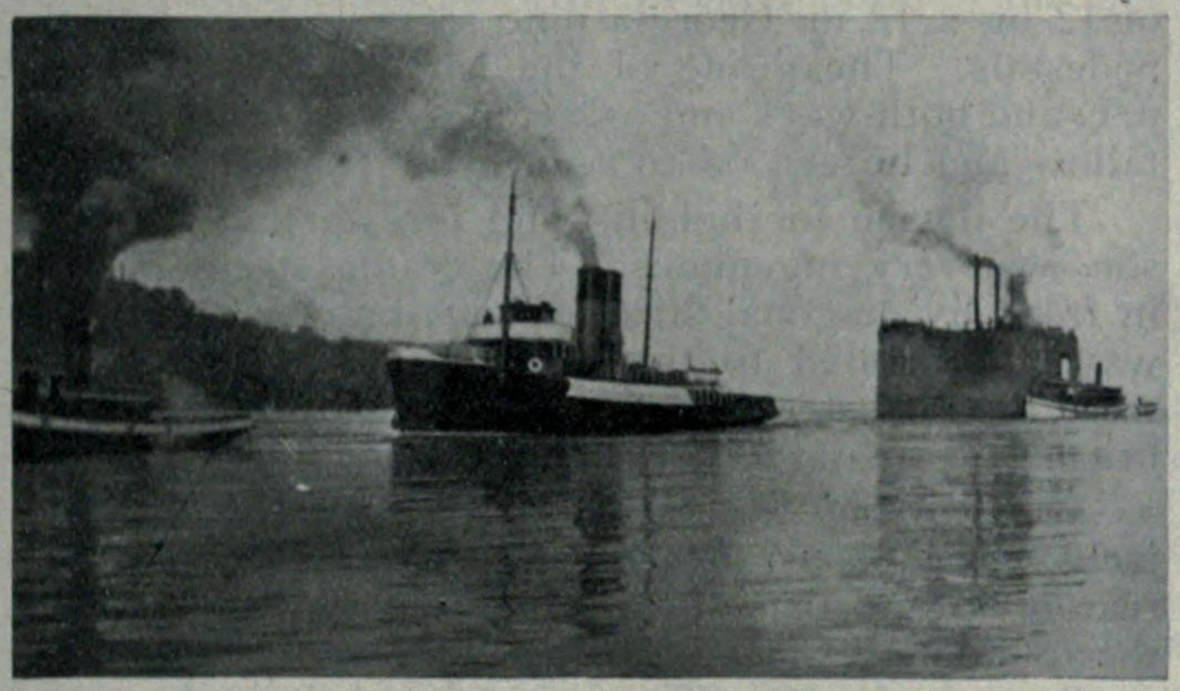
Caissons for Main Piers, Quebec Bridge

Caisson No. 1 in Place, Nos. 2 and 3 Launched—Difficulties are Many

Special to the Contract Record

Caisson No. 1 was built originally for the north main pier, but owing to difficulties met with in sinking it was decided by the Board of Engineers to use it on the south side of the river where the soil is not as hard as on the north side. (For description of the construction of this caisson see Contract Record September 7th, 1910.)

Caisson No. 1 passed the winter of 1910 in the dry dock at St. Joseph de Levis, and in April, 1911, repairs were begun to strengthen it for its trip up the river and for the sinking. The cutting edge timber which had been strained was repaired by the use of oak fish plates at the splices. The walls were filled in solid between the vertical posts with 12 in. x 12 in. timbers of Georgia pine for a height of 11 ft. above the deck. The roof of the air chamber was sheathed with yellow pine 12 in. x 6 in. and thoroughly caulked.



Caisson No. 1 being towed to bridge.

A false bottom was put in consisting of 32 longitudinal pine stringers 12 in. x 6 in., 180 ft. long, made up of 20-foot lengths spliced beneath each bulkhead with pine fish plates eight feet long. Each stringer was supported at three intermediate points by 6 in. x 6 in. spruce braced against the underside of the caisson roof.

The planking consisted of 3 in. spruce planed with edges slightly tapered, and was spiked directly to the stringers and thoroughly caulked.

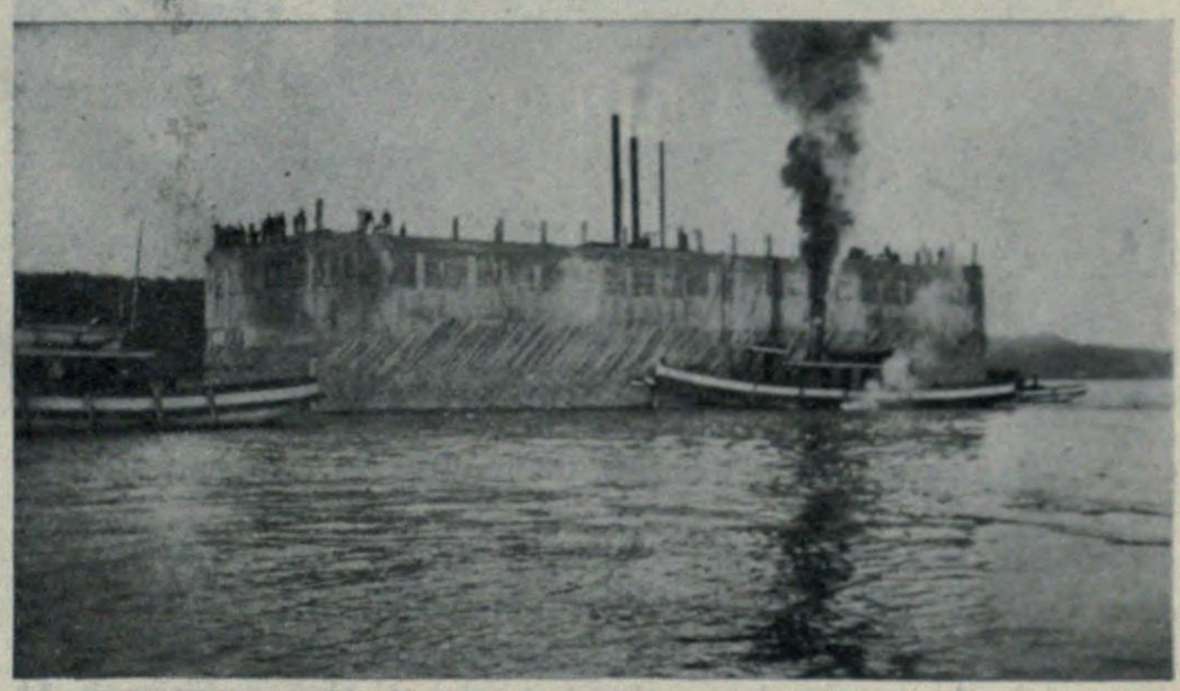
Three boilers were installed on a platform on top of the crib work of the caisson—2 of 75 h.p., and 1 of 25 h.p. The water was supplied by two syphons extending over the side of the caisson into the river.

Five pumps were installed on the crib work, one centrifugal and four reciprocating. Four of these pumps had their suction pipes down the air shafts to draw water off the false bottom, and one was extended to pump water from the deck of the caisson in event of leakage.

About 50 tons of broken stone were placed on the deck of the caisson along the centre to trim the caisson when afloat.

Owing to the great rise and fall of the tide in this vicinity, (a miximum of 20 feet), and to the strong current and eddies at the bridge site, the plans for placing of the caisson had to be worked out in advance so that the caisson should reach the bridge site (10 miles from the dry dock) and be secured in place before the current should change.

The submerged debris of the old bridge also added a feature to the risk, together with the rocky nature of the shore, making it imperative that the caisson



South Caisson No. 1 before placing

should not ground in which case it would probably be a total loss. At the bridge site the bed of the river had been levelled carefully to give the caisson an even bearing when it should rest in position. Timber cribs filled with stone were built to guide the caisson to its final position and a stone filled breakwater erected at the west end of the main pier

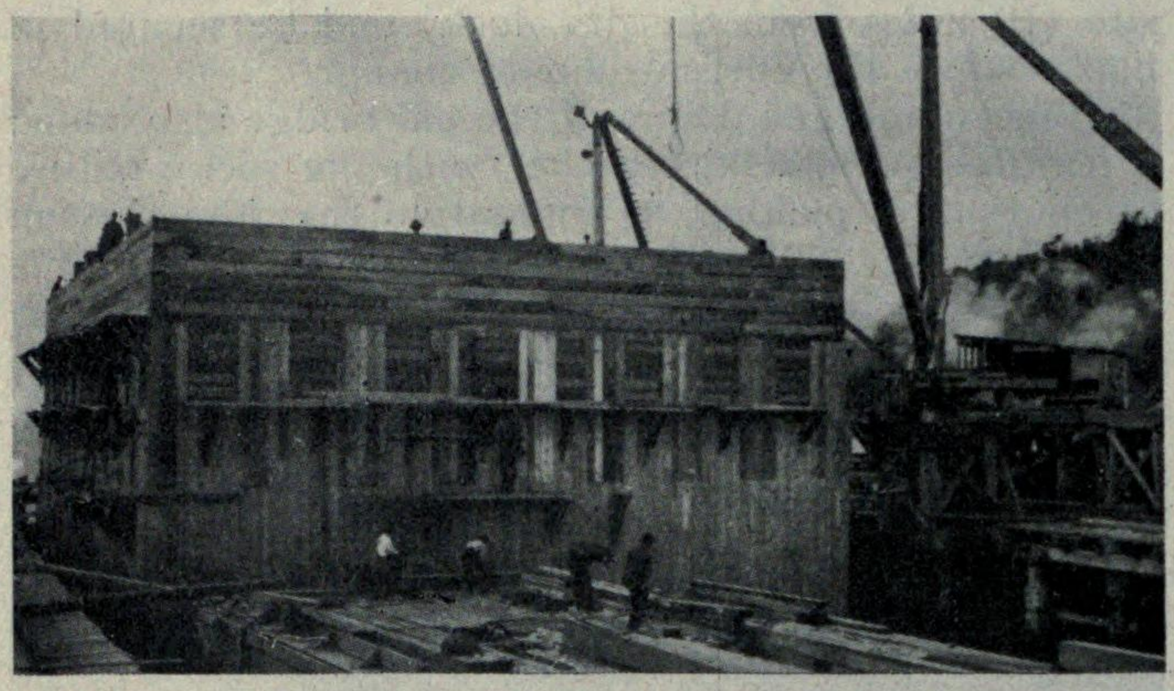
Placing South Caisson No. I.

to break the force of the current (see Plate No. 1). The path to be taken by the caisson was also marked out by buoys and the danger points by flags.

During the night of May 27th, 1911, water was let into the dry dock and the caisson floated, drawing about 10 feet of water. It was towed through the gates at 3.15 a.m. and up the river with the incoming tide. Five tugs were used, one large ocean-going wrecking tug pulling in front, and four smaller tugs

used more for steering than pulling, as the large tug handled the caisson without difficulty.

The caisson was towed up the river east end first and reached Sillery at 4.30 a.m. In crossing from the north side to the south it was swung completely around into its correct position, the tide meanwhile carrying it toward the bridge site. When within about 150 yards of its correct position it was held against a very strong current by the large tug, while lines were taken ashore to the three hoisting engines anchored there, and a line from the hoisting engine on the caisson made fast on shore. Then by the aid



Caisson No. 2 at bridge, preparing for concrete.

of these four hoisting engines and three small tugs the caisson was worked, first toward the shore until it rested against the cribs and then westward until it reached its final position against the bumpers at 6.30 a.m.

At low tide it rested on the level bottom in its correct position and was scuttled by large holes cut in the false bottom to prevent it floating again. The entire false bottom has recently been removed.

This caisson is 181 ft.-0 in. long x 55 ft. 6 in. wide x 44 ft. high and weighed with boilers and pumps, 2600 tons.

The caulking had been so well done that not one of the five pumps had to be used at all, in the trip up the river.

The contract for the repairing and towing of the caisson to the site was sublet to Mr. Geo. T. Davie of Levis, and the placing in charge of Mr. M. P. Davis, both of whom were present in person.

It is intended to sink this caisson during the summer far enough into the bed of the river to resist the action of the ice during the coming winter and to finally sink it farther and build the south main pier on it in the summer of 1912.

LAUNCHING OF CAISSON NO. 2 FOR WEST HALF OF NORTH MAIN PIER

The north main pier is to be built upon two caissons each 85 ft.-0 in. long, 60 ft. 0 in. wide and 55 ft. 0 in. nigh, placed end to end and 10 ft. apart (see Contract Record June 7th, 1911). These two caissons were begun in March 1911, and the one for the west end of the pier known as caisson No. 2, was launched on May 29th. Caisson No. 3 was launched on June 26th. As these caissons are identical in construction and launching, a description of one applies to both.

At the time of launching, caisson No. 2 was built 21 courses of wall timber above the cutting edge a total height of 23 ft. 6 in.

The verticals in place reached to about 42 feet above the wearing timber and 14 courses of cribwork had been built above the deck and bolted to it by 1½-in. round rods 16 feet long.

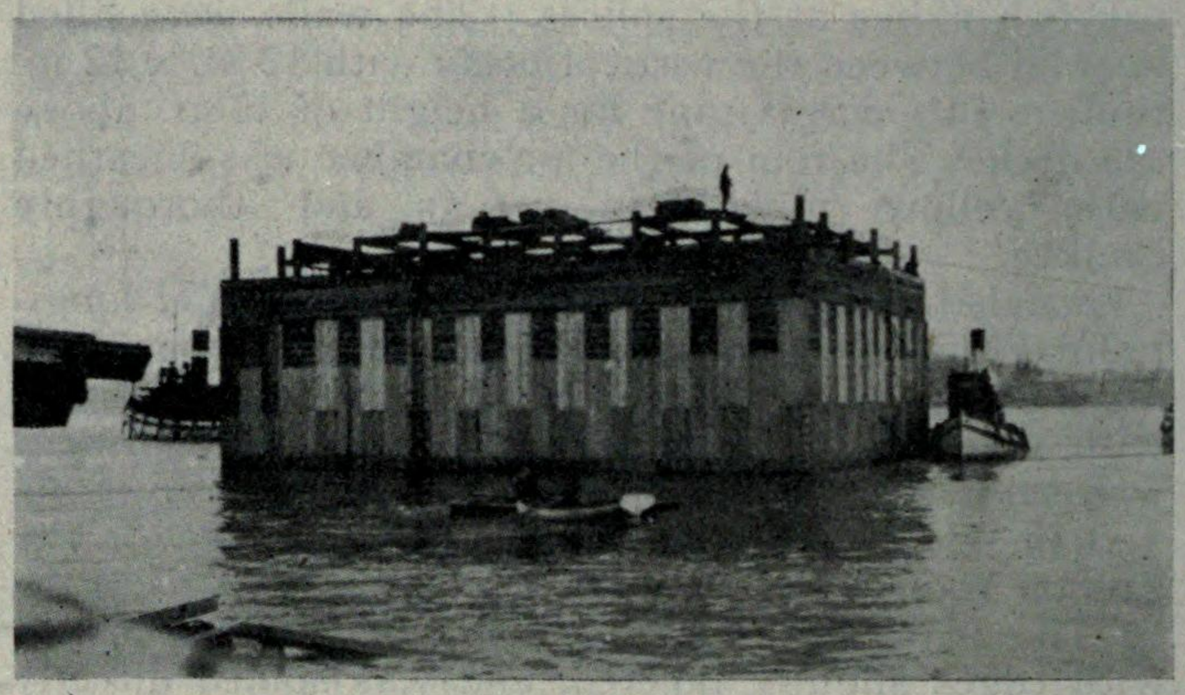
One ten foot length of air shafting 3 ft. diameter was in place at each of the six air shafts and pipes for water, air, electric lights and whistle signals were all in place, as well as the entire electric lighting system for the air chamber. All pipes were sealed and the shafts closed with oak doors made with pure rubber gaskets bearing against the deck.

The caisson was built level, resting on timber supports carried to concrete foundations on solid rock.

Before launching, the caisson was lowered 3 feet at the outer edge by four 350 ton jacks and blocked onto the oak cradles which slid on the lanuchways. The launchways, three in number, consisted of concrete pedestals on solid rock carrying each 3 sticks of 12 in. x 12 in. Georgia pine securely bolted to the pedestals. The grade of the launchways was 10.39 p. c. and both ways and oak cradles were greased with tallow and linseed oil to reduce the friction.

The device for holding and for starting the caisson was very ingenuous. The cradles were blocked in front by diagonal struts of oak braced against the ways and bolted to them. In the rear the cradles were held by steel chips hooked over 2 in. steel bars bearing against the back of the launchways.

For starting the caisson four 350 ton hydraulic jacks were placed beneath the cutting edge at the rear of the north side to raise it slightly and permit the foundation blocking to be removed. Behind each cradle was placed a 70 ton screw jack braced against the crib work on shore. The front braces were removed first and then at a given signal the 2 in. steel bars were knocked out simultaneously and the jacks were started. The caisson began to move almost



Caisson No. 2 being towed from Sillery to the bridge.

immediately and slid slowly down the ways taking about 30 seconds to reach the water.

As it was built without a false bottom it lost the greater part of the air from the working chamber upon reaching the water. It drew 8 ft. 6 in. immediately after launching and lost all the air, settling down to a draught of 11 feet. It was taken in tow by two tugs and towed out between two cribs where it was anchored and further work was done on it.

The caisson lay at its anchorage from May 29th till June 10th when it was towed to the bridge. Sixteen additional wall timbers were added while it lay there making a total height of 39 ft. 2 in. and the

cribwork was carried up to the level of the top of the wall.

The timber was floated out in rafts and handled by a derrick on a scow. The compressed air for the carpenters' augers etc. was carried out from the main plant by a two-inch pipe suspended from a steel cable.

On June 10th the Caisson was towed to the bridge by four tugs and placed in its proper position without difficulty. It drew 13 ft. and weighed about 940 tons. It is anchored by steel cables attached to "dead men" about 1,000 feet up and down stream respectively. These cables pass over six timber floats and are slackened and tightened by a hoisting engine on the wharf as the tide rises and falls.

The final building of the caisson is being done at the bridge and the placing of the concrete began on June 21st.

The concreting of the caisson and the plant at the bridge will be described in an early issue of the Contract Record. The work is in charge of Mr. J. D. Wilkens, resident engineer for the Board of Engineers. Mr. Walter M. Retner is chief engineer for contractors Messrs. M. P. & J. T. Davis.

Mistakes in Sidewalk Construction

By Jerome B. Landfield

A good proportion of all of the sidewalk work that is being done nowadays is constructed under the direction of engineers, or in accordance with specifications laid down by them. It is therefore strange that there should be such a diversity in the methods employed and in results obtained. This is a curious state of affairs, considering the extent of the work and the opportunities afforded for determining to a nicety the best possible practice.

Where there is such diversity of practice it naturally follows that in some cases it is correct and in others all wrong. There seems to be a mistaken notion that sidewalk work is not deserving of serious attention and may be properly left to the untrained man. What is true of sidewalk work is equally true of concrete curb and combined curb and gutter work. Surely this is a great mistake and municipal engineers in particular should realize that they owe it to the profession to devote sufficient attention to the subject to secure first-class results.

In this paper I desire to point out a few fallacies that have crept into sidewalk and curb and gutter work from different sources, especially those which have been sanctioned in many instances by engineers of standing.

Cinder a Poor Sub-base

Probably the most generally accepted fallacy is that of the cinder sub-base, and it is a fallacy that has cost our cities hundreds of thousands of dollars. It is probable that the fact that many are to-day specifing that a sub-base of cinders or sand should be put under a walk can be explained in this way. In the laying of flags of natural stone the under side of the flag was nearly always irregular and to dig out and shape the natural soil to fit it was a task quite out of the question. It was far easier and more practical to fill the excavation with cinders and sand, which would naturally mold itself to fit the configuration of the under side of the stone. What was more natural than to continue the same practice when concrete walks came to be laid, and to set up the argument that this sub-base ensured good drainage and was a safeguard against heaving due to frost?

This sounded perfectly plausible. In fact, I presume that a large portion of those who read this article will regard the views expressed in it as heretical. But the following fact appears pertinent. If one lifts a good-sized flat stone from its resting place in a field in the winter time he will notice that there is rarely to be found beneath it any frozen ground, while all around are evidences of frost. The reason is that, first of all, the natural soil that forms its bed is tightly packed so as to make a snug resting place that did not admit water readily, and, next, that the stone itself under these conditions affords good protection.

Now consider for a moment the concrete sidewalk. In constructing this, first the natural soil is removed whether it be clay, gravel or hardpan, making a trench that becomes the finest kind of reservoir to collect moisture. This trench is then filled with porous material that never becomes as compact as the original soil, but which absorbs and holds moisture like a sponge. Even if tile is placed in the bottom of this trench, this does not make the sub-base any the less a sponge. Four or five inches of concrete would have protected the compacted natural soil that would hug it so closely as scarcely to admit any water, but severe cold is very liable to freeze the cinder foundation in spite of the concrete. These are some of the considerations that lead me to believe that the cinder sub-base is useless and detrimental, even when carefully drained with tiles, and extended practice bears this out.

Water Should be Carefully Gauged

Another fallacy that is very prevalent, but which is happily growing less, is the idea that a sloppy top-coat is good practice. Somehow or other many concrete men have got the notion that in sidewalk work the wetter the mix the better. They argue from experience in other kinds of work where they find that poured concrete makes a dense mass and reduces the voids, and do not take into account the points wherein the conditions differ. Let us consider just what the conditions of sidewalk work are and how they affect the question of how much water to use.

In sidewalk work water-tight molds are not used in which to form the blocks. The mass dealt with is thin and has two large surfaces, one of which is exposed to the absorbant action of the ground beneath, and the other to the drying action of the air. If, therefore, too much water is put into the concrete there is a tendency for it to drain away and carry with it particles of cement washed from the aggregate. If less water were used and the mass well mixed, the whole amount of water would be closely engaged with the cement. In warm climates it is frequently argued that more water should be used in order that the surface may not dry out too rapidly. But here we have also a fallacy. If there is more water at the surface than is needed for the setting of the cement, there is almost certain to have been flushed to the surface considerable neat cement and as the surplus water evaporates the foundation is laid for hair-cracks. The correct way is to use the proper amount of water and then protect the surface against the heat.

The lower course should have just enough water so that it will not quake when tamped. The top-coat should be mixed stiff enough so that you can mold it in the hand and it should be put on while the lower course is fresh and green. Then tamp it lightly, remove the surplus material by striking it off, and fin-

Is the Quebec Bridge Design a Failure?

Prominent U. S. Engineer's Exhaustive and Sweeping Criticism— A Great Opportunity but a "Disappointing and Lamentable" Result

The modus operandi of the Dominion Government in the whole project of the Quebec bridge, as well as the adopted plans, are the subject of an exhaustive criticism by Gustav Lindenthal in a recent issue of the Engineering News. This article includes an instructive comparison of the Forth Bridge and Quebec Bridge designs. Owing to pressure of space however, we are unable to extract more than the generalities expressed; but these are of outstanding interest.

Mr. Lindenthal criticizes the procedure of the Board in no measured terms. It is one thing, he says, to lay down general rules and specifications for a large structure and an entirely different thing to work out a design. The first can be done by a Board or Commission quite well; but the second cannot be done that way satisfactorily. If a bona fide competition was desired, then it should have been invited from a number of firms or designers to whom at least the actual expense of making the plans for such an unusual structure should have been paid. This is a just and recognized practice in architectural competitions.

Invitation of Competitive Designs; Remarbable Conditions of This Invitation

The Board after much labor and time brought forth minute specifications and an official design called the Board's Design (with several variations of trivial importance), on which tenders were invited from bridge construction companies. With feigned impartiality these companies were also invited to submit designs of their own, if they desired to do so, also with tenders thereon. The Board's Design was for a cantilever structure, carrying a double-track railroad and two wagon roads and trolley lines, the same as for the collapsed bridge but for a greater live-load.

The preparation of that design cost the Canadian Government about $500,000 and 2½ years' time. But the bridge companies were expected to make their competitive designs without compensation and in four months' time. If five or more of the world's bridge firms had been invited to prepare competitive designs, on a proper general specification, in six months' time, and for a compensation to cover expenses, then at 20 per cent. of the cost of the official design (which afterwards was ignored) and in less than one-quarter of the time there would have been a choice from a number of superior plans with tenders thereon, which would have represented the best practice and advance in the art.

Fairness required that all designs invited by this Board, including its own, should, if need be, on its own motion, be subject to scrutiny and decision by a special and unbiased commission of engineers. The impression prevailed, not unnaturally, that the Board would be prejudiced against other designs but its own. In fact the specifications were pointed to as proof of bias. But as it was, the same Board responsible for the official design (with only one member out of three changed) was and presumed to be also the judge of the designs competing with it. How much or how little confidence that Board or its majority, which had prepared and adopted the official plan, had in its own qualification may be gaged by the fact that it required its own design, which presumably represented its best collective wisdom, to be guaranteed by the contractor, who had to assume under Par. 5 of the specifications "the entire responsibility not only for the materials and construction of the bridge, but also for the design, calculations, plans, and specifications and for the sufficiency of the bridge for the loads thereon specified."

One may wonder why under such conditions the Board should consist of engineers at all. What confidence could a body deserve or command, which having been under no limitations for engineering expenses or for time in making plans, was still so doubtful about them as to avoid responsibility, which it placed wholly upon the bidders, who had not been consulted about the plans, who had no share in making them or a voice in selecting the engineers that made them?

The psychology of that provision, of course, is not hard to understand. The old bridge fell down; it was the fault of the engineers. Engineers are irresponsible; they have no wealth. They cannot respond in damages, but the contractor can, so if he is anxious enough for the contract and the profit from it, put the whole thing on him. What a conception of professional duty, honor and dignity for engineers!

It is quite true that the contractor has and should have the sole responsibility for the erection of the structure, as the erection, once its method is decided on and approved by the engineer, depends largely on the management and organization of his own forces and appliances. But this responsibility is sharply distinguished from that for the design and for the strength and safety of the bridge and for its erectability. This should be wholly the responsibility of the engineer.

While thus the contractor has a responsibility placed upon him under the specifications and contract which should not be his, there are some strange provisions in them which put power into the contractor's hands which he should not have. Under Par. 113, certain "plans, submitted or approved by the Minister, shall be subject to the joint approval of the Board and Contractor." If under that clause, the Board and contractor should not agree, or even if they did agree, in overruling the Minister, (who, by the way, appoints the Board), what then? It would seem that even greater confusion of authority is here evident than existed for the bridge which collapsed. Directions may be variously issued under these specifications by the Board, by a Chief Engineer, who may or may not be a member of that Board, and by the Minister of Railways and Canals, for whom other things is reserved the determination, presumably as befitting his rank, of the last two coats of paint (§ 295). Engineers who draft such specifications, or

countenance them, make the engineering profession ridiculous, and lay it open to reproach, not infrequently heard in the press and from public men, that they lack in executive and administrative ability. It would be painful in this connection to contrast the engineering conduct of this work with the very able management of the construction of the Forth Bridge by its engineers, who upheld the best traditions of the profession and richly deserved the honors bestowed on them.

Of other provisions of the specifications it could have been foreseen that they would greatly increase the cost of the work, without any corresponding benefit. Such was the provision of a deposit of $500,000 in cash with any tender, as a guarantee that the bidder will accept the contract if awarded to him. A deposit of a certified check with tender on public work is usual and necessary to exclude irresponsible bidders, but that the deposit with the tender should be so large and in cash, withdrawn from bankable funds, is an onerous and unwise provision, because it has the effect of reducing the number of responsible bidders and greatly increasing the cost of the work.

So also is the provision of an additional deposit in cash of 10 per cent. of the contract, with only 3 per cent. annual interest on it. A large bond for large work is justifiable and should have been provided, but to insist that the security be also in cash, the two together exceeding the capital of some large banks, must result in another needless increase of cost. Judging from the exceedingly high unit-prices in the tenders, there is no doubt that the cost was increased many hundred-thousand dollars for a hypothetical surety. For if the bridge should fall again, the cash deposits would be entirely insufficient to pay for the loss and damage.

Notwithstanding the unfair conditions under which the competitive plans were invited, several plans were submitted with tenders from Canadian, English, American and German firms, such is the keen rivalry for large contracts.

Excellence of the Forth Bridge Design

The more the Forth Bridge design is studied, the more evident it appears that the engineers of that structure used with masterly skill every device that would promote economy, stability and reserve of strength. They had no precedents to go by, and had to solve the problems on original studies. The enormous difficulties arising from the extremely large riveted connections, and in providing for them the necessary large contact surfaces, all of which enhance weight, were ingeniously met. In this respect the American pin connections offer the great advantage of simplicity, cheaper fabrication and easier erection, which were not available to the English engineers.

Its architectural appearance is imposing, but not sightly. A different treatment of the towers and a slight bend in the top chord of the high trusses would have esthetically enhanced the character of the cantilever type. But this would have produced greater complexity in the angles and conditions of web members, lying in warped surfaces, which may have been the reason for not doing it.

The writer did not, at one time, favor the insertion of the stiff diagonal members (subject to tension and compression) in the side towers, regarding them as redundant members, which made that part of the system statically indeterminate. That was before the completion of the bridge. But the official tests later on showed remarkably small deflections, maximum only 5 ins. for the Queensferry cantilever ends, 1/4, 100 of the span, and this result may be due in large part to the stiffening effect of those diagonals, which also help to reduce the secondary stresses in the trusses. A comparison with the double-track railway bridge of 470 feet span over the Niagara River will in part confirm this view. The trusses here have no diagonal in the towers. The bridge was tested in 1883 and showed a maximum deflection of 7¾ ins., or 1/730 of the span.

It appears that the Forth Bridge, although designed for a live-load of only 4,500 lbs. per lin. ft., can safely carry much heavier train loads, as indicated above.

Possibilities of the Cantilever for Quebec

If the competitive designers for the Quebec Bridge could have been at liberty

First, to use in the trusses unit-stresses averaging one-fourth of the ultimate strength of steels as in the Forth Bridge, which are more than ample;

Second, to choose greater height in trusses as in the Forth Bridge, thus reducing the chord stresses;

Third, to use curved bottom chords, thus carrying a large part of the web loads directly to the piers and reducing the web stresses (the bottom chords in the Phoenix Design are too sharply curved and are liable to produce reversible web stresses, which must be avoided in long members); and

Fourth, to use double or multiple-system webs, thus with small ambiguity obtaining the great advantage in a heavy bridge of diffusing the web stresses and reducing the column lengths and the bulkiness of connections;

Then the competition would have proven that a cantilever bridge with the same large margin of strength as the Forth Bridge could have been produced for a live-load of 12,000 lbs. (retaining the heavy floor-system of the Board's Design) with about 112,000,000 lbs. of steel, as indicated above. The saving over the official design, which contained 147,000,000 lbs. in the cantilever portion, would have been (at the lowest unit-prices bid) about $2,700,000.

But every feature which would tend towards economy was inhibited by the specifications, without any apparently good reason. The height of trusses was arbitrarily limited to 200 feet. The chords of the cantilever and anchor arms had to be straight; but the top chord of the suspended span, curiously enough, could be curved.

The trusses of the official design contained enough steel to carry, in better designed trusses, with a large margin of safety, the floor and train loads of four heavy railroad tracks, besides the wagon roads and trolleys; while the floor was dimensioned for only just two railroad tracks, two roadways and two trolley lines. It was not in any respect a well balanced de-

The Accepted Plan

About 24 tenders and eight or nine competitive plans were submitted by four bidders. The only variations in the cantilever bridge of the Board's design offered by bidders related to erection, web details, and length of anchor arms. The tenders on the Board's design varied from $11,000,000 to the extravagant price of $16,000,000, and from 7.6 cents to 11 cents a pound for all steel (carbon and nickel).

Among the competitive plans there were indeed several (all from one firm) which were much lighter

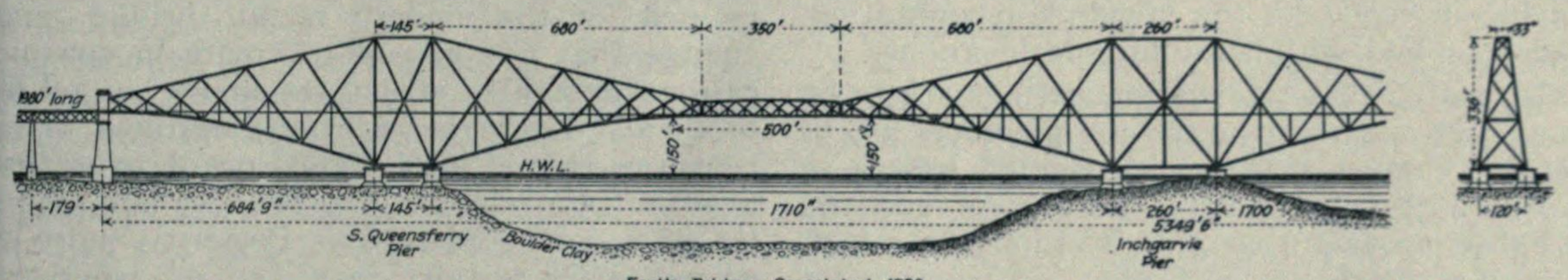
and cheaper than the Board's design, but these were, every one, in contravention of the official specifications. Dire consequences were apprehended by the tenderers, the least of which was the throwing out of their plans if they did not comply in every respect with the Board's specifications. One firm, understanding probably better than the others the home-atmosphere, dared to ignore the rules of the game, and in that way it happened that cheaper designs were submitted. One design had only 96,000,000 lbs. of steel in it, including approaches, and cost $9,000,000; it was just the plan chosen and accepted by the Canadian Government.

The Government's Attitude

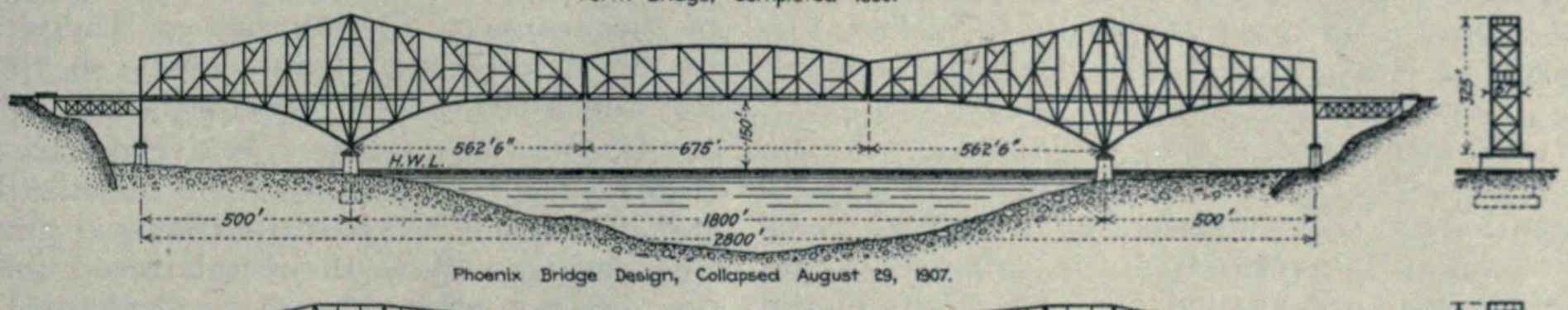
The action of the Government in this respect was not fair to the other competitors, who had acted honestly and in their designs had strictly adhered to the bridge structure could be built for a sum much below the cost of that officitl design. One can understand how under these circumstances he may have had the desire to lose no more time, and that probably from motives of expediency he adopted, although in violation of good faith to all the other tenderers, the lightest and cheapest design (but not the cheapest in unit-price) submitted to him.

That the rules of ethics which govern honorable men in their private affairs may thus be ignored by officials in public affiairs, seems to be viewed by the public in this age not as the immorality which it is, but as a matter of indifference. So the "injustice" had to be accepted with complacency by those directly concerned—there was no help for it.

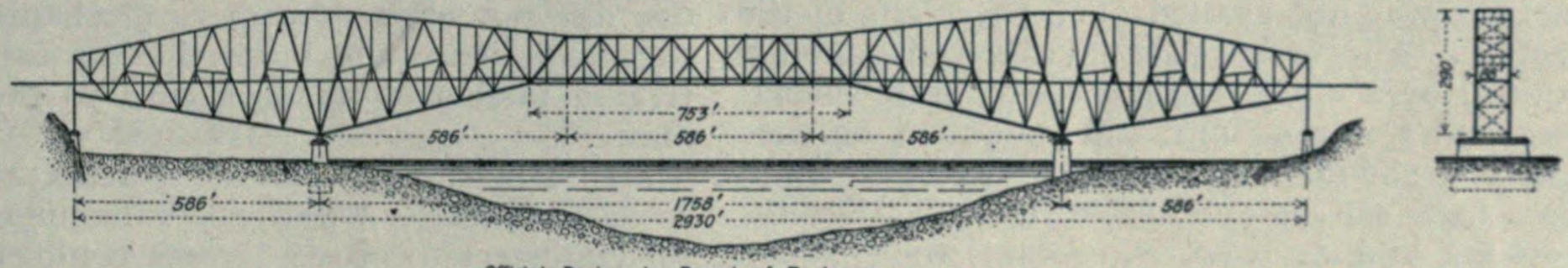
The public interest would have been better pro-



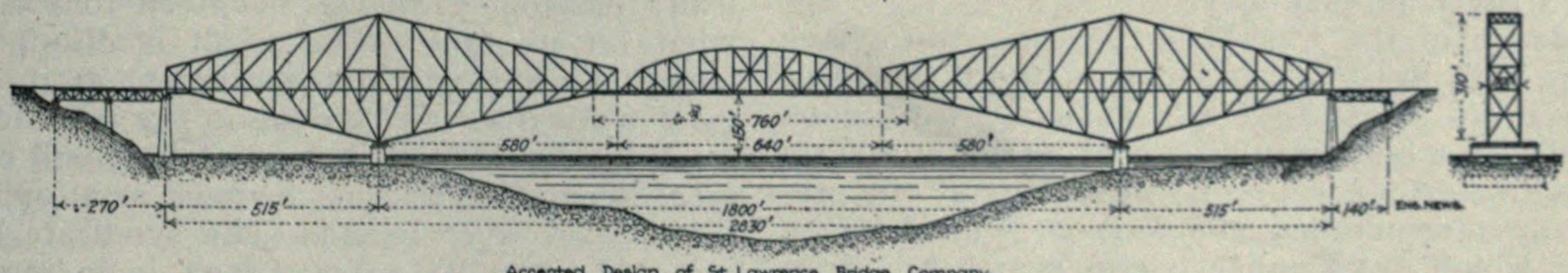
Forth Bridge, Completed 1890.



Phoenix Bridge Design, Collapsed August 29, 1907.



Official Design by Board of Engineers.



Accepted Design of St. Lawrence Bridge Company.

Cantilever Bridge Designs: The Forth Bridge and Three Quebec Designs.

conditions laid down. There is no doubt whatever that, had they taken similar liberties with the specifications, the nine-million-dollar design would not have been the cheapest.

But what was an ill-advised, perplexed Minister of Railways and Canals to do?

The Canadian Government has already expended (or obligated itself for) over $7,000,000, including the cost of the collapsed structure, engineering and contracts for new piers, and had lost three years' time in commencing the new bridge, with the intersst account running on. From the fact that the very costly Board's design was not adopted by the Canadian Government it can hardly be claimed that in the end it valued highly the ability and the expensive surveys of its own technical advisers.

The responsible Minister had to find out in that way, almost by accident, that a strong and serviceable tected if all the plans had been rejected and new plans and tenders invited. With the preparation which all the bidders had, new plans and bids could have been submitted by them in two months' time. But to order and do these things would have required some competent head, which did not exist.

Nor does any really responsible technical head seem to exist now. Since the conclusion of the contract there have been other changes in the personnel of the Board, only one of the original members remaining. There are good reasons for the belief that quite different and better results would have been produced by the present Board; but it is too late. The contract is made and the hands of the Board are now tied. Under the contract the entire responsibility for design, execution, etc., had to be assumed by the contractor, as above mentioned, so that the present Board, it appears, has no discretion, no power and no respons-

ibility, except that of seeing that the work is executed as per contract.

No detailed information about the adopted design has been published. The proportions of nickel and carbon steel have not been stated. Those who have studied the Quebec problem will at once concede that a good cantilever bridge and its approaches can be built within 96,000,000 lbs. and within the contract price of $9,000,000. But it is also a fact that within the same weight and price the bridge could have been made sufficient to carry two heavy railroad tracks, two wagon roads and trolley lines, since the live-load of 10,000 lbs. per lin. ft. is ample for these on an 1,800-ft. span; and this fact the Canadian Government could ascertain for itself, if it chose seriously to do so. If, as reported, the adopted design does not provide for wagon roads and trolley lines, then the choice is a stupid blunder, not by any means excusable by an apparent saving in cost over the other plans submitted, which had complied with wasteful specifications.

It is also stated that riveted connections are to be used throughout and that the tension members are to consist of nickel-steel shapes with riveted splices in place of the well-tested forged nickel-steel eyebars, so much lighter in useful weight. If this be the fact, it would be a retrogression in bridge construction for which no good reason can possibly be furnished. In that respect, at least, the Board's design was much better.

As already mentioned, it was a distinct loss to the Government that the special knowledge and experience gained by the able engineers of the Royal Commission, which had investigated the collapse of the first structure, was not availed of in the plans of the new structure. They were particularly well qualified and cautioned by their investigations to draft specifications for and to sit in impartial judgment on new designs, which should have complied with the high standards which can be set for such work. Several million dollars and at least two years' time would have been saved in that way.

The desire of the Canadian Government to have the bridge built in Canadian shops and with Canadian steel as far as practicable was perfectly legitimate, and should have been frankly stated in the invitation to bidders, instead of veiling its intentions by the pretense of an international competition, which was a farce and which put English, German and American bridge firms to large and unnecessary expense.

The Aesthetic Phase of the Quebec Bridge Problem

The aesthetic considerations which present-day civilization has a right to expect in a work of this magnitude and importance were entirely neglected. Not a word on that feature was contained in the specifications; not the slightest effort was made in that regard. There are several cantilever structures, in this country and abroad, which prove that they can be made architecturally sightly.

The bridge which collapsed had some grace of outline; so has also the Forth Bridge, so much derided for its bulky appearance. But none can be claimed for the new cantilever designs for the Quebec Bridge, which are ugliness itself. It would seem that as in no other monumental work, benighted amateurishness found true expression (we believe, quite involuntarily), not only in the coarse outlines of the structure, but even in such small features as the short approaches consisting of little, miserably weak-appearing girders on the slopes between the abutments and the anchor piers, instead of solid concrete masonry arches, which cost hardly more at present cement prices.

As is well known, the cantilever bridge is one of the oldest types. Some ancient examples still exist, built by savages of tree trunks and bamboo sticks, anchored down with boulders. Made almost without tools and with scanty resources, the vernacular architecture of these crude structures, set into a wild landscape, has a certain charm of its own which is a delight to the lover of simple comeliness and should be a lesson to the educated engineer

To give a pleasing form to its creations seems to be an instinct of the human race as far back as history can trace it. The higher the culture, the more refined that instinct, in all races and in all ages, as proven by thousands of structures for thousands of years. This fact makes architecture an accepted standard and measure of civilization. It remained for the modern metal bridge engineer to change that notion and to create in conspicuous locations unsightly structures and even to feel proud of them. Every large bridge destined to last many centuries should be designed on pleasing lines. This need not add anything to its cost but requires a little more work and study. Posterity, more enlightened in science and art, may well ask whether the wits of the designers of the Quebec Bridge were all used up by details and strain sheets so that none were left for artistic form and character.

As long as engineers as a class are indifferent in this regard, or satisfied to be mere utilitarians (and sometimes mere tyro utilitarians at that, ranking in this respect below their unlettered forbears and in our day not above the mere mechanic), so long will they experience and merit the low esteem which cultivated taste and minds accord to them in aesthetic matters.

Here in the case of the Quebec Bridge, destined to last centuries, was an unhampered opportunity for engineers to prove, if they could, that an aesthetically pleasing form can be given to a large bridge, whatever its type. The result is disappointing and lamentable; it will not represent, as it should, the good work that can be done in the twentieth century.

A syndicate of British capitalists will erect an immense cement works on Saanich arm, opposite Todd Inlet, Vancouver Island. The syndicate has already acquired about 100 acres of land, including a mile and a half of water frontage. The purpose of the company is to install a plant having a daily capacity of 2,000 barrels, the machinery for which is already ordered. Three hundred thousand barrels of cement have been imported into the province during the year. The syndicate, therefore, considers that there is an immense field for that business.

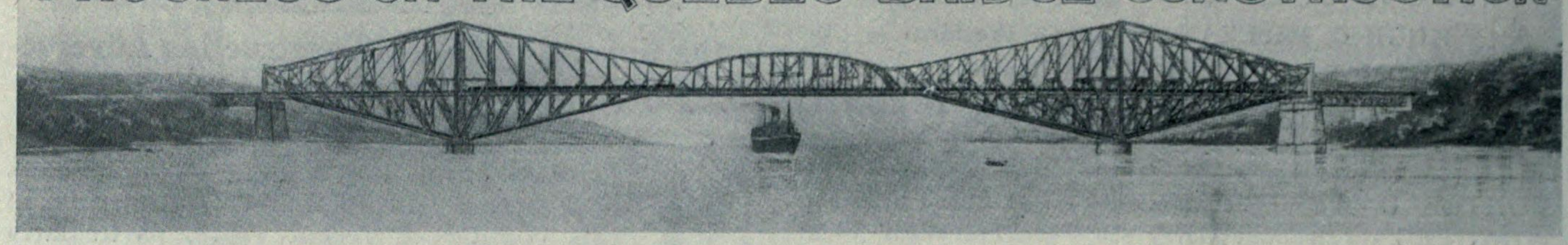
The old Pembina highway, running southward out of Winnipeg, is in a fair way to become the most important road in North America. A chain of six of the United States have signified their willingness to join forces and funds in constructing a great transcontinental highway from Winnipeg to the town of Galveston, Texas, situated on the Gulf of Mexico.

According to the recent census, Montreal ranks ninth and Toronto thirteenth in population among the large cities of the North American continent. The first three places are occupied, of course, by New York, Chicago and Philadelphia.

munity will lose balance and repute—and in no business is reputation a more valuable asset than in this one.

The question set forth in the heading under which this article is written cannot fail to be of interest to those concerned with the award of contracts, and a discussion of the subject by contractors themselves will perhaps help to mould ideas which may come to fruition at a later date. We could cite instances where the award of important contracts to the lowest bidder in face of the weightiest advantages attached to a slightly higher figure, has been attended by loss and even disaster. Doubtless the testimony of our readers will be illuminating in this particular.

PROGRESS ON THE QUEBEC BRIDGE CONSTRUCTION



Special to the Contract Record and Engineering Review

THE substructure of the Quebec Bridge consists in all of seven piers; two main or river piers, built with the aid of pneumatic caissons; two anchor piers, two abutments, and an intermediate pier between the north abutment and the north anchor pier. The north anchor pier having its foundation below high water requires a cofferdam, while the remaining ones are well above the water line and can be built dry on the solid rock.

The piers will be of uniform appearance, being constructed of granite masonry with concrete backing. The abutments remain practically as built for the old bridge, the only alteration being a slight change in the coping and in raising the retaining wall to conform to the new elevation of the base of rail. The main and anchor piers are being built entirely new, using some of the granite from the old piers which have been taken down. The location is slightly different from that of the old ones, but the centre line of the bridge remains unchanged.

During the present season the work on all the piers will be carried on simultaneously, but it is not expected that the substructure will be completed until the season of 1913. One of the chief difficulties with which the contractor has to contend is the short working season. Work is practically impossible from December 1st until March 1st—not only on account of the severe cold and deep snow, but also owing to the heavy ice in the river and along the batture, which destroys all falsework and stagings below high water line.

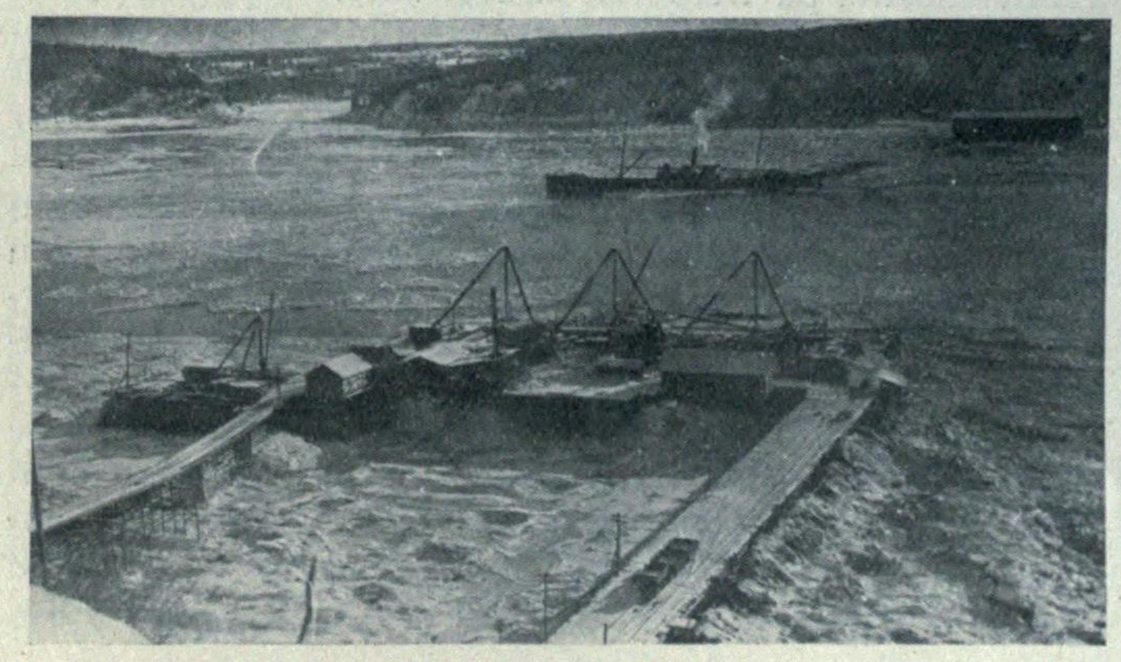
The Close of the Season of 1911

The two pneumatic caissons which form the foundation of the north main pier were described in the "Contract Record" of July 5, 1911. These caissons were sunk to elevation 20.0, about 81 feet below high water, and the chambers were sealed on October 29, 1911. Owing to the lateness of the season it was impossible to reach solid rock. The soil at this elevation is a glacial drift of sand, gravel and large boulders, which after being tested was found to make a satisfactory and safe foundation for the maximum load which will be placed upon it. The Chief Engineer decided that it would be safer to stop sinking and seal the caissons at this depth than to hold them during the winter and attempt to reach rock the following spring, exposing them to the danger of damage from the ice.

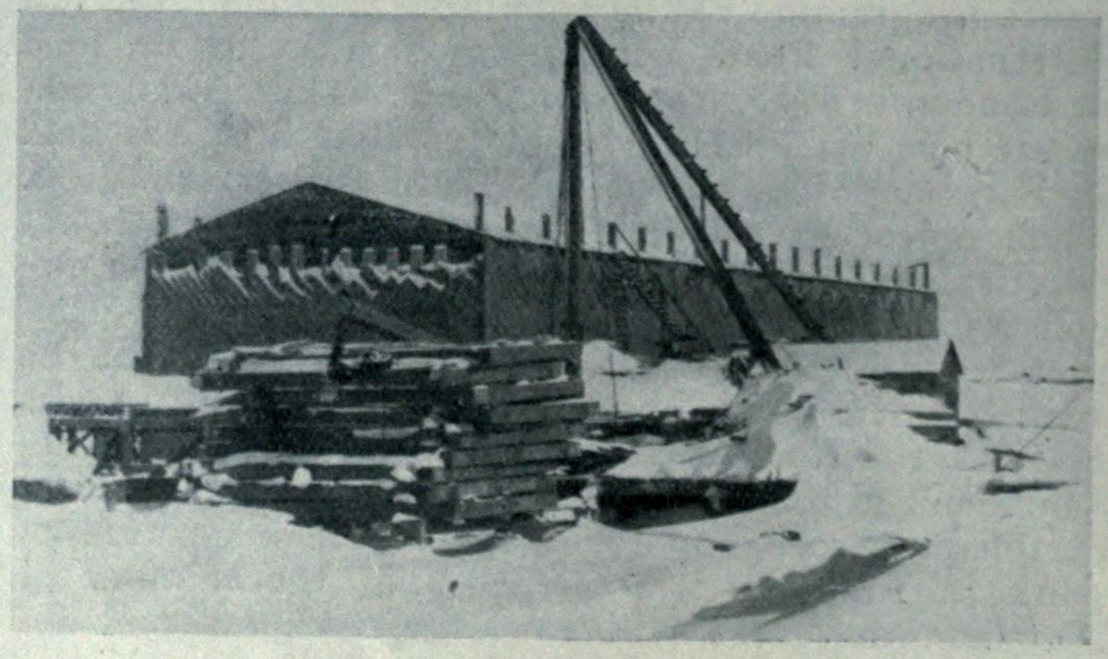
The laying of granite masonry was begun immediately after sealing the caissons, but had to be stopped on November 18 on account of the early arrival of cold weather after two courses had been placed.

From October 28th until November 25th the contractor was busy preparing the plant for the winter. The derricks and working platform on the south or river side of the caisson were taken down to escape damage from the ice, and both caissons were protected on this side by rip-rap. Large blocks of stone, about one cubic yard each, were used, running them out on lorries on a track built on top of the caissons along the south edge. The crib work of the caissons was also protected by weighting it down with about 100 tons of granite piled upon it on a timber grillage. The caissons were then allowed to fill with water and freeze solid. On thawing in the spring no damage was found done to them except to the caulking, which had to be removed.

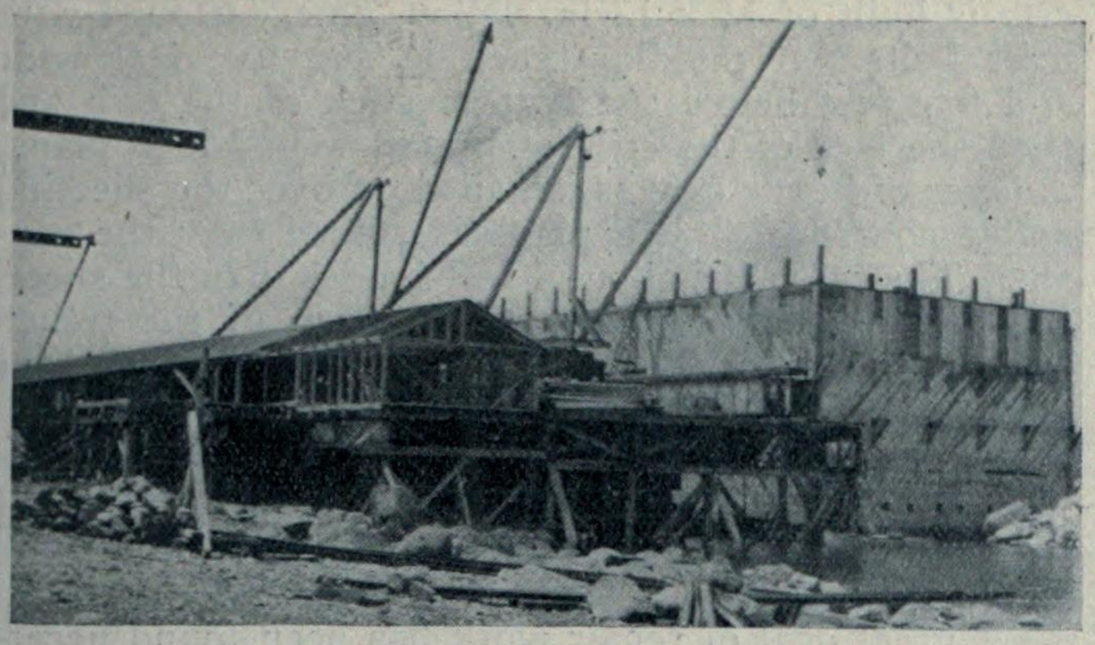
During this time the entire air and steam plant



The last steamer down from Montreal, December 8, 1911



South caisson in January, 1912

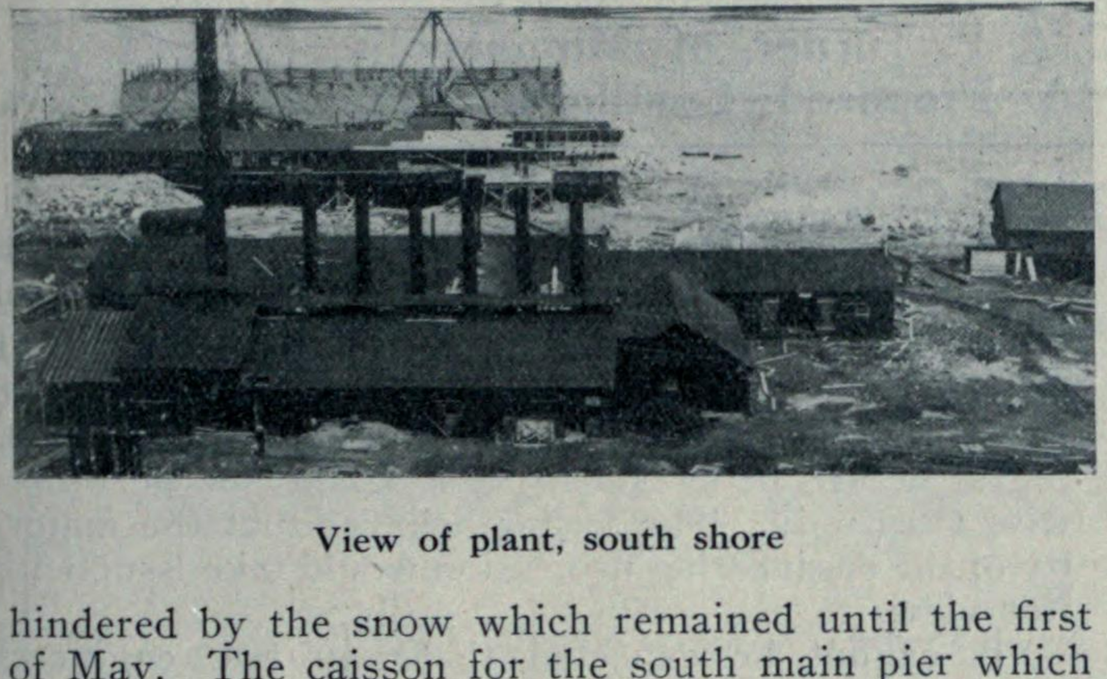


View of caisson, south shore

used in sinking the north caissons was dismantled and carried on scows to the south shore. Here the compressors and boilers were placed on their concrete foundations and houses built around them. Steam coils were put in the compressor house and the work of overhauling and fitting up the machinery was carried on all the winter in order to make an early start in the spring. This was the only work at the site during the winter.

Season of 1912

On March 1st the contractor started work on his plant on the south side, the progress being greatly



View of plant, south shore

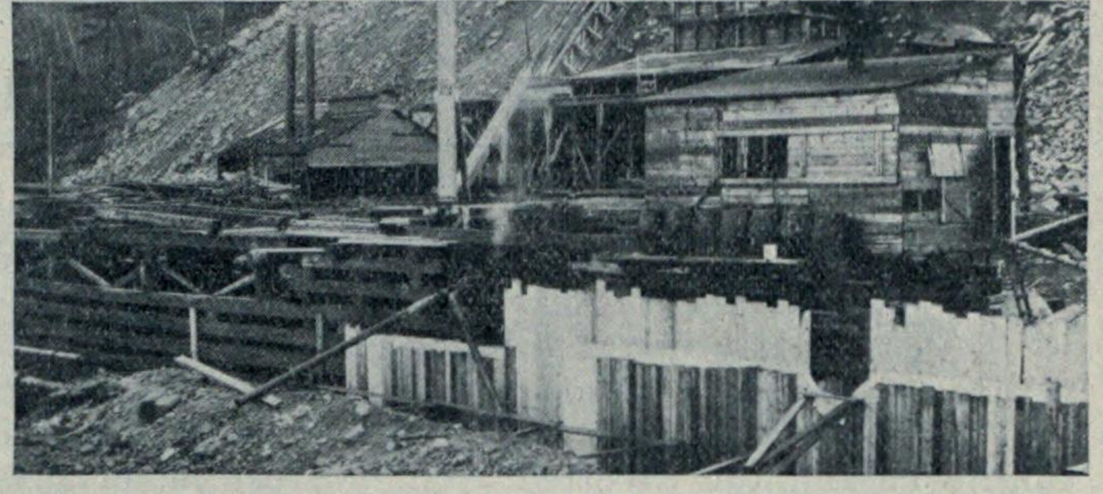
hindered by the snow which remained until the first of May. The caisson for the south main pier which was described in this journal in July, 1911, is 181 feet long and 55 ft. 6 in. wide. Extensive repairs have been made on it since the attempt to sink it on the north side in 1910. It has been thoroughly recaulked and an additional layer of 3-inch spruce sheeting has been placed on the outside. The deck has been reinforced by a course of 6-inch yellow pine. Ten 2-inch round rods have been run the entire length of the caisson just above the deck. These rods run through the end walls and are secured by nuts and washers and are tightened by turnbuckles. The old cribwork has been removed and re-arranged to allow an unbroken block of concrete to be laid on the deck 15 feet in depth. Eight 2-inch square rods will be placed in the concrete, 4 ft. above the deck, to prevent deformation. It is proposed to carry this caisson to solid rock a distance of about 100 feet below high water and about 84 feet below the ground level where it now rests.

The plant used on the north shore was considered insufficient for the larger caisson and is being added to. The additions include three new water tube boilers of 125 h.p. each, manufactured by the Polson Iron Works; two double-phase compound Ingersoll-Sargent air-compressors; a No. 8 gyratory stone crusher (McCully), and a new 1½ cu. yd. Ransome concrete mixer.

The air and steam plant is one of the largest ever installed for a single caisson, and has a capacity of 1,600 boiler h.p. steam, and air compressor capacity of 13,100 cu. ft. of free air per minute. In addition to this there are several small boilers to furnish steam for the derricks and a high pressure compressor for the air drills used in the caisson.

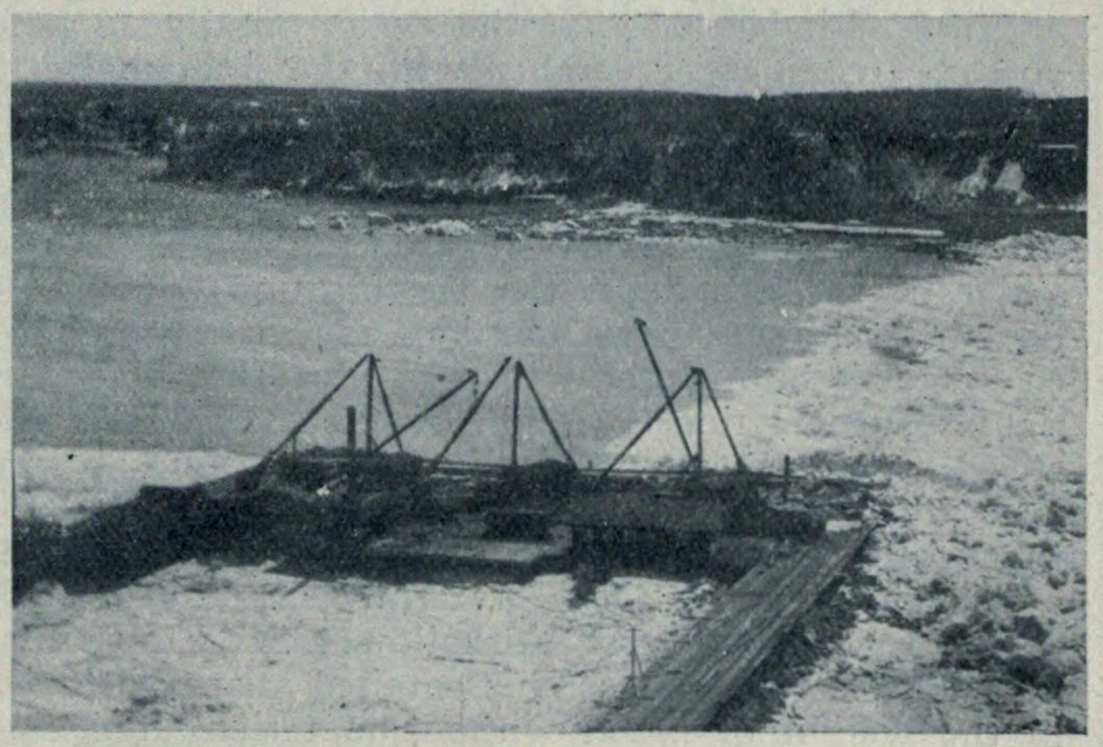
As the caisson rests on the ground which is bare at low tide, it is possible to do some of the preliminary work without the use of compressed air. On May 21st about eighty sand hogs began to excavate under the cutting-edge, working at both low tides for two periods of about three hours each. The work is carried on from the outside and inside simultaneously, and consists in ditching and clearing beneath the cutting edge. This is done by opening up alternate sections of about six feet in length and excavating with pick and shovel, blasting the numerous boulders which are too large to be removed. When one section is cleared it is filled in with clay until the entire edge is free and ready for a drop. The caisson is supported meanwhile on timber blocking and forty sand jacks which will be used to lower it. No attempt to sink the caisson will be made until about six feet of concrete has been laid on the deck and the compressed air put on.

The work on the concrete plant has been pushed



Work on cofferdam, north anchor pier, May 18, 1912

ahead since March 1st and it will be ready for operation early in June. The plant is laid out down the face of the cliff, the material being received at the top and the mixers placed at the bottom to discharge directly into cars on the lower level. Gravity has been used to handle all the materials, coal, sand, cement and stone. The operation and layout of this



Ice jam on centre line of bridge, April 27, 1912

plant will be described in detail in a later issue of the Contract Record and Engineering Review.

Interesting Problems on the North Side

Although the most interesting part of this season's work is in connection with the sinking of the south pier caisson, yet, with four piers to build, the work on the north side includes several interesting engineering problems.

The contractor has opened a new quarry at La Tuque and has a gang of stonecutters at work preparing the granite for the piers. A great deal of the stone from the old piers is being re-cut for the new ones.

The intermediate pier is to be built on a shelf cut in the solid rock with its foundation about 55 feet above high water. The excavation for this pier is nearly finished and the laying of masonry will be begun in a short time.

The foundation for the anchor pier is on solid rock at the foot of the cliff. Since it is below high water, a cofferdam is being built to keep the site dry during excavation and building. The cofferdam consists of a rock-filled crib, ten feet high and fifteen feet wide, forming the three sides of a rectangle around the pier. The fourth side is unnecessary as the surface of the rock is above high water on this face. The crib is built of 12 x 12 in. yellow pine, fastened with drift bolts. A puddle trench is dug five feet wide and five feet below the bottom stick of the crib and then the face of the crib is sheeted with 3-inch plank. A layer of heavy canvas is nailed on over the sheeting and a course of 2-inch plank is spiked over the canvas. The canvas is about 4 feet longer than the sheeting and extends out over the bottom of the trench to hold the clay. The trench is then filled with blue clay, level with the ground surface, and covered with gravel and rock for protection. The work on the cofferdam is being carried on every day at low tide, at the same time as the excavation for the pier, the spoil being used to fill the crib.

A great deal of repair work has been found necessary on the north side owing to damage done by the ice. On both the east and west platforms a large number of broken piles have been replaced. Both caissons have been thoroughly recaulked, but no stone has yet been laid on the main pier this season.

The contractors, Messrs. M. P. & J. T. Davis, are represented by their Chief Engineer, Mr. S. H. Woodard, of Noble & Woodard, and by their Superintendent, Mr. Jas. Taber. The Board of Engineers in charge of the work for the government are represented by Mr. J. D. Wilkens, Resident Engineer, and staff.

Is the Quebec Bridge Design a Failure?

Further Criticism made by Mr. C. A. P. Turner, of Minneapolis—Fundamental Points Discussed—A Proposed Cantilever Design

THE writer was much interested in the recent articles* by Gustav Lindenthal on the Quebec Bridge, and his exceptionally interesting design of an inverted braced arch for the structure. He is inclined, however, to believe that, if a fair comparison is made of the relative merits of the cantilever and the inverted arch, the cantilever presents for the consideration of the engineer the more desirable structure.

The writer is inclined to agree with the general conclusions of the Board of Engineers for the Canadian Government in the following particulars: (1) that the cantilever type of structure is to be preferred; and (2) that a single intersection design is to be preferred and should be more economical than a double-intersection. He disagrees with them as to the details of carrying out such a design, and agrees with Mr. Lindenthal that the design finally adopted does not compare favorably with the famous Forth Bridge.

The writer further agrees with Mr. Lndenthal in his condemnation of the conduct of the so-called competition for this work. As regards the height permissible for the structure, the specification appears to have been drawn not with an idea as to what might be economical, but rather with the idea that this particular specification would of necessity limit the structure closely or practically to the outline decided upon by the board. The height of truss adopted for the Forth Bridge at the piers was 336 ft. on centres, while the Board of Engineers arbitrarily limited their design to 290 ft., or 50 ft. shallower, for a structure carrying heavier loads. This entailed a large increase in the weight of metal without materially reducing the overturning moment.

The shore arm of the original design of the board is much longer than economy would dictate, and this lack of proper proportion gives the official design a peculiarly clumsy and ungainly appearance. But the view of one of the engineers of the board was that, the structure being so large, it could not be otherwise than ugly. The writer believes that the majority of the engineering profession would take issue with this view.

It cannot be expected that any two engineers would arrive at once at the same conclusion or opinion regarding a structure of such unusual proportions, and this is one of the reasons why the writer has taken the trouble to present herewith the outcome of some little study made by himself on a design for this structure. The design which resulted from this study is presented below, and some drawings are given. Before taking it up, however, some general remarks are offered.

The Fundamental Question of Tension and Compression Members

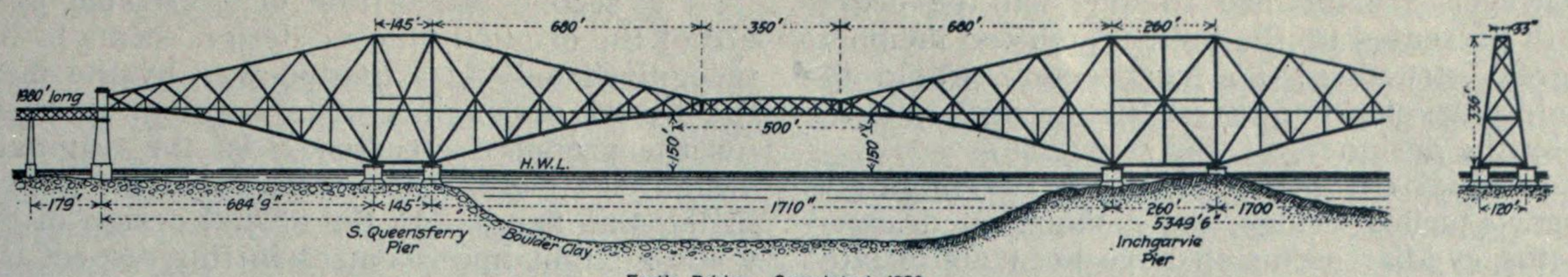
The failure of the original Quebec Bridge demonstrated two important propositions in bridge design:

First, that for a heavy tension member no form can be devised which will present so little uncertainty as to its degree of security and strength as a chain of well made eyebars.

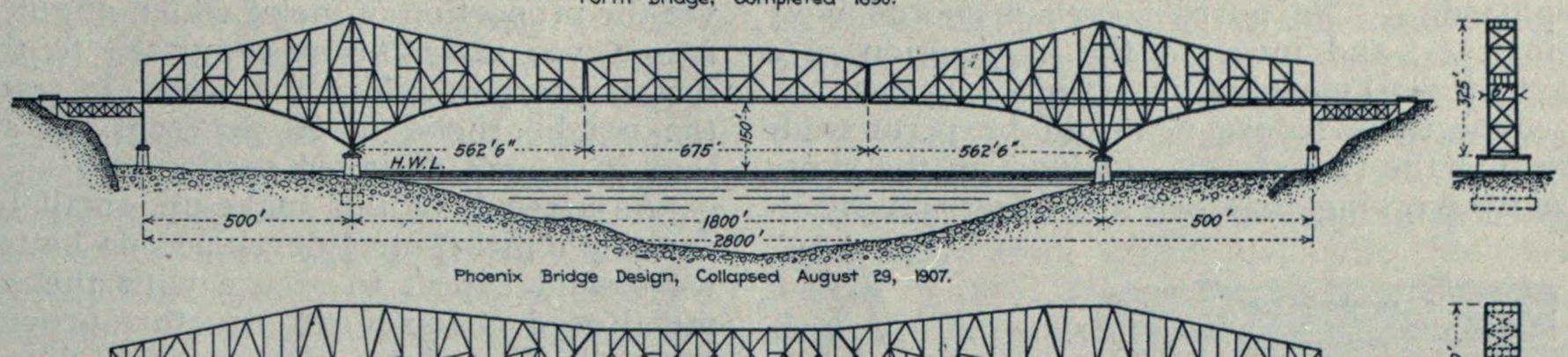
Second, that in the make-up of compression members stiffness and rigidity in all directions is an essential requirement, if we expect to develop the value of the material of the section.

No one is inclined for a moment to question the absolute security and strength of the compression members of the famous Forth Bridge. Many engi-

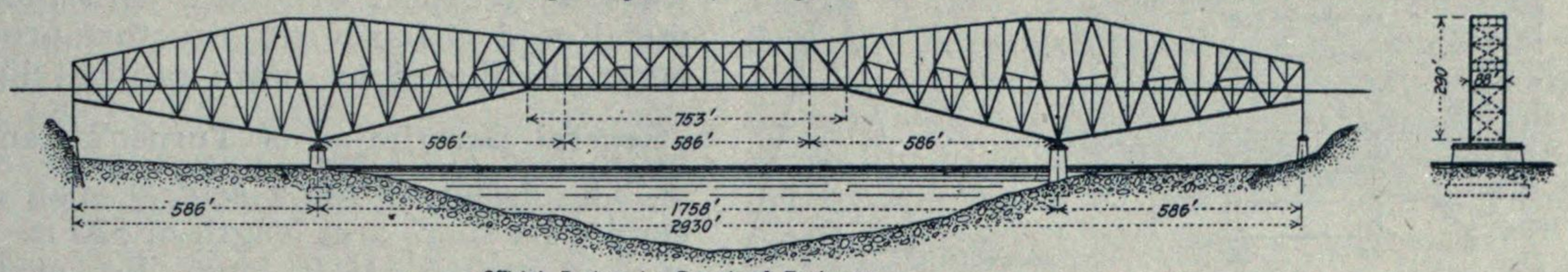
* Engineering News, May 30, 1912; Contract Record, November 29, 1911.



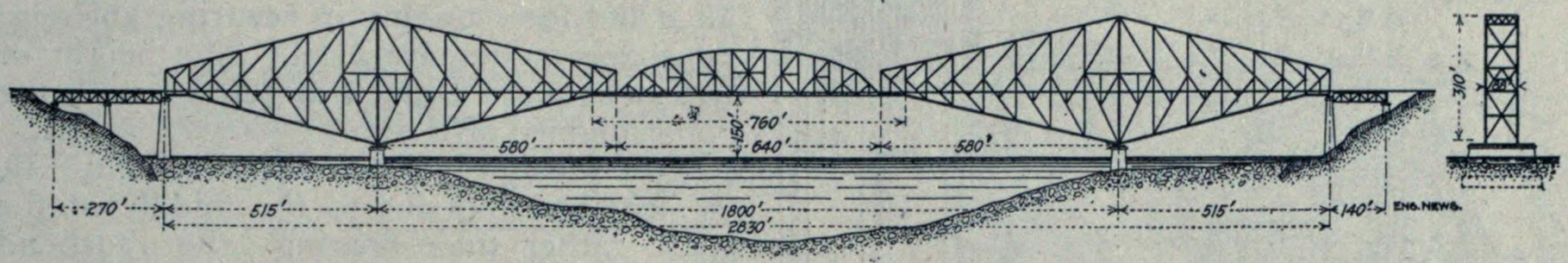
Forth Bridge, Completed 1890.



Phoenix Bridge Design, Collapsed August 29, 1907.



Official Design by Board of Engineers.



Accepted Design of St. Lawrence Bridge Company.

Cantilever Bridge Designs: The Forth Bridge and Three Quebec Designs

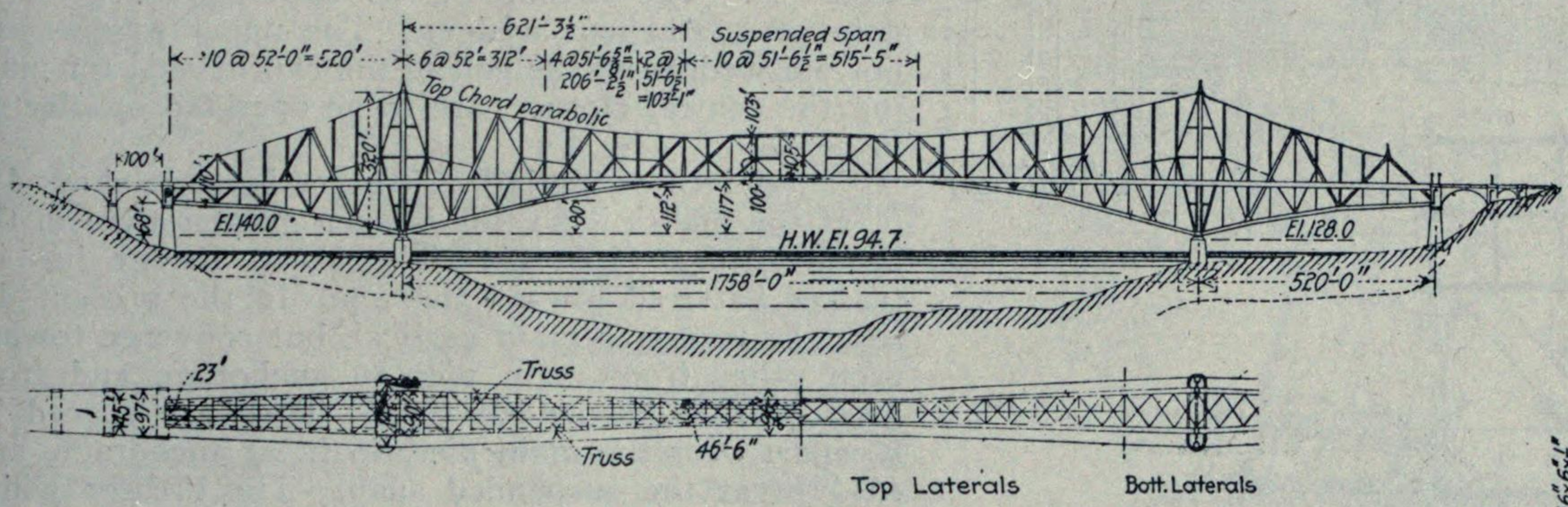


Fig 1—Outline sketch of Turner's design for Quebec Bridge

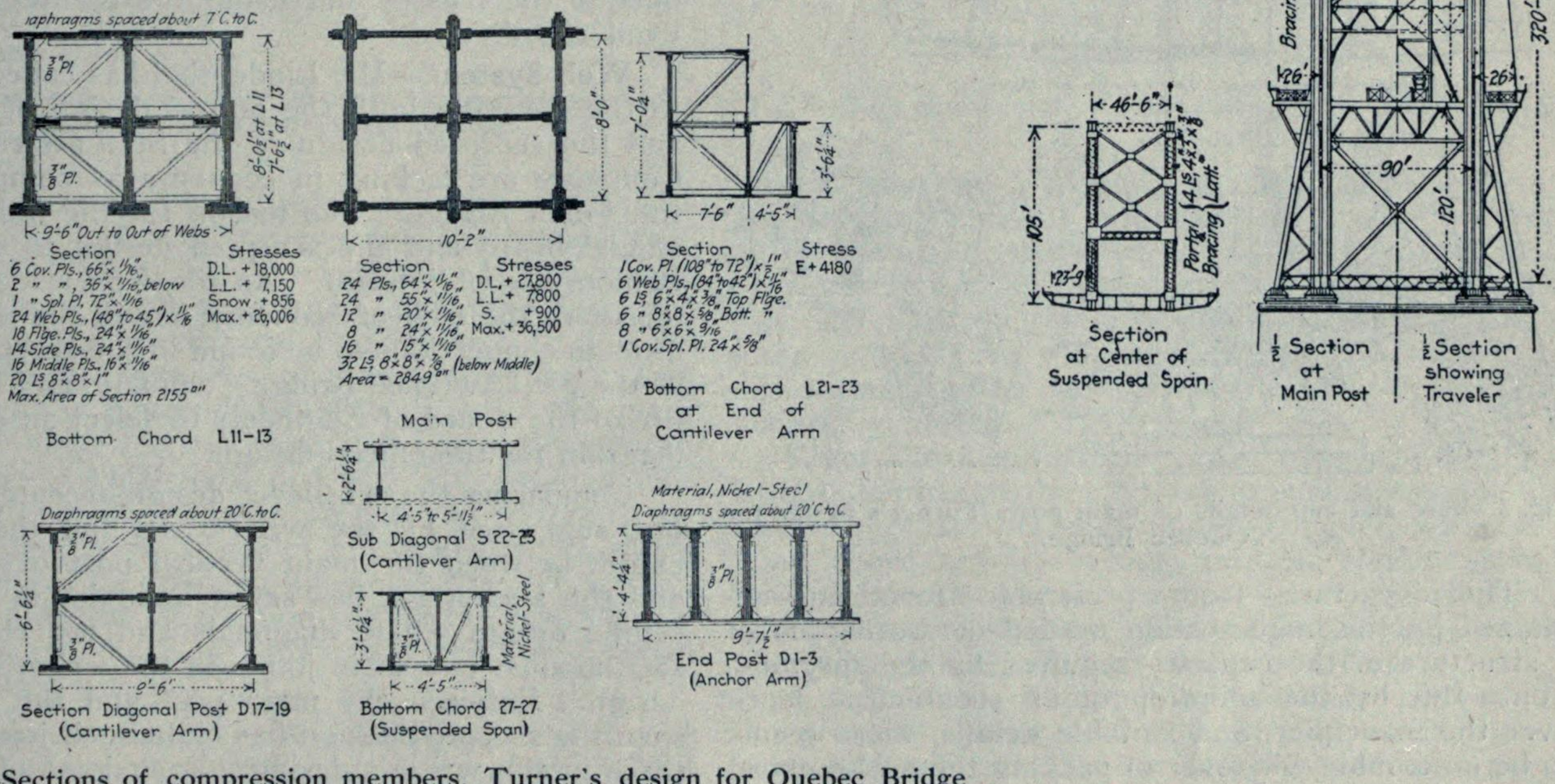


Fig 2—Sections of compression members, Turner's design for Quebec Bridge

neers, however, are inclined to question the degree of strength presented by the built-up tension members in this great structure: To what extent would the riveted joints develop under test the strength credited to them by the designers of this structure?

In the official design by the Board of Engineers for the new Quebec Bridge, the demonstrated superiority of the eye-bar seems to have been appreciated and recognized. The board's eyebar chords were double, however, and involved the assumption of a high order of workmanship in boring for their respective connections before it would be permissible to assume that the two sections making up the chord were actually working together in perfect unison.

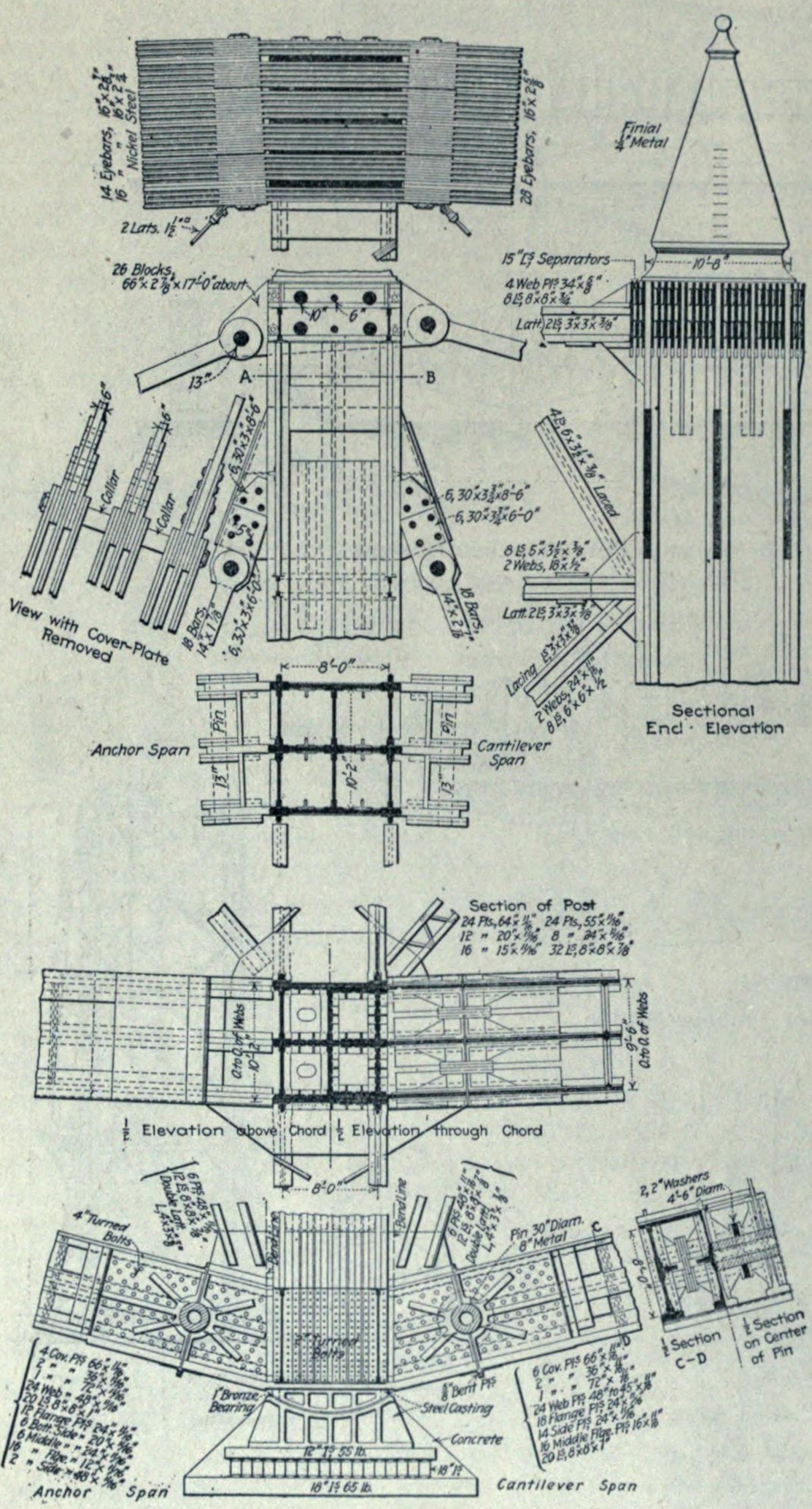


Fig. 3—Base and cap details of main post, Turner's design for Quebec Bridge

This departure from preferable form was explained by the huge section needed in the chords of a structure of the capacity required by the specification. But by the adoption of an economical depth over the main pier, and suitable details, there seems to be no trouble whatever in packing the entire chord on a single pin.

The second proposition demonstrated by the failure of the original Quebec design seems to have been recognized only in a limited way by the members of the Board of Engineers in working up their design for the proposed structure. In the original Quebec design, the metal was concentrated in the webs with little or no flange. In the official design of the board, while a slight improvement in this respect was made, yet the proportion of metal which might be considered flange was insignificant compared to the amount of metal incorporated in the webs, instead of being in the neighborhood of 50 per cent. as should be the case in a well designed section.

As a result of this make-up, small test models of expensive nickel-steel developed no better values than we should expect to secure with the same grade of metal used in the Forth structure provided the metal were distributed on more rational lines.

General Description of Turner's Cantilever Design

The design is for a central span of 1,758 ft. and employs a shore-arm length of 520 ft. The suspended span is made 515½ ft. long. For neatness of appearance and for economy in securing anchorage, concrete approach arches are used. The height of truss over the main piers is fixed at 320 ft., with regard to proper economy of design.

The design contemplates building the structure by cantilevering out to the middle of the suspended span, rather than floating the suspended span in (which is too costly with a span as long as economy dictates). The closing of the upper chord is to be done on permanent wedges. The upper toggles and bottom wedges at the end of the cantilevers, for making the central closure, are to be operated by electric motors.

The width of the lateral trusses is made about 140 ft. at the main piers; this is even greater than in the Forth Bridge (120 ft.). The Forth Bridge has its trusses battered toward the top. In the present design the trusses remain vertical, but converge toward each other from main pier to anchorage and from main pier to suspended span. They are spaced 90 ft. apart over the main pier, 45 ft. at anchorage, and 46½ ft. at the suspended span. The greater width of the wind truss is obtained by placing the roadway outside the trusses and using the roadway chord as wind chord.

Web System.—Mr. Lindenthal has called attention to the fact that both the official design of the board and the accepted design of the St. Lawrence Bridge Company are lacking in economy as compared with the Forth Bridge. The reason for the failure of the official board and the accepted design to secure this economy is of interest. As the writer looks at this question, the lack of economy lies in the multiplicity of main connections to be found in the accepted design of the St. Lawrence Bridge Company, and in the failure of the Board of Engineers to select an economical diagram for the official design.

Comparing the cantilever design accepted with the one suggested by the writer, we find that the top chord, between the main vertical post over the pier and the anchorage, has seven main joints in the accepted design where diagonals and top chord intersect, against two main joints in the writer's proposed design. Between the main post and the suspended span the accepted design has eight such joints against three in the writer's design. Each joint of this kind involves a large amount of metal and runs rapidly into

weight, besides adding to the complications of erection.

Although the main diagram is laid out with wide meshes, sub-chords are used for convenience in erection and to assist in distributing the panel-load concentrations into the web.

The diagram outline of this proposed design was worked out primarily from the standpoint of ease of erection and simplicity of details. Rather than allow the desire to obviate secondary stress dictate and determine the character of the diagram, the question of provision for secondary stress was left to be provided for by mechanical ingenuity.

The displacement diagrams of the design (taking into consideration the dead-load after the structure is completed) would indicate large secondary stresses in the diamond frame over the main piers, unless mechanical provision were made to reduce them. Such reduction is accomplished by wedge-pin adjustment of length in the sub-posts forming the lower part of the diamond; as the main post shortens or the ties lengthen, the sub-posts can be adjusted in length so that the sub-chord or horizontal tie crossing the central portion of the diamond is not overstrained. The main shoe details, comprising a hinge, complete this provision from the mechanical standpoint. It will be noted in the diagram selected that a large part of the dead weight is concentrated directly over the main pier. The huge vertical posts and bracing, weighing approximately 4,000 tons, produce no bending moment whatever in the truss proper. In contrast, the official design by the Board of Engineers has its heavy posts arranged on diagonal lines over the pier, involving much difficulty of erection and necessitating heavy temporary members in order to place the finished structure in position.

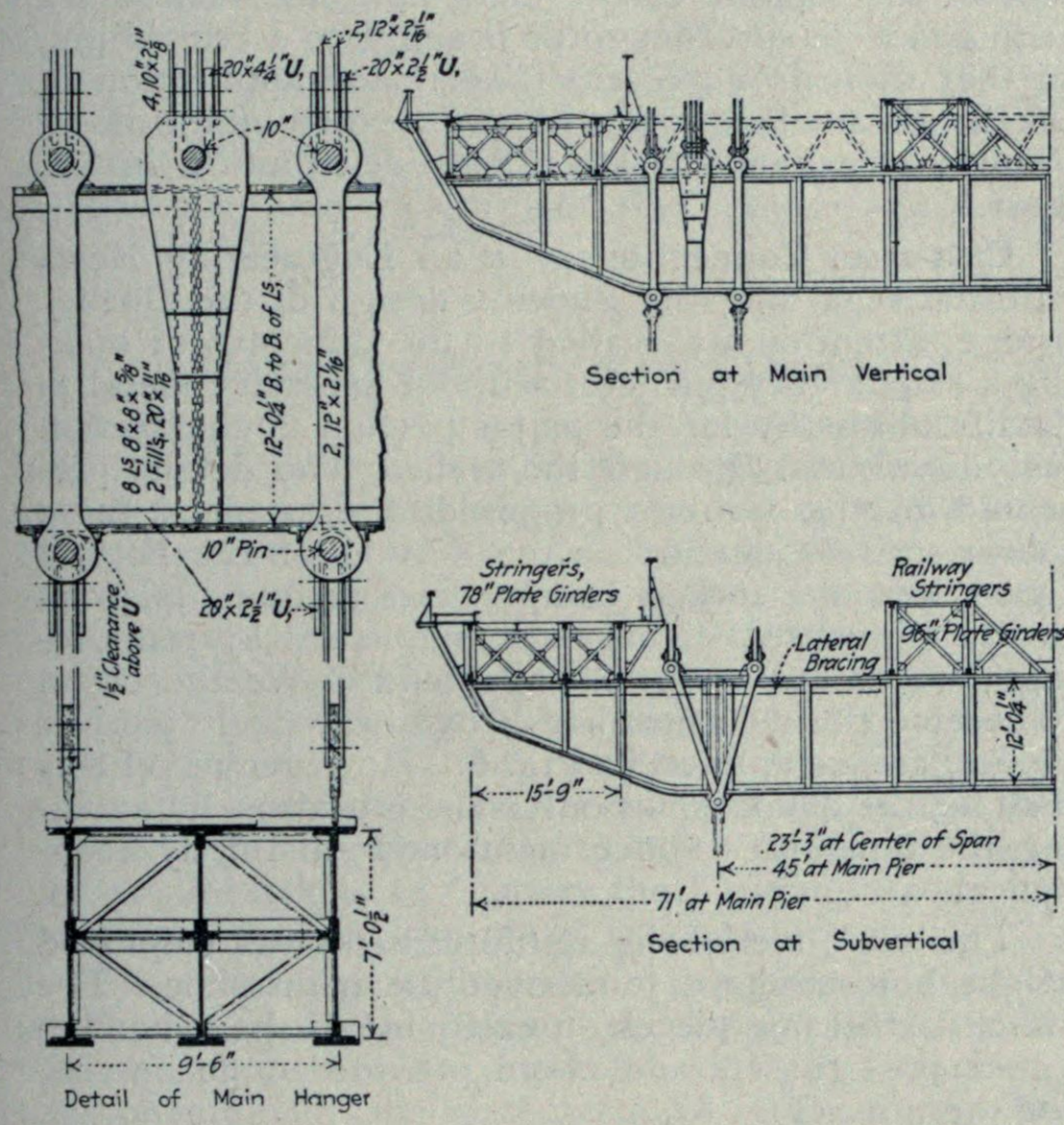


Fig. 4—Cross-sections of bridge, showing hanger construction, Turner's design for Quebec Bridge

Erection Appliances.—In erecting a structure of this type, provision must be made for handling and delivering the material as the work is built out. In the Phoenix design of the Quebec Bridge, heavy girders were attached to the bottom chord, projecting outside of the trusses, and a traveler spanning or straddling the trusses was used. With the proposed design this method of procedure would not be practicable, and the writer's idea was to adopt a mushroom type of traveler supported directly from the steam-railway tracks, and deliver the truss material as the bridge is built outward on the roadway or electric-railway tracks outside of the trusses. In this manner the material may be delivered at practically the point from which it is desired to raise it, and, with the overhanging traveler stayed to the ends of the floor-beams we have thus a simple and comparatively light frame from which to handle the work. The weight of the 1,000-ton traveler used by the Phoenix Bridge Company in erection was made up in large part of the heavy members needed to support the traveler. Eliminating these, as we can readily do through the method of support outlined, the weight of the traveler would be much less than half that which it was necessary to provide for in the original Phoenix design.

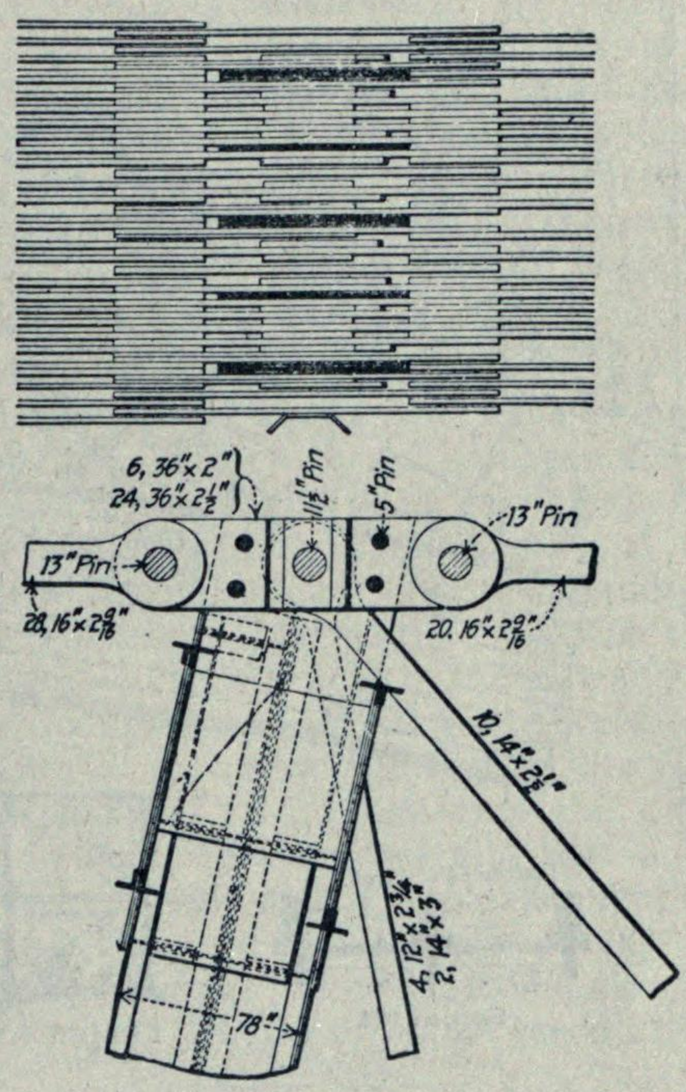


Fig 5—Top chord joint, Turner's design for Quebec Bridge

Arrangement of Floor.—In the proposed design the roadway and the street-railway tracks are kept outside of the trusses, and the railway tracks are placed between trusses. By this arrangement the dead weight of the roadway counterbalances in a large measure the dead weight of the railway, which reduces the bending moment in the floor-beams very materially indeed.

Wind Chord and Bracing.—By arranging the buckleplate flooring of the roadway in such a manner that it is riveted to the longitudinal stringers, we have a wind chord of unusual section and rigidity, which with a fair amount of diagonal bracing furnishes a wind truss independent of the chord lateral bracing and lying directly in the plane of the floor.

Heavy lateral bracing is provided between the compression chords, while the wind stress in the upper system is provided for largely by transverse or portal bracing.

Compression Members.—The make-up of the compression members is simple in the extreme. Three webs are used throughout the main chords, and there is ample room to work inside. Typical sections of chords and other compression members are shown in Fig. 2.

The characteristics of the chord make-up are: Provision for approximately forty per cent. of the section in the flange; cover-plates covering the top of the heavy section, well riveted to heavy flange angles connecting the webs; no cover-plate whatever for the bottom of the box, but wide flange-plates, giving a heavy flange (24 in. in width) at the bottom of each web; concentration of metal in the centre of each web and the stiffening of the whole box by heavy diaphragms spaced about 7 ft. apart. The construction gives in effect a cellular member of such ample dimensions that the work of riveting up splices, etc., can conveniently be carried on therein.

The make-up of the main posts, like the make-up

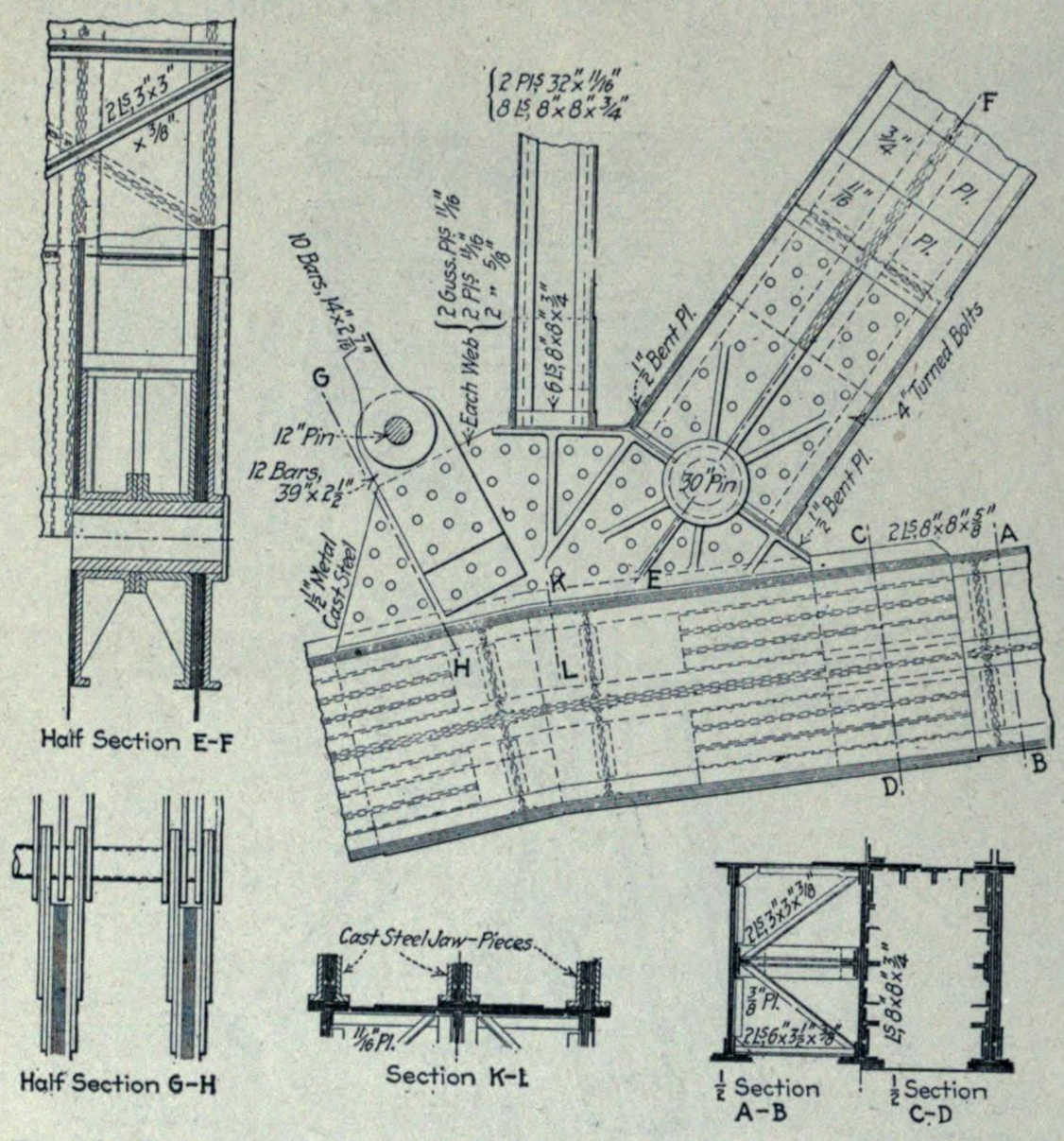


Fig. 6—Bottom-chord joint with cast-steel pin-jaws, Turner's design for Quebec Bridge

of the main compression chords, presents approximately the same stiffness in both directions. The post is made up of three webs in the plane of the truss, and a transverse web connecting the centre of these. The webs (parallel to the truss) are each provided with heavy flanges well latticed, a combination which gives a high degree of stiffness under bending from wind pressure, in view of the unusual width of the member, and renders the connection to the upper and lower chords a very simple matter indeed.

To secure an economical as well as aesthetical design of trusses, the upper chord eyebar chain is hung on a parabolic curve and the anchor and cantilever-arm lower chords have each two breaks in direction. The lower-chord members are tapered both in width and in depth from the main pier toward anchorage and suspended span.

The section of the lower half of the main posts is 2,849 sq. in. The lower chord of the anchor arm in the panel adjacent to the main post has a section of 2,155 sq. in., and the maximum section of the cantilever-arm chord is 1,951 sq. in. All these members are of carbon steel. The upper chord in the sections extending from the main post contains 1,348 sq. in. on the anchor-arm side and 1,176 sq. in. on the cantilever-arm side. This chord is made up of nickel-steel eyebars.

Floor Hangers.—The suspension of the floor from the panel-points of the truss is worthy of notice. In the hangers dropping from the main panel-points of the top chord the suspenders are made up in two sections independent of each other, one section taking care of the floor-beam loading directly beneath the panel-points, and the other section continuing to the lower chord and taking care of the truss dead load plus such portion of the live load as is transferred through the sub-system.

These suspender connections, an unusual feature, are illustrated in Fig. 4. The great width of the chord, varying from 8 to 12 ft., necessitates a wide separation of the strands of the main hangers. These are arranged by a spreader to be brought to a central pin, so that there is no eccentricity in the application of the floorbeam load nor will any flexure of the floorbeam under live-load affect this distribution in the least.

Cast-steel Connections.—In an Engineering News editorial regarding the Phoenix design of the Quebec bridge, attention was called to the difficulty of making a satisfactory pin joint without excessive metal in details unless by far the major portion of the section was distributed through the webs. The details presented in the writer's proposed design place these joints entirely outside of the section of the bottom chord, and the forked compression member is practically eliminated. This is accomplished by reinforcing the gusset-plates, which extend above the chord to receive the web members, by cast-steel pin-jaw blocks, as exemplified in Fig. 6. However novel this may be, the detail is not only safe, but also—by avoiding the difficulties above mentioned—distinctly economical.

The same method of reinforcement was employed at the bottom-chord joint over the main shoe. The six cast-steel jaw pieces on each side of the splice between post-gussets and chord provide ample bearing for the pins (Fig. 3).

Turned Bolts in Place of Rivets.—These heavy connections were made practicable by the rather radical innovation of substituting large turned bolts for the rivets. At the splices over the main pier and in most other cases, 4-in. bolts are used, but in some joints 2-in. bolts. They are to be fitted tight to their holes, and forced in by hydraulic jacks; their nuts are then to be screwed up tight so as to pinch the plates firmly together. The writer believes this to be a decidedly novel scheme for making connections.

Double-pin Link Connections.—The top-chord connections of the web necessarily involve forked ends on the compression members. These forks, however, are never longer than three or four times the thickness of the metal. The design of these top-chord joints was simplified effectively by the link construction illustrated in Fig. 5.

Multi-pin Connections.—For certain connections, a group of small pins was laid out, in place of a single pin or rivetting. These pins are usually 5 in. in diameter, but in some cases pins of different sizes are used

together. The details of the post-cap and diagonal connection, in Fig. 3, illustrate multi-pin connections.

Rigidity and Weight

Deflections.—The computed maximum displacement at the centre of the suspended span for E-75 loading was 17½ in. For maximum one-sided loading it was estimated that the middle top-chord section of the suspended span would be swung 14½ in. out of line, assuming the lower chord to be held true to line by the floor system and the heavy lateral system in the plane of the chord. An interesting feature of the one-sided loading is the live-load stresses set up in the sway bracing connecting the main posts, due to the convergence of the trusses.

Weight.—In Mr. Lindenthal's article he discusses the possibilities of a cantilever for Quebec, and I regard his discussion as quite conservative, taking exception only to his view that the double-intersection or multiple-system web is economical. Mr. Lindenthal figures that with the double-web system a design should be gotten out with 56,000 tons of steel, using increased working stresses. Using the working stresses provided for in the specification of the board the writer's estimate of weight was approximately 10,000 tons less than the estimate of the board, and this with a saving of nearly $1,000,000 worth of nickel, as nickel-steel was figured on only for the eyebars and some special details.

Labor Organization in Canada

A report on labor organization in Canada has just been issued by the Federal Department of Labor. The report deals with conditions generally as prevailing at the close of 1911 and the publication contains much valuable detail concerning the various unions, councils, federations and national organizations of the country. Statistical tables showing the numerical strength of the various bodies make the report additionally valuable. Where the names of officials are given the information, as far as possible, is for the year 1912. It is interesting to note that of 48 federated organizations in Canada the building trades include nineteen and the metal trades fourteen.

A noteworthy comparison is made in a table which gives in one column the total trades union membership to the total population. Of thirteen countries mentioned this percentage is highest in the United Kingdom, where it is 5.4; in the German Empire it is 4.1; in the United States it is 3.0; in France it is 2.5, and in Canada, 2.0. The percentage is lowest in Hungary and Italy, where it is .4 and .5 respectively. Canada is less highly unionized than many European countries. In the list to which we have referred she stands about midway. While the percentage of trades unions in Canada is much smaller than in the United Kingdom it must be borne in mind, however, that in Canada the proportion of population engaged in manufacturing industries is also much smaller.

The total estimated membership in Canada of trades is 133,132, the Canadian international roll reaching 119,415. The remainder belong to purely Canadian unions.

It is of interest to note that the Industrial Workers of the World, an organization of U. S. origin, has nine Canadian unions representing various industries with an approximate membership of 4,000. The methods of dealing with industrial questions favored by this organization are more radical and drastic than those of other bodies—but this, perhaps, is beyond the pale of a review of the report.

Professor Gibson on Wave Impact

A paper by Professor Arnold Hartly Gibson, selected for printing in the "Proceedings" of the Institution of Civil Engineers, deals with wave impact on engineering structures. The main conclusions to be drawn from the investigation described are that while, on the assumption of simple hydrostatic transmission of pressure, the effective internal pressure due to wave impact cannot exceed that exerted by wave impact on the sea face of a breakwater, the pressures produced, if the energy of the wave is devoted to compression of air in tne open joints, may amount to approximately twice this magnitude. If, however, conditions are favorable to the production of water hammer, considerably greater internal pressures, up to some fifteen times the face pressure with very high velocities of impact, are to be regarded as possible. The results suggest the desirability of providing a free outlet for such water as may percolate to the interior of a sea wall or breakwater, by means of a series of weep holes or drains opening on its sheltered face. Such drains, preventing the accumulation of internal water, would be an effective guard against the production of internal pressures of sufficient magnitude to affect the stability of the structure, whether due to water hammer or to air compression.

Electric elevators for pedestrians and vehicles are features of the tunnel under the Elbe river at Hamburg, Germany. There are six of these elevators operating in the vertical shafts at each end of the tunnel and separate equipment takes care of the traffic in each of the two directions, thereby avoiding crowding at the entrances and exits. In the tunnel the traffic is handled through two tubes, each about 13 ft. 6 in. in diameter and 26 ft. on centers, which are located about 20 ft. below the bed of the river. The tunnel is about 1475 ft. long with the outlet shaft on the left bank at Steinwarder and that on the right at Saint Paul. These shafts are each about 72 ft. in diameter and the one at Saint-Paul was excavated entirely in open cut. The work on the left bank, however, required the use of compressed air.

When completed, the new London Building, which is being erected for the London and British North America Company will be among the finest buildings in Vancouver. This structure will have a frontage of fifty-two feet on the south side of Pender street, half way between Granville and Seymour streets, and will extend back 120 feet. It will be ten storeys in height with a full basement. The new building will be on a reinforced concrete construction throughout, and will be absolutely fireproof. One feature of the construction is that wherever possible, British or Canadian material is to be used. The front is to be completely faced with Haddington Island stone richly carved and surmounted by a cornice of the same material. The east, west and south sides are to be covered with hollow brick. The partitions are to be hollow clay tile and the floors in all the halls and corridors are to be of terrazza tiling with marble borders. On all the elevations, with the exception of the front, the windows will be of the self-closing metal variety, glazed with patent wire glass.

Erection Features of the Quebec Bridge

St. Lawrence Bridge Company's Elaborate Equipment—Erection Travellers—Systematic Method of Building Various Parts of the Structure.

THE new Quebec Bridge is located at Neilsonville, at the site of the old structure, which is about eight miles from Quebec. The bridge has a center span of 1,800 ft., consisting of a suspended span of 640 ft. and two cantilever arms of 580-ft. span each; two anchor arms of 515-ft. span each; and approach spans, the total length of the structure being 3,240 ft. The new bridge is much heavier than the old structure, which made it impossible to use the old piers. The new piers for the main span are each 67 ft. south of the location of the old piers. The bridge has a clearance of 150 feet above high water.

The new bridge was designed and is being constructed by the St. Lawrence Bridge Company, which was organized to build this structure. The designing office is in Montreal, and the bridge shop is about five miles from Montreal, being about one mile from the Dominion Bridge Company's plant at Lachine Locks. The capital stock of the St. Lawrence Bridge Company is held equally by those interested in the Dominion Bridge Company and in the Canadian Bridge Company, and many of the officers of the new company are former employees of the latter companies. The bridge shop of the St. Lawrence Bridge Company is a new structure, and was designed expressly to build the new bridge. It contains considerable special machinery designed to fabricate the large sections of the new structure. The plant was built at a cost of about $1,000,000, and must be paid for out of the profits of the new Quebec Bridge.

The St. Lawrence Bridge Company has an elaborate equipment at the bridge site. The various bridge sections are unloaded from the cars by means of a large traveling crane, and are transported to the bridge site over the company's system of tracks. There is now stored at the site a considerable amount of fabricated material, principally for the floor system. The piers and abutments are now completed and the approach spans are in place. For constructing the piers at the north end of the bridge an inclined railway was built on each side of the north abutment. The material for the piers was transported to the site, where it was transferred to the inclined railway, which in turn carried it to the location of the pier. The material was then picked up by derricks and set in place.

Each of the cantilever arms is to be erected as a separate structure, with its individual erection equipment. The center span, which will weigh about 6,000 tons, will be assembled on barges near the bank of the river. It then will be floated into position, and by hydraulic power will be raised to its final position in the structure.

Each erection traveler for the cantilever arms is constructed of steel and is about 200 feet in height. The traveler is carried by four trucks having six wheels each. At its base it spans two railroad tracks, on which are transported the cars containing the material for the bridge. The total weight of each of these travelers is about 840 tons, although an attempt was made to make this weight a minimum by constructing the crane girders which project over the traveler of nickel steel.

The hoisting equipment of each tower is both elaborate and diversified. On each of the four corners there is a 90-ft. 15-ton derrick, and on top of the traveler there are two traveling cranes, each crane carrying two 55-ton main hoists and two auxiliary gantry cranes. On each auxiliary gantry crane there are two 5-ton hoists. All motions are motor-driven, except the bridge travel of the auxiliary gantries. The main traveler will be moved along the cantilever arms by using, temporarily, two of the 50-h.p. motors of the 15-ton derricks. Table I shows the distribution and capacity of the motors for one traveler. It will be seen that 26 motors, with a total horsepower of 752, are used for hoisting operations.

On each side of the river, high tension hydro-electric power is stepped down by transformers, and is converted into 250-volt, direct current at two sub-stations, one on each side of the river. These sub-stations are supplied by separate systems, and are connected by submarine cables. Each sub-station is of sufficient capacity to operate all the motors on both sides of the river, including those required for the air compressors, which requires about 1,600 horse-power.

Direct current is used exclusively on the erection towers, as it affords better control than alternating current, and permits the ready employment of dynamic braking for the lowering machinery. The lowering of some of the heavy members used in the construction of the cantilevers would generate an excessive amount of heat in any type of friction or mechanical brake. By dynamic braking is meant that the motors are temporarily converted into generators during the lowering operations, the different speeds being obtained by inserting or removing a series of resistances. This enables most of the heat to be dissipated in a cast grid resistance, which is located in the base of the main traveler.

The returning effect of the dynamic braking action, as applied to the lowering of a load, exists practically only while the motor armature is rotated. It therefore requires a separate means to hold the load stationary. For this purpose a magnetic brake is placed on the armature shaft to lock the motor when the controller is brought to the "off" position. On some of the hoist motors safety devices are provided to stop the motor automatically if the operator should allow the load to over-travel. A large switchboard is installed in each main traveler, and numerous push buttons are located at points easily accessible to the operators, by which they can open or close the motor circuits.

The two main trusses are to be erected symmetrically on each side of the main traveler. It is planned first to erect the north anchor arm over falsework, using one of the travelers. After this arm has been erected the south anchor span will be erected by using the second traveler. At the same time that the south anchor arms is being erected the first traveler will be at work on the north cantilever arm, and this will be finished at about the same time that the south anchor arm is completed. The first traveler will then be taken down and reassembled at a point about two miles below the bridge site, where it will be used for erecting the suspended span on barges. In the meantime the

second traveler will be at work erecting the south cantilever arm, and it is planned to complete the erection of this arm and the suspended span (on barges) at the same time. The suspended span then will be transported to the bridge site and raised into place.

An operating platform will be built on each traveler at a height sufficient that a clear view can be secured of the material as it somes from the flat cars and is elevated into its final position. A house will be built in the center of this platform to protect the control apparatus, except that portion which is directly operated by the workmen—this will not be enclosed. Six men will be stationed on the operating platform and two men on each of the main cranes at the top of the traveler. To secure the proper co-operation between the widely separated workmen, a telephone system will be installed with a central switchboard and permanent connections with the shore. An electrically operated passenger elevator will serve the different levels of the traveler.

The following is a brief description of the method of erecting any typical part of the structure: The member first is brought beneath the traveler on flat cars, and is elevated and placed by two, or possibly four, of the 55-ton main hoists. The pin is then brought into position by one of the five-ton auxiliary hoists. A large ram for driving the pin is then brought into position by another five-ton auxiliary hoist, and the pin is driven into position.

It is expected that work can be prosecuted only for about eight months of the year. With this condition in mind it is expected that the bridge will be completed in 1918.—**Engineering and Contracting.**

Water purification at Albany, N.Y., where Hudson River water is passed through a sedimentation basin, preliminary filters, slow-sand filters and finally receives a dose of hypochlorites, cost $6.19 per million gallons, including pumping, during 1912, according to the report of Mr. J. B. Kilbourn, superintendent of the Bureau of Water. This cost is apportioned among the following items: Pumping, $3.19; sedimentation basin, $0.02; preliminary filters, $0.56; slow-sand filters, $1.15; laboratory, $0.61; hypochlorite, $0.35; superintendence, $0.31. During the year 7,600,456,000 gallons of water were treated. The average rate of filtration was 3,535,000 gal. per acre for slow sand and 81,000,000 gal. per acre for pre-filters.

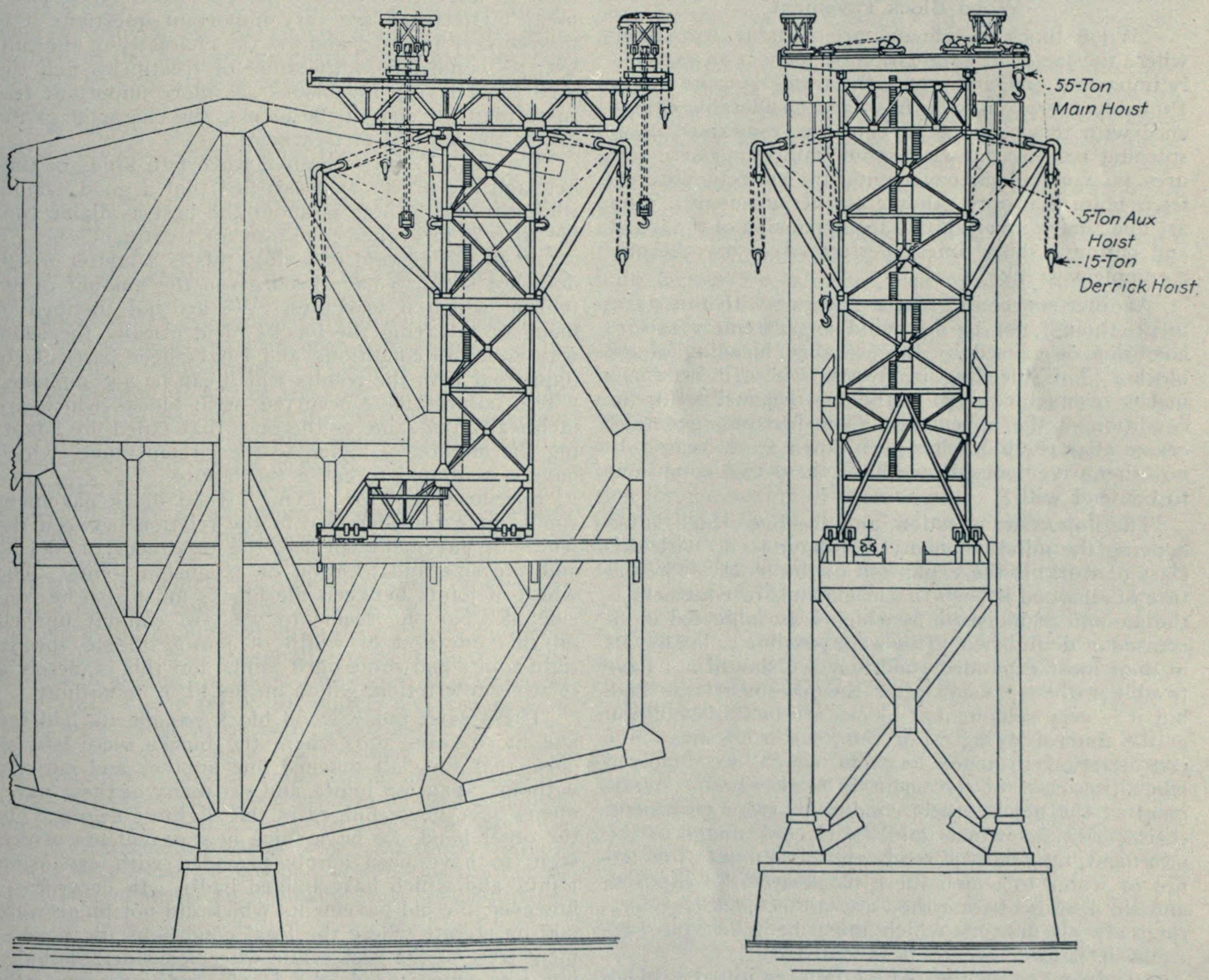


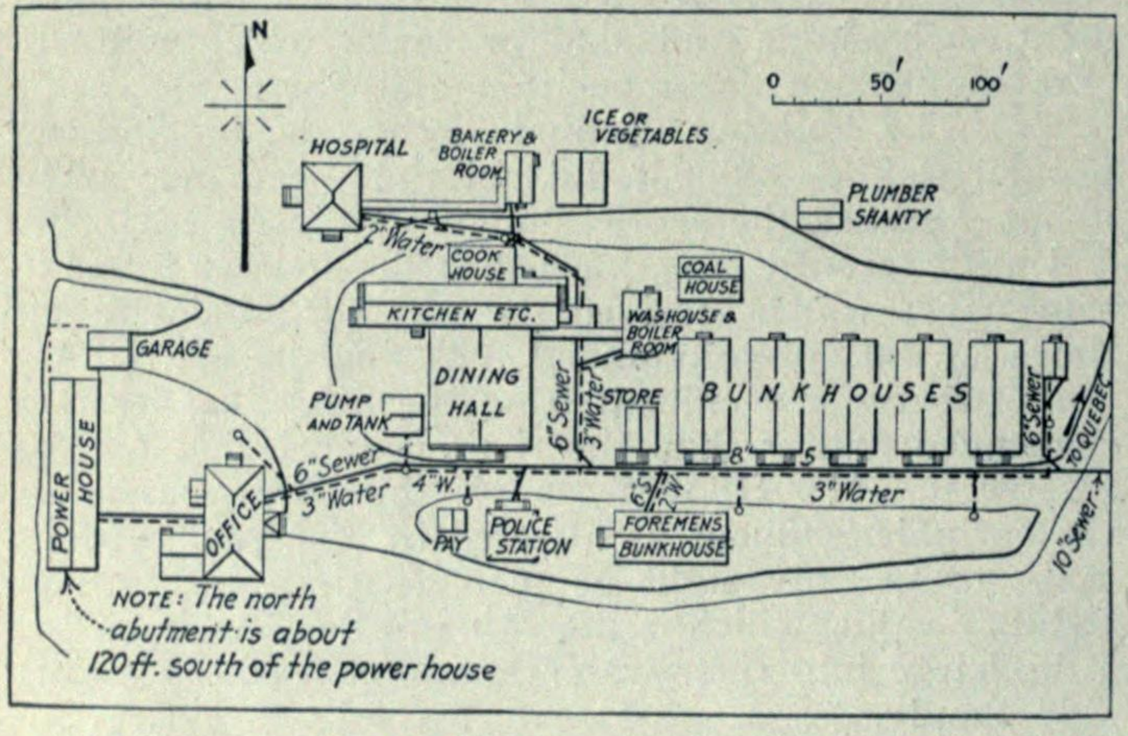
Fig. 1. Side and End elevations of erection traveller for new Quebec Bridge, showing type of Traveller and location of motor hoists.

and of nuisance caused by the generation of sulphureted hydrogen. If there were any need for further evidence, which in my opinion there is not, the Scioto River at Columbus again clearly indicates the objectionable result of sludge deposits. We can improve many of our rivers at and below cities discharging raw sewage into them, simply by removing the sludge deposits and getting clean bottoms, both near the shores and in the docks, as well as in the beds. I believe that in time river cleaning will be considered as desirable as street cleaning.

Columbus' experience once more verifies the opinion of many, that offensive odors do not arise from sewage-polluted rivers, if their water still contains residual oxygen, and that it is unnecessary to spend large sums of money to oxidize liquid sewage on land wherever it can be oxidized in running water in such manner that at no time and at no points the dissolved oxygen in the water will be depleted. The latter condition positively secures the absence of a nuisance, as evidenced not only at Columbus but at many other cities. The question of water-supply, of bathing, of fish life and of agriculture, where they arise, must be answered on a different basis from that of a nuisance.

Contractors' Camp for Workmen on the New Quebec Bridge

THE camp of the St. Lawrence Bridge Company, Limited, at Quebec Bridge, described by L. G. Jost in Engineering News, is situated near the north abutment of the bridge, on a natural plateau which slopes gradually toward the east. It is protected on the north by a wooded hill and on the east and south by a low ridge of rock. As the bridge site is about half a mile from the main road, three miles from a street-car line, and eight miles from Quebec, and as the housing facilities in the neighborhood were inadequate, it was necessary to build prac-



Lay-out of St. Lawrence Bridge Company's Camp at Quebec Bridge

tically a complete village. This was commenced in August, 1912, on land leased from the National Transcontinental Railway.

The plan gives a general layout of the camp, including the water-supply and sewerage systems.

There are five bunk houses, each 24 x 53 ft. in plan and comprising eight 10 x 10-ft. bedrooms and a 12 x 24-ft. sitting room in front. The inside partitions are of single sheathing 8 ft. high; each room contains two two-tier bunks. A large stove in the living room with a pipe running the full length of the building provides heat in winter. The bunk house of the foreman is similar but has nine smaller sleeping rooms and a bathroom.

The common toilet is at the east end of the camp, and is 11 x 18 ft. in plan with sloping concrete floor which may be hosed out. It contains two range closets; and the automatic flush tanks are kept warm in winter by coils from a jacket heater. The 17 x 30-ft. wash-house building contains 18 porcelain wash basins and six shower baths. At the rear is the boiler room with a low-pressure boiler from which housed pipes are run for heating the dining hall and kitchen.

The dining hall is a bright room 47 x 58 ft. in plan; the roof has a slope of 1 on 12, and is carried on six 15-in. 42-lb. I-beams resting on 8 x 8-in. posts on sides and center. It has a seating capacity for about 150 men.

The kitchen building is two storeys high, the upper being used as office and bedroom for the camp steward and quarters for the culinary staff. One end of the ground floor is a storehouse for dry groceries, while the other end is a cold storage room (heretofore cooled by ice, but now by an ammonia plant).

The cooking is done in an 18 x 30-ft. addition at the rear. The steam cooking utensils are operated by a high-pressure boiler in a house at the rear. This boiler also supplies heat for the hospital. The latter is a 24 x 28-ft. building and contains an office and bedroom for the resident physician, and one ward with bathroom, etc. It is intended only to administer first-aid treatment. All serious cases will be removed as soon as possible to the Quebec hospital.

The office building is a two-storey structure 28 x 53 ft., with a one-storey wing 20 x 20 ft. used as a draughting room. The interior of the building is sheathed. On the second floor there are seven bedrooms, a bathroom and a living room; in a small concrete cellar, there is a low-pressure steam boiler.

Other buildings not mentioned are a garage, a small pay shack, a general store, coal house, plumber's shanty, stable, police station, and bungalow for the superintendent and the engineer in charge of construction work.

Water is supplied to the camp by an artesian well. The water is pumped to a 10,000-gal. tank on a 40-ft. tower. Five 3-in. fire hydrants take care of the entire camp. At each hydrant is a small hose house containing two 50-ft. lengths of fire hose. The vitrified sewer mains range from 6 to 10 in. in diameter, and with the water line are buried about 2 ft. deep and follow the natural slope of the ground, which gives a gradient of from 3.5 to 0.5 ft. per 100. At the outlet the sewage runs into a 10 x 10-in. wooden chute and is carried over a bluff to a point below high-water level, some thousand feet downstream from the bridge.

The camp is lighted electrically by current transmitted from Quebec. Should this supply fail, the company's power house is able to carry the lighting load.

Substructure and Approach Spans Completed — Storage Yard and Contractor's Camp Established—Steel Received and Traveller Tower Erected

IMPORTANT progress has been made in the construction as well as in the design and fabrication of the $12,000,000 Quebec Bridge, and although the work is not yet imposing from the layman's standpoint, it has reached a stage and has included preliminaries that will permit rapid future progress. At the site the short approach spans and the difficult and costly superstructure for the main span have been completed, a camp established, contractor's yards laid out, plants installed and operations commenced in the storing of superstructure steel and the erection of traveller and falsework, thus providing for vigorous operation in the spring and for the erection of the main steelwork, which is now being fabricated and shipped to the site.

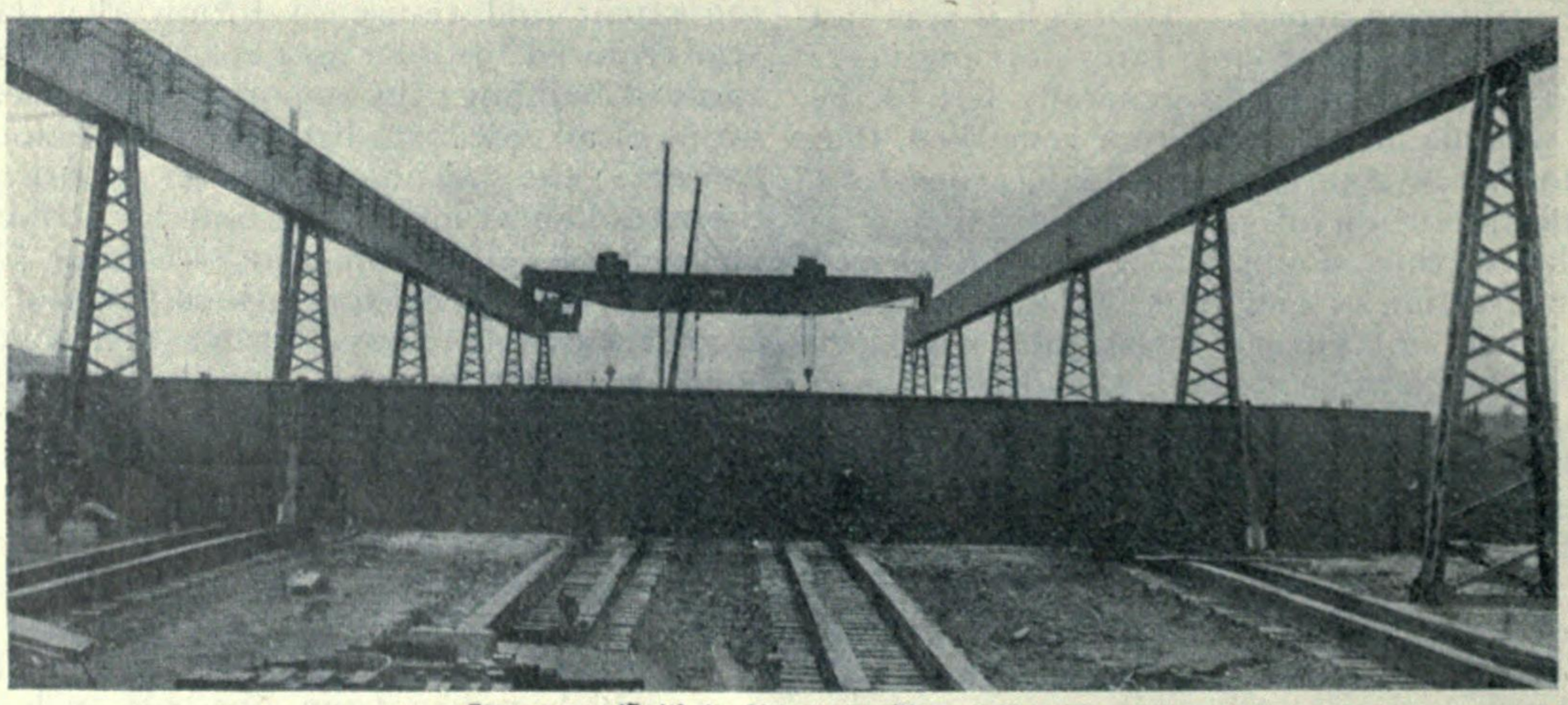
The two large main piers, located 1,800 ft. apart on the edges of the very deep-water channel, are of concrete construction with masonry facing and pneumatic-caisson foundations. The anchor piers, 2,830 ft. apart, are of similar construction, with foundations on solid rock above water level. They are a few feet eccentric from the old piers, so as to clear them instead of utilizing a portion of them, as was at one time intended. The old piers have been removed to low-water level, and part of the stone masonry contained in them has been used. The short approach spans at the north end of the bridge have been erected and standard-gage tracks on them connected with the railroad branch, so that material and equipment can be received and stored and the erection of the main spans can be undertaken as the falsework for the anchor arms is erected. The construction equipment is installed and the steel is at the site.

Erection will be commenced this spring at the north end of the bridge and at the south end next year, after which the work will progress simultaneously on both sides of the river until completion. At present the principal activities are on the north side of the river, but will be substantially duplicated on the south side in time to commence the erection there as soon as required by the programme of scheduled operations.

North Shore Plant

As the bridge site is in a rural district at considerable distance from towns large enough to provide convenient accommodations for the workmen, a construction camp has been established on the north shore to accommodate the erection force. Quarters have been provided for the engineers and other officers of the bridge commission and the contractors. The camp contains bunk houses with steam heat, electric lights and artesian water supply, besides which there are an office building, a commissary, kitchen, dining room, wash house, hospital, police station, repair shop and storage houses. Owing to the severity of the climate the working season for erection is limited to about six months, and the camp, which will be in service about four years, has been constructed with a view to durability and comfort for at least that length of time.

The power house is of fireproof construction and is equipped with four Ingersoll-Rand air compressors--



Storage yard with its 90-ton travelling girder crane.

one of which is intended to be kept in reserve—with a combined capacity of 2,000 cu. ft. of free air per minute. The compressing-current motors of 100 h.p. each, and two 250 kw. motor-generator sets are installed to reduce the 2,200-amp. current to 220 alternating current for the operation of the motors on the erection travellers. All of the principal installation is in duplicate and is proportioned so that there will always be a reserve.

The electric current is purchased by the contractor and is delivered on both sides of the river and connected by a cable across the channel so that either side may supply the other side. A duplicate plant will be established on the south shore of the river, thus providing for the eventual installation of four units, which, besides affording flexibility and reserve, were found to be cheaper than the installation of a single large plant with the required total capacity and excess.

The main travellers are each operated by mill-type General Electric motors. It is estimated that a total of about 500 h.p. on each side of the river will be required for all erection purposes when the work is in maximum progress, and that of this amount about 500 h.p. will be required to operate the air compressors which supply power for the pneumatic tools. Although a capacity of 800 h.p. is provided, it is expected that not more than 400 or 500 h.p. will be used at any one time.

Storage Yard

The storage yard is commanded by a two-trolley 90-ton girder crane of 81 ft. 3½-in. span, travelling on a runway 495 ft. long. The space commanded is crossed at one end by two standard-gage service tracks connecting with the bridge track and with the railroad branch. The remainder of the space between the runway girder is occupied by four full-length lines of double timber skids 4 ft. apart on centers, which have a capacity sufficient for the storage of all the steel required for either the anchor arm or the cantilever arm.

The girder crane and runway are substantially duplicates of those already installed in the storage yards of the fabrication shop in Montreal, and will eventually be removed there to supplement them. Excepting 33 ft. and 49½ ft. odd spans at the ends, the runway girders are 66 ft. long and are supported on battered steel columns 7 ft. wide transverse to the tracks at the base. Each column is made of four corner angles united by lattice angles and having the upper ends bent vertical and riveted between the inner faces of the double runway girders. The columns on one side of the runway are staggered with those on the opposite side so as to allow members longer than the width of runway to be moved to any position without turning.

Erection of one of the main travellers was commenced on shore at the north end of the bridge last fall and was completed to the top of the tower, a little beyond the point shown in the accompanying illustration, before work was suspended for the winter. The traveller, about 200 ft. high, has clearance between the trusses of the permanent structure and is of heavy riveted construction with a vertical tower of rectangular cross-section made with four vertical posts X-braced on all faces and horizontal bracing at each panel point.

The base of the tower is extended by trusses projecting from one side and is supported by four six-wheel trucks running on two 6½-ft. gage tracks. A pair of vertical trusses framed into the top of the tower cantilever 50 ft. front and rear, serve as runway girders for a pair of travelling cranes of 110 tons capacity with nickel-steel girders. These girders cantilever beyond both sides of the traveller so as to extend across the trusses and command them with their 55-ton trolley hoists.

The traveller weighs about 930 tons, or, with its full equipment, about 1000 tons. It will be provided with electric passenger elevator and hoisting apparatus. After erecting the falsework, the anchor arm and the cantilever arm on the north side of the river will be dismantled and reassembled at another site for the erection of the 640-ft. 5,000 ton center suspended span on shore falsework.

The fabrication of the 7,400 tons of steel in the floor system of the entire bridge and of the 1,400 tons of inside falsework and 470 tons of outside falsework for the north shore has been almost completed, and on February 1 about 8,000 tons of steel had been shipped to the site, besides 1,000 tons of floor system which had been completed and which are still stored at the fabricator's shops.

The work is under the direction of the board of engineers, of which C. N. Monsarrat is chairman and chief engineer. It is being executed by the St. Lawrence Bridge Company, of which Phelps Johnson is president and G. H. Duggan, chief engineer.

BRIDGE RIVETS OF UNUSUAL SIZE

Fabrication of the very large members of the new Quebec Bridge required the driving of numerous long carbon-steel rivets of large diameter, and unusual pains have been taken at the St. Lawrence Bridge Company's shop in their perfection and in the demonstration of the results obtained in driving them. Satisfactory results are reported to have been secured for the 1⅛-in. iron rivets in the pedestals under the main vertical posts. These rivets have a 9-in. grip and are 12 in. long before driving, thus requiring great efficiency in the machine and making it a difficult and costly matter to attempt cutting out and redriving, so that it is essential that they should be satisfactory at the outset.

The requirements are for the rivets to be driven at a cherry red. The cylindrical holes are drilled or reamed to a uniform diameter and the rivets are tapered about 1-32 in. in 12 in. from the end near the first head so as to completely fill the hole there when inserted. The points are chilled by being dipped in water before driving, thus tending to increase the upset in the middle of the shank, and the first heads are made long, affording a sufficient excess of metal to insure the formation of a 1-16 to 3-16 in. burr next the metal.

These rivets are driven as fast as those driven at a much higher temperature, and are not subjected to as much stretching by the springing of the riveted plates as when rivets are hotter. The driving has been so successful that practically no rivets have been condemned and cut out. Heating the rivets to a very high temperature for driving is objectionable on account of the scale that is formed and because the metal is then too soft to transmit the compression and produce a sufficient upset a long distance from the driven head.

The shop rivets are driven with pneumatic yoke machines and the field rivets will be driven with pneumatic guns and special pneumatic buckers-up having a pneumatic hammer contained in the plunger and

operated during the first part of the driving. The plunger is controlled by a special valve, which first sets it up against the riveted member and maintains the pressure, after which the hammer may be simultaneously operated until the rivet is nearly driven from the opposite end, when this hammer is stopped and the static pressure continued until the driving is completed by the gun.

Specimen 1⅛-in. rivets 12 in. long were driven through several plates by the 80 and 100-ton yoke machines and by the pneumatic hammers. Afterward the plates were planed apart through the center line of rivets and those driven by the pneumatic hammers were found to be as good as those driven by the yoke machines and almost indistinguishable from them, all of the rivet holes being completely filled.

PRELIMINARIES TO ERECTING A GREAT BRIDGE

In this country where the shop fabrication of steel bridges is highly developed, where facility of erection is recognized as an important element of design and where extensive equipment is devoted to the erection of the superstructure, the field work on even very large spans is so rapid that it is generally measured by weeks or months and seldom, except for the very largest spans, involves very remarkable plant or is far removed from the commonplace. In notable contrast to this almost routine work is the erection of the Qeubec Bridge, the greatest span in the world. Over 60,000 tons of steel are to be assembled in three spans, of a combined length of 2,830 ft., 150 ft. above the water. The river is 200 ft. deep, with a tide of 15 ft. and a current of 8 miles. Pieces weighing 185 tons and compound members nearly 300 ft. long, weighing more than 1,200 tons, are to be handled in mid-air and assembled and maintained with precision. Two cantilever arms must be built out self-supporting for 580 ft. beyond their piers and remain exposed for months to the severest storms and a 640-ft. double track 5,000 ton railroad span must be built at a distance, floated to the site, raised 150 ft. and connected to them with great speed and accuracy.

It is expected that all this can be accomplished in four years of elapsed time, or less than half as much working time, since work must be discontinued during the long and severe winters. To do this, elaborate provision is now being made for all the construction operations, the schedule is prepared for the successive steps and the details of operations are being minutely worked out, instructions prepared and machinery, tools, supplies and every needed facility provided in advance, due regard being had for the utilization of certain parts of the equipment repeatedly to avoid unnecessary duplication. Even with this care the cost of installation of the whole erection equipment will considerably exceed $500,000, exclusive of maintenance, supplies and labor, so that the total erection expense reaches thousands of dollars a day for the actual working time.

The structural steel in the falsework, travellers and yard equipment for temporary work will be about 4,000 tons; two 800 h.p. electric power plants and two sets of air compressors will be required; two 1,000-ton steel tower-travellers, 200 ft. high, must be erected and equipped, and a massive steel falsework, more than equivalent to permament railroad viaducts, must be built not only for the temporary support of the permanent trusses, but also for the separate support of the great travellers. Barges and falsework must be built for the 640-ft. span, and special hydraulic apparatus provided for lifting it to place. Provision must also be made for the maintenance of a large force of men at the site.—Engineering Record.

THE civic investigation, now closed, into the cause of the break of Montreal's water conduit was characterized by a remarkable divergence of opinion between experts. Broadly speaking, the experts were divided into two camps, one attributing the accident to the poor design of the conduit, and the other to the excavation of earth in the widening of the aqueduct, thus undermining the conduit. Messrs. Jamieson, Lea and Heckle, the engineers who reported on the break for the city, gave evidence to the effect that the conduit failed to stand the conditions for which it had been designed; the concrete was good, but the metal reinforcement was not strong enough. It was admitted, however, that the excavation of the earth was a contributing cause to the break. Opposed to the views of the above experts, which was supported by the evidence of others, were the opinions of Col. H. R. Lordly, chief engineer of the Lachine Canal, Mr. G. Janin, and others. Their evidences went to show that the break was due to the excavation on the aqueduct side, making an unbalanced load. The use of the drag line excavator was also criticised, it being further declared that the design of the conduit was good. Mr. M. J. Butler, president of the Canadian Society of Civil Engineers, and head of the Armstrong Whitworth Company of Canada, expressed the opinion that the excavation could have been done safely by building a retaining wall in short sections, as the excavation proceeded. The wall should have been built especially opposite to such places where the conduit was too close.

Grading has been started on the last section of the Canadian Northern Pacific Railway on the mainland of British Columbia. According to a statement made a few days ago by Mr. S. H. Sykes, assistant chief engineer, the entire line will probably be ready for the rails next july. About sixty per cent. of the grading has been done on the twenty-mile section west of Albredo Summit, and track laying will be commenced from the present end of steel ten miles west of the Yellow Head Pass, early next month. Between the present completed sections of the line several bridges are now under construction.

The salary of Mr. Alfred Craven, Chief Engineer of the Public Service Commission, First District, New York City, has been raised from $15,000 to $20,000 per annum, making his salary the highest of any engineer in the service of New York City or the State. In the capacity of chief engineer of the commission Mr. Craven has charge of all the work of the dual subway and transit system now under construction, involving the expenditure of $167,000,000.

A deputation of about two thousand from Western Ontario waited upon the Premier and the Cabinet at Ottawa a few days ago to urge upon the Government the necessity of proceeding immediately with the deepening of the St. Lawrence River, to make an ocean waterway. The deputation also urged that the projected 6,400 miles of Hydro Radial lines in Ontario should receive the same government subsidy that other railways on the continent received.

The Quebec Bridge Anchor-Arm Spans

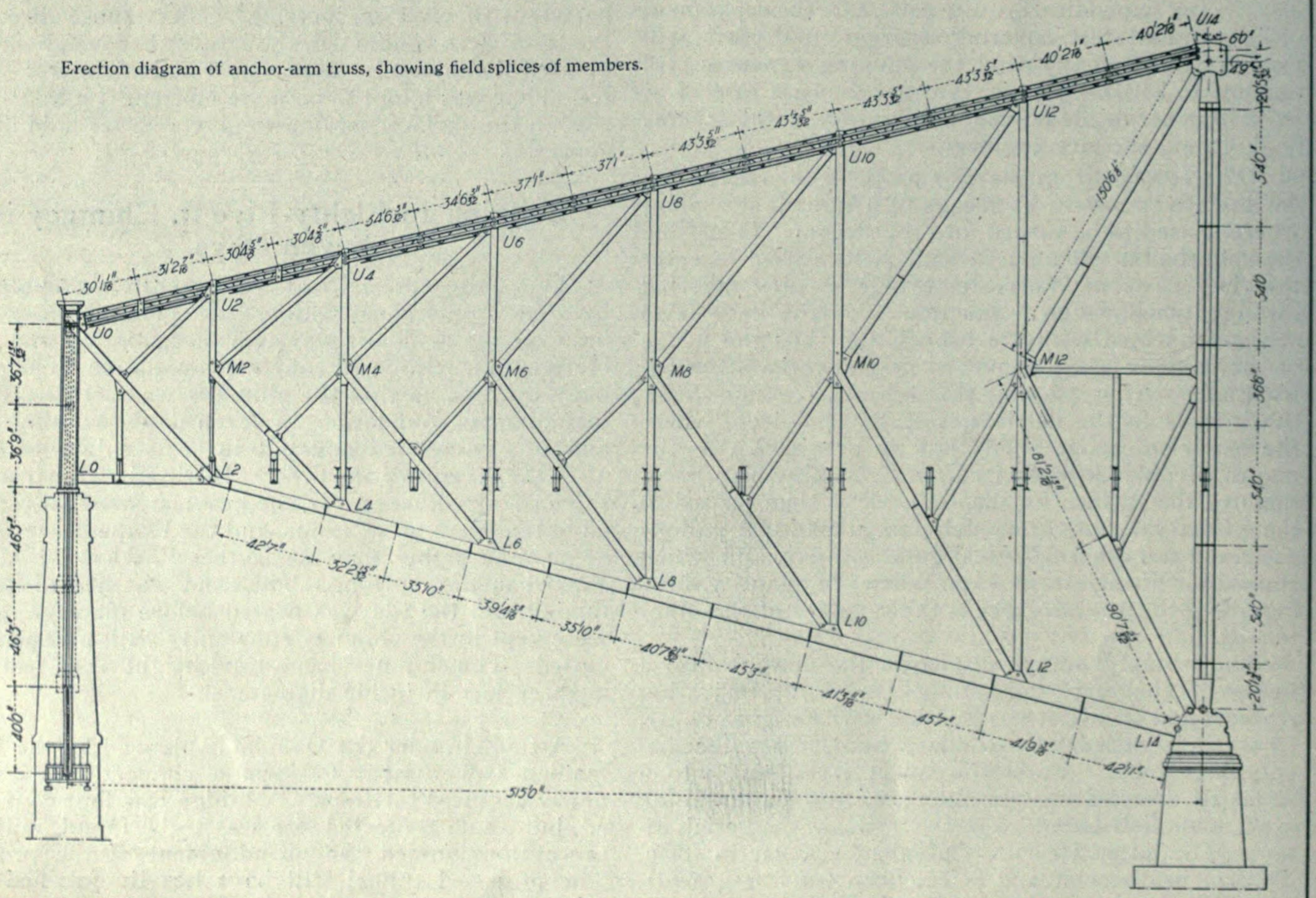
Important Developments in Main Trusses, Bracing, Twin Tension and Compression Members, Multiple-Pin Connections and Field-Spliced Shipping Units

IMPORTANT modifications in both type and details of long-span steel-bridge construction have been developed in the 2,830-ft. double-track Quebec Bridge. Many of them appear in the anchor arms and are described in this article. The type of main-truss bracing is special. The usual top lateral system is eliminated. The extraordinary dimensions and great weight of the truss members necessitate shipping some of them in sections, afterward united by field splices to make the panel units. Auxiliary trusses have been provided to support long flexible members, main panel-point connections have been made with multiple pins, and special connection pieces have been introduced at important panel points. Transverse and longitudinal girders in the floor system have dimensions comparable with large plate-girder spans. Deep transverse latticed traction girders have been introduced between the trusses in diagonal planes.

The anchor-arm spans, each 515 ft. long and 310 ft. deep on centers at the main posts, have two pin-connected trusses 88 ft. apart, and weigh 16,600 tons each, exclusive of the steel in the anchor piers, but inclusive of the 2,700-ton main vertical posts and their 900-ton bearings, which are common members in them and in the cantilever arms. The trusses are each proportioned for a live load of two E-60 locomotives followed, preceded or followed and preceded by a train load of 5,000 lb. per linear foot. They are made entirely of carbon steel, with the exception of the end diagonals L_2U_0 and the connection details at L_2 and at U_{14}, which are made of nickel steel.

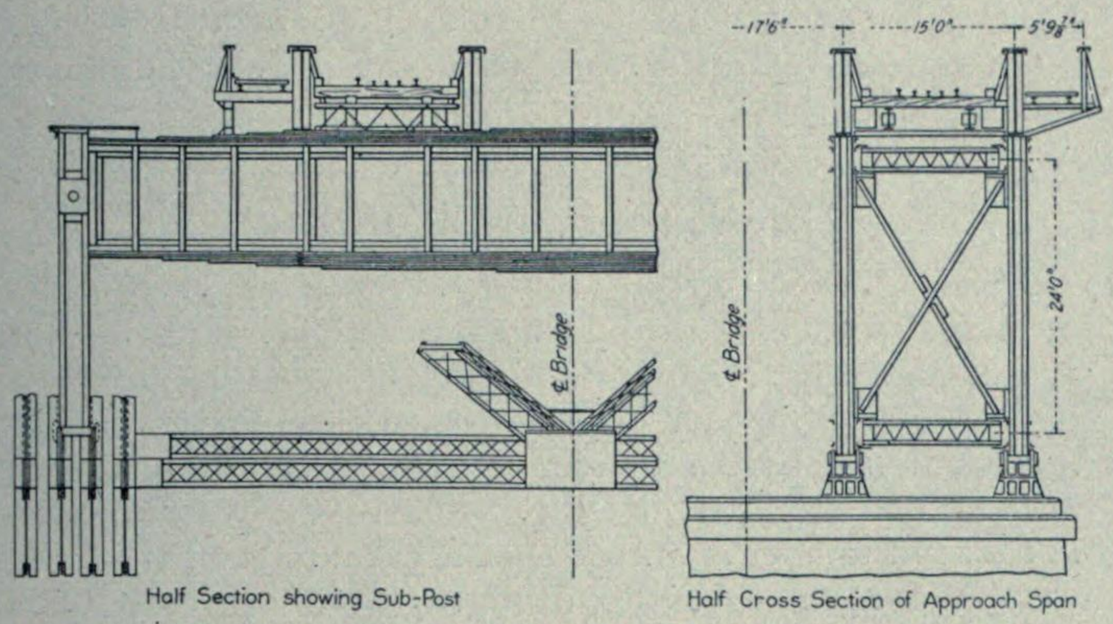
The web members of the trusses are arranged to make a K-shaped type of bracing, and all carry both dead and live loads, except the horizontal members in the center of the panels adjacent to the main posts on the cantilever side, and the trusses supporting the top-chord eyebars. The chords are in straight lines. None of the principal stresses are indeterminate. The long double-hop-chord eyebars are supported at the center of each panel on special lattice girders connected to the tops of the vertical posts. The 7 x 10-ft. bottom chords are made of four built I-beam ribs laced together, and with horizontal bracing on the center line, the webs being held in place by transverse diaphragms. The principal compression members have intermediate field-riveted transverse splices, and in some of them the sections between these splices are made of two pieces shipped separately. All web members are made up of plates and angles and are pin-connected at their intersections. At the main panel points the web members are connected by pins through gusset plates riveted to the bottom chords.

Erection diagram of anchor-arm truss, showing field splices of members.



independent connections being thus provided for each member.

Some of these features are of special interest in comparison with the 500-ft. anchor-arm spans of the original Quebec Bridge. The trusses of the latter were 315 ft. high and 57 ft. apart and weighed 6,250 tons for each span, exclusive of the 700-ton floor system. Both top and bottom chords were parabolic curves, and the trusses were divided into 100-ft. main panels and 50-ft. sub-panels. The types of truss, secondary bracing systems, top-chord and web-member



Part sectional elevations of anchor-arm and end spans.

design and floor system conformed in general to standards for ordinarily long spans. The bottom chords were made of four built channels having their flanges connected by tieplates and lattice angles. They were about 4½ ft. deep and 5½ ft. wide, with a maximum cross-sectional area of 776 sq. in., as compared with a maximum area of 1,902 sq. in. in the present structure. The heaviest chord piece, 65½ ft. long, weighed 165,000 lb.

Secondary Bracing and End Anchorage

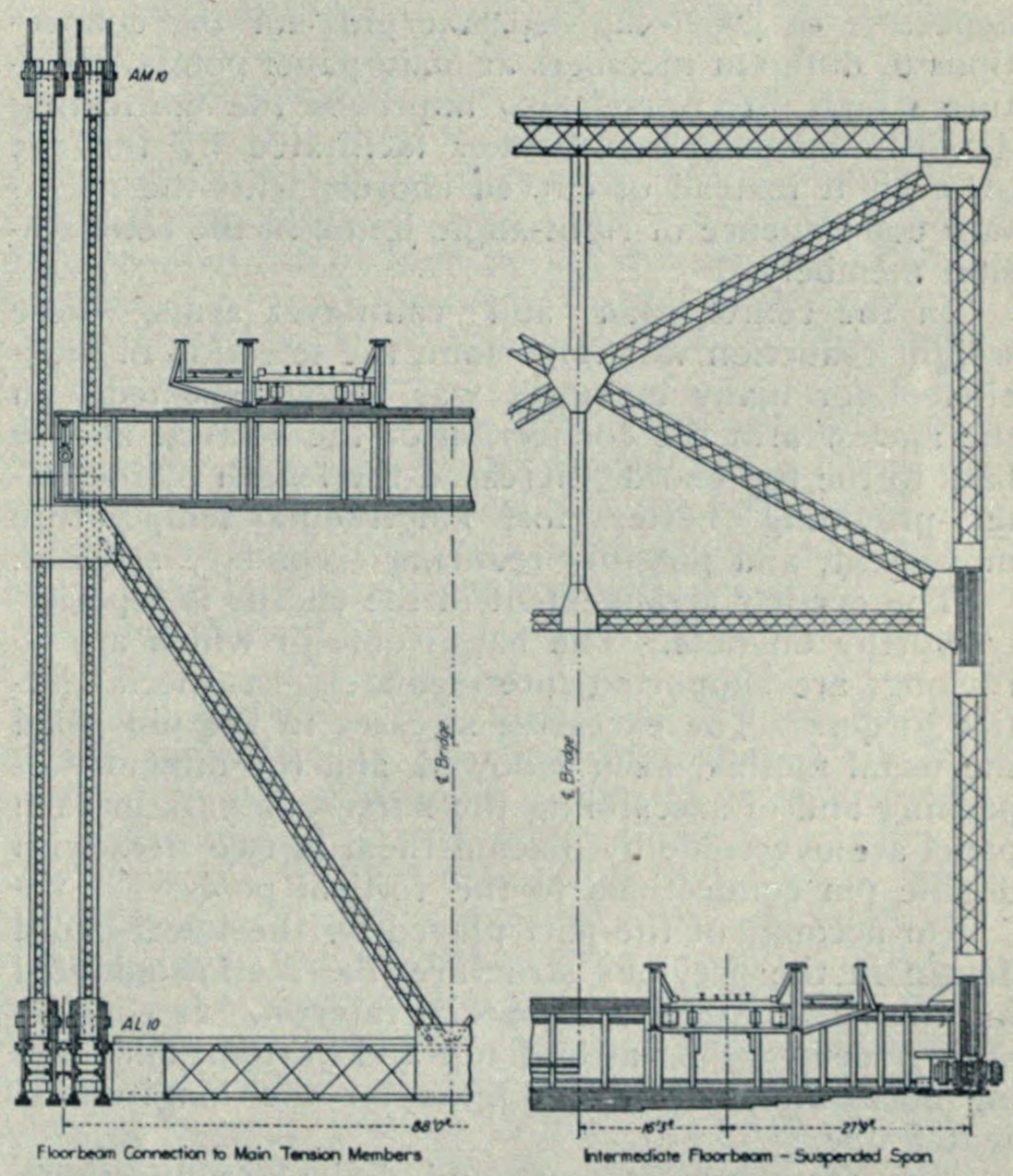
The system of transverse bracing in the anchor and cantilever arms of the present bridge is unusual in that it does not require top laterals. The trusses are connected by transverse sway bracing in the planes of the upper sections of the vertical members and in the lower sections of the inclined members, thus transmitting all transverse stresses directly to the X-braced bottom lateral system in the plane of the lower chords. There are horizontal transverse braces at the top and bottom chord panel points which, like the diagonals and bottom laterals, have rectangular cross-sections made of four large corner angles latticed together with diagonal angles. All of the bottom lateral diagonals are tapered to correspond with the varying depth of the lower chord.

As all floorbeams are located at a considerable height above the bottom chords, the vertical transverse panels under them are braced by diagonal struts reaching from the ends of the floorbeams to the centers of the bottom horizontal transverse struts. The diagonal braces between the upper parts of the vertical posts are connected at their intersections to short vertical members supporting the horizontal transverse struts below them.

The upper part of the masonry in the shore pier, together with the structural steel inclosed in it, is designed to resist a maximum vertical uplift assumed to be 8,000,000 lb. for each truss under extreme conditions. This is provided for by two sets of vertical eyebars connected to the ends of the top chords at U_0. These eyebars have a combined length of about 206 ft. from their connection with the truss to their connection with the reaction girders. Of this distance 89½ ft. are in an open well in the masonry, which, added to 77 ft. from the top of the masonry to the top of the truss, gives a length of 165½ ft. that is free to move longitudinally in accordance with temperature expansion without disturbing the 40-ft. lower section of bars concreted solidly in position. The lower ends of the anchor eyebars are pin-connected to transverse distributing girders, forming part of the reaction platform, built into the lower part of the pier masonry.

The bridge has a clear height of 150 ft. above extreme high water. The floor is level on the center span and has a 1-per cent. grade on the anchor and cantilever arms. The lower chord is level with the floor at the anchor piers and about 110 ft. below it at the river piers. The floorbeams are therefore connected to the trusses in relatively different positions, which govern their type and the manner of connection. At panel points L_1 and L_2, nearest the anchor pier, the floorbeams are field-riveted through connection angles. Floorbeam L_1 supported by a riveted vertical member pin-connected to the end diagonal $U_0 L_2$. Floorbeam L_2 is connected to the lower chord. All other floorbeams are connected to the web members of the trusses by 11-in. pins in 15-in. steel bushings.

At the main panel points 4, 6, 8, 10 and 12 the double floorbeams are made of duplicate girders, one on each side of the vertical hangers, to which they are connected by a common pin. At the main vertical post L_{14}-U_{14} the floorbeam is a single-web girder in the center plane of the post and passes between the duplicate halves of the post, being connected to them by a single pin at each end. The remaining floorbeams at the intermediate panel points 3, 5, 7, 9, 11 and 13 are single-web girders connected to short vertical members from the intersections of the main and sub-diagonals in each panel. At the shore end of the span the floorbeams are located below the intersections of the sub-diagonals and the vertical tension members. At the river end the floorbeams are above their inter-



Half cross-sections of anchor-arm and centre spans.

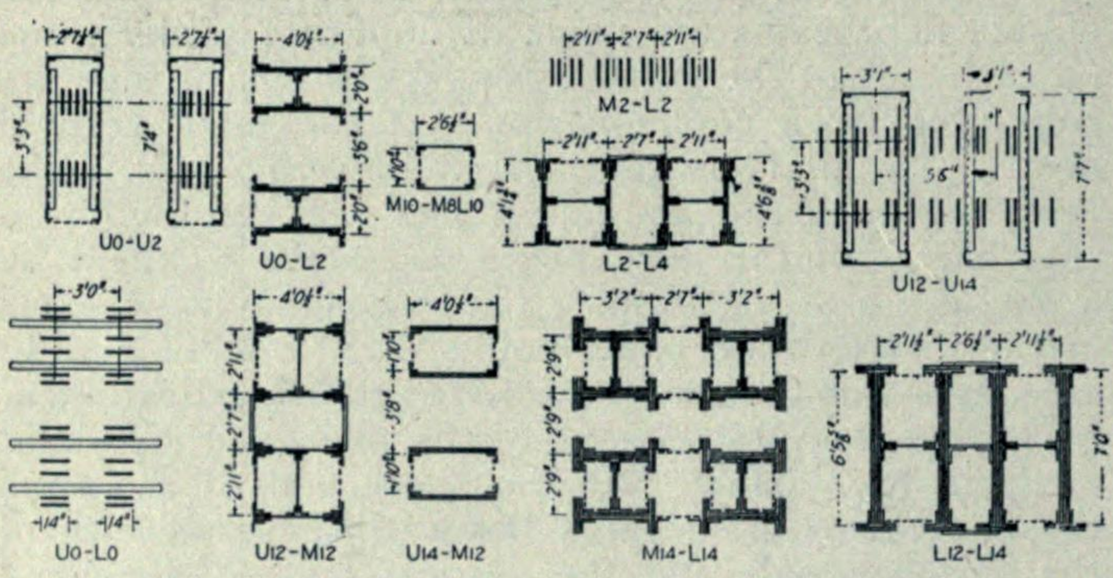
sections and the sub-verticals are compression members with pin connections to the diagonals.

The bridge is designed and constructed subject to the approval of the Board of Engineers, consisting of C. N. Monsarrat, chairman and chief engineer, and Ralph Modjeski and C. C. Schneider. It is being fabricated and erected by the St. Lawrence Bridge Company, Limited, of which Phelps Johnson is president; G. H. Duggan, chief engineer; W. P. Ladd, shop superintendent; G. F. Porter, engineer of construction; S. P. Mitchell, consulting engineer of erection, and W. B. Fortune, erection superintendent.

Important Features of the New Quebec Bridge

The design of the new Quebec Bridge, as was expected, embodies not only a number of important features developed in the largest spans previously built but also some new ones of a radical character. This statement applies to both the main 1,800-ft. span and to the 515-ft. anchor arms.

In the general truss design, the K-shape bracing has important advantages in distributing the shear between two members in each panel, thereby reducing the sizes of the members, simplifying the connections and facilitating field assembling. A decided advantage in erection, too, is found in the very interesting



Typical cross-sections of principal anchor-arm truss members.

departure of providing separate pins for the connections of different members at main panel points, a feature which, of course, also improves the fabricating details. Shopwork is further facilitated by the use of straight instead of curved chords, with the necessary consequence of right-angle joints in the compression members.

In the center span and cantilever arms, where weight reduction was important, the selection of nickel-steel for many members was to be expected. In the anchor arm the connection of the vertical anchor bars to the top chords increased the length of the latter, providing better for longitudinal temperature movement, and possibly reducing secondary stresses.

The eye-bar arrangement in the chords is especially worthy on note. The bars, some of which are 85 ft. long, are supported intermediately by special lattice girders. The excessive stresses in the pins, had the usual method been followed, and the difficulty of packing and of assembling the numerous bars in each panel are overcome by placing them in two tiers with double pin connections to the vertical posts.

On account of the part played by the lower-chord design in the previous structure, the section adopted for the new bridge is of special interest. It consists of four deep webs, latticed top and bottom, and having horizontal plate diaphragms on the longitudinal center line.

The secondary stresses and difficult connections, due to the riveted joints at the ends of the enormous single and double-web floorbeams, have been avoided by pin-connecting them to the vertical members. Symmetrical loading is obtained by placing the double webs between the double webs of the hangers. All pins subject to turning have full-length bushings. All transverse forces have been concentrated in the planes of the lower chords by the elimination of the top chord lateral system and by the combination of vertical and inclined sway-braced system transmitting the horizontal forces directly to the bottom-chord panel points.

These and other special features indicate the substantial progress that has been made in this design and suggest the direction in which future advances will be made.

Day Labor and Contract

"Saving the contractor's profit" by carrying out a municipal undertaking by day labor is often an expensive proceeding, comments Engineering and Contracting. A Pacific Coast city projecting extensive harbor developments began deepening the waterway with a municipally operated dredge. The result was unsatisfactory; in fact, it is stated that a good part of the fund was used up before the dredging had scarcely been started. The same city also undertook to construct a bridge by day labor. It is reported that this structure cost $50,000 more than it would if the work had been done by contract. These unfortunate happenings have had one good effect, for the advisory committee in charge of improving the water system has recommended that this improvement be carried out by contract. Experience is a good teacher; so is common sense. By a judicious use of the latter almost any city councilman should be able to see the fallacy of the day labor system of doing public work.

One of the more recent apartment operations in the city of Chicago affords a fair illustration of the way modern builders and architects are treating the housing question. It in reality is four separate buildings occupying an area 150 feet square and will contain 15 apartments of from five to ten rooms, each suite having an individual sun parlor, sleeping porch and a bath attached to every bedroom. The buildings which surround a terraced court centered with a fountain, have an underground tunnel for service and public utility piping. The architecture is in the English Tudor style, the facades being dark red brick with terra cotta trimmings topped by a roof of harmoniously colored slate.

The chief of architecture of the Panama-Pacific International Exposition has approved the design for the Grand Trunk's building, and construction will proceed immediately. This is the first of the Canadian buildings to be erected, and sets the general style for the whole Canadian group. It will contain 10,000 feet of floor space and will be occupied by an extensive and valuable exhibition of Canada's resources. Its location is in one of the best parts of the exposition grounds, and the style of architecture will be that of the Spanish renaissance.

Powder charges used in grading work on the Canadian Northern Railway in British Columbia are said to have given best results when varied from a minimum of ½ lb. of powder per cubic yard of shale to a maximum of 1½ lb. per cubic yard of hardest country rock.

adam and soft roads including gravel and earth, the gravel sometimes being worthy of a place in the first classification. The material to be selected will depend upon the kind of road to be treated. Brick and concrete roads will be maintained in a comparatively dustless condition by rain water and need not be considered further. The most satisfactory method of treating macadam is by a surface treatment of hot asphaltic oil or refined tar covered with gravel, slag or stone chips. Other things being equal, this method is recommended in preference to cold treatments with lighter oils and tars, for although these are applied at a much less cost the results are not so lasting. If, however, the road cannot be cleaned so as to expose the large stones in the surface the lighter oils and tars are likely to give the better results. Provided both are of suitable grade and of good quality, there is not much preference between oil and tar of this class of work. A good tar is preferable to a greasy paraffin oil, and a good asphaltic oil is far better than a poorly prepared or high temperature tar. Gravel roads have been treated with both oil and tar, but more generally with the former. In the case of a good, hard gravel road, practically the same treatment as recommended for macadam may be applied. The cold surface treatment has been used to a greater extent than the hot treatment for this type of road, and Glutrin has also been used to some extent.

It may be said in conclusion that it is essential to give careful consideration to all local conditions governing the selection of proper material and the proper method of application. Care must also be taken to secure good quality in the material which is selected, which means that the material should be examined and tested. It is also important that the treatment should be renewed as soon as the condition of the road demands it, if it is desired to maintain the road in good condition and free from dust.

Quebec Bridge Anchor Arm Diagonal and Posts

Description of Largest Web Members of 515-Foot Trusses, Which are Erected in Several Units

THE principal web members of the 515-ft. anchor arm trusses of the Quebec Bridge are all of unusual length and weight, reaching or approaching the limits of transportation and, whether for compression or tension stresses, are of rivetted construction. Most of them are designed with four webs of built channel or I-beam section which are strengthened by longitudinal and transverse diaphragms, the flanges being connected by tie-plates and latticing. The largest intermediate post of all, L12-U12, and the two adjacent diagonal members M12-U14 and M12-L14 have four webs and are shipped and erected in halves. The tension diagonal M12-U14 is shipped and erected in halves which, after erection, are connected by three tie-plates, in order to keep the member as a whole in line. All pins are finished to an accuracy of 1/1000 in., pin holes being bored 1/32 in. + 1/100 in. larger than their pins.

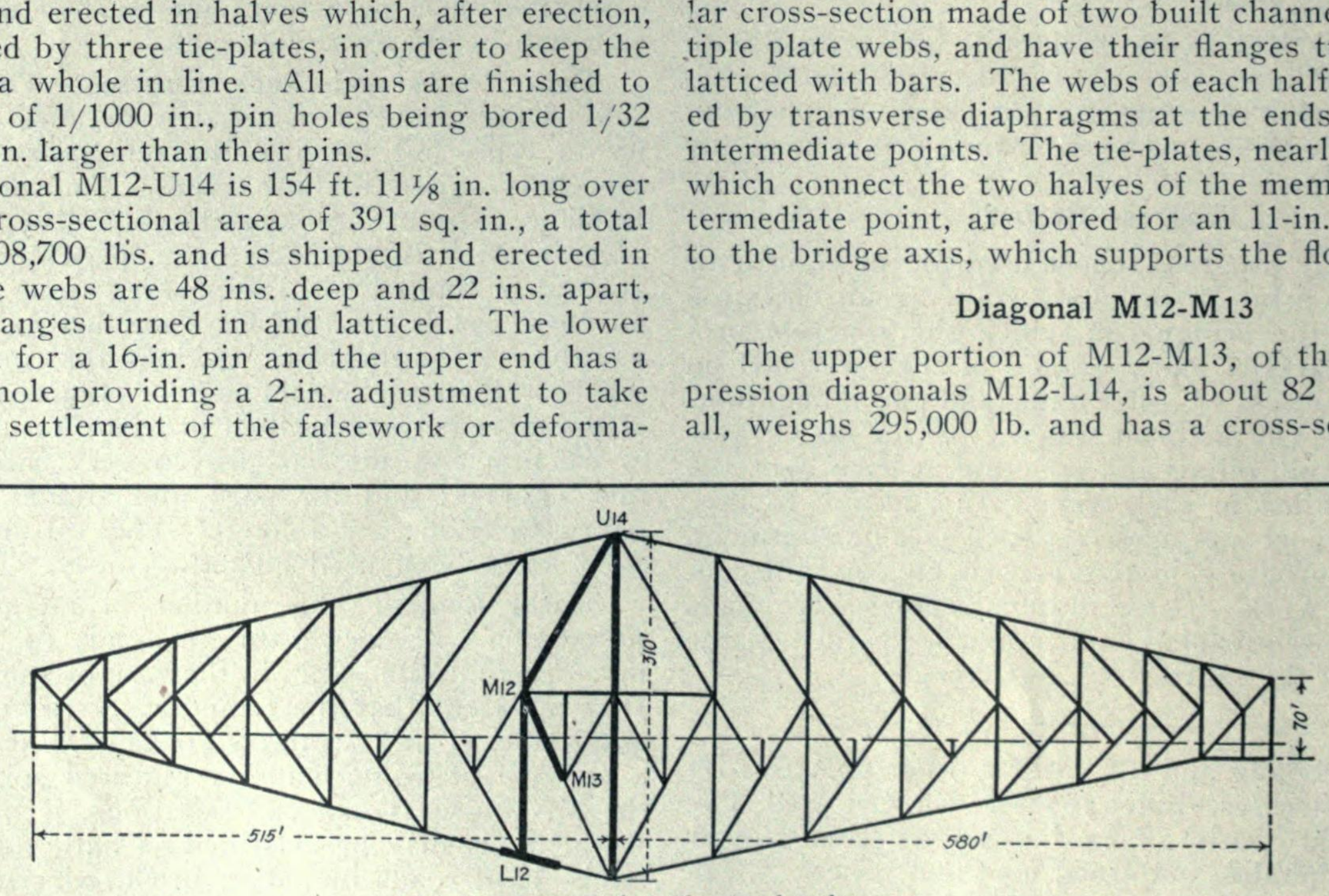
The diagonal M12-U14 is 154 ft. 11⅛ in. long over all, has a cross-sectional area of 391 sq. in., a total weight of 308,700 lbs. and is shipped and erected in halves. The webs are 48 ins. deep and 22 ins. apart, with their flanges turned in and latticed. The lower end is bored for a 16-in. pin and the upper end has a 16 x 18-in. hole providing a 2-in. adjustment to take care of any settlement of the falsework or deformation of the members under their own weight during erection. Each half of the member weighs 154,300 lbs. and will be shipped in two parts, but will be field rivetted before being erected.

Vertical Member L12-M12

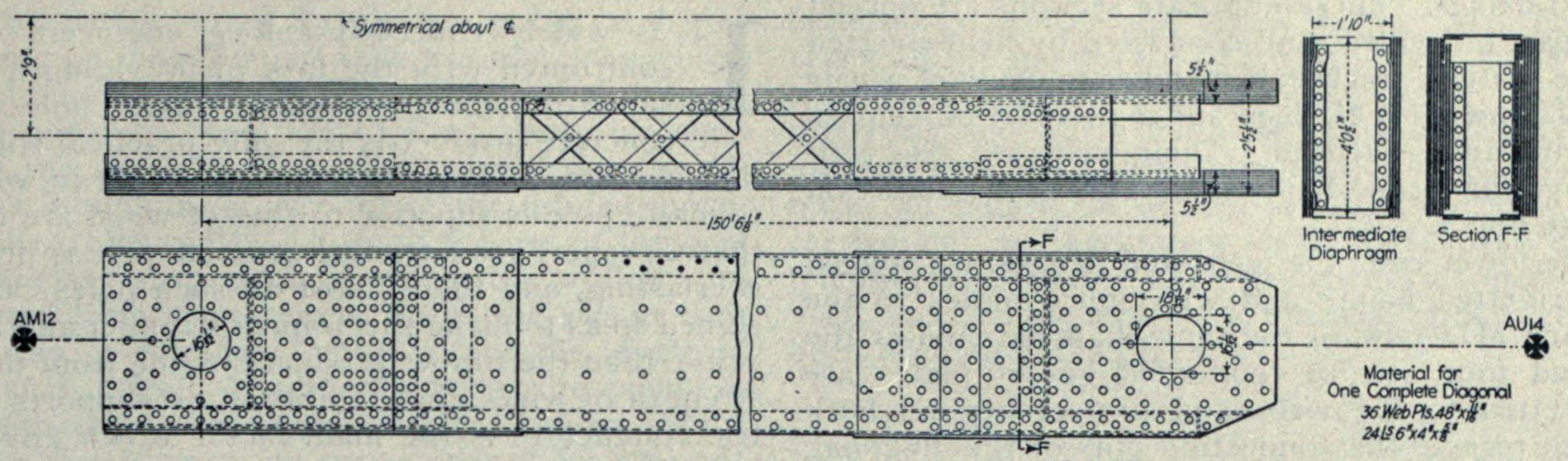
The lower half of L12-M12 of the vertical tension member at panel point 12, is 130 ft. 8 1/16 in. long over all, weighs 232,000 lbs. and has a cross-sectional area of 373 sq. ins. Each half is symmetrical about the axis and will be shipped separately and field rivetted together with idaphragms and tie-plates. The halves, 5½ ft. apart on centres, each have a 2 x 4-ft. rectangular cross-section made of two built channels with multiple plate webs, and have their flanges turned in and latticed with bars. The webs of each half are connected by transverse diaphragms at the ends and at four intermediate points. The tie-plates, nearly 12 ft. long, which connect the two halves of the member at an intermediate point, are bored for an 11-in. pin parallel to the bridge axis, which supports the floorbeams.

Diagonal M12-M13

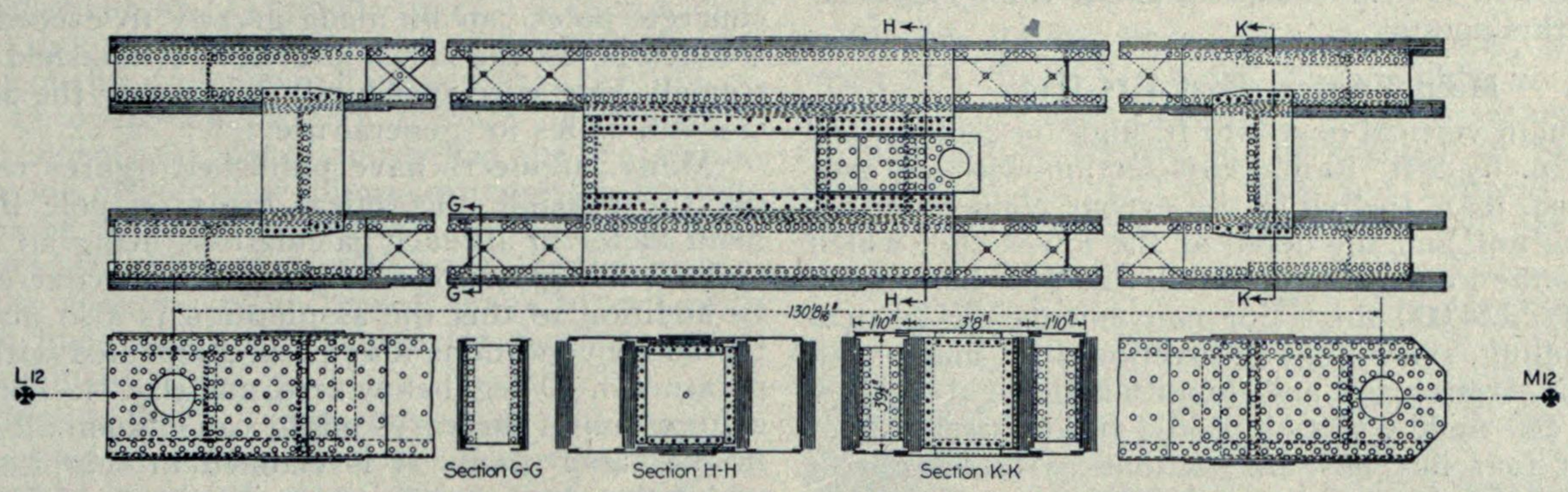
The upper portion of M12-M13, of the main compression diagonals M12-L14, is about 82 ft. long over all, weighs 295,000 lb. and has a cross-sectional area



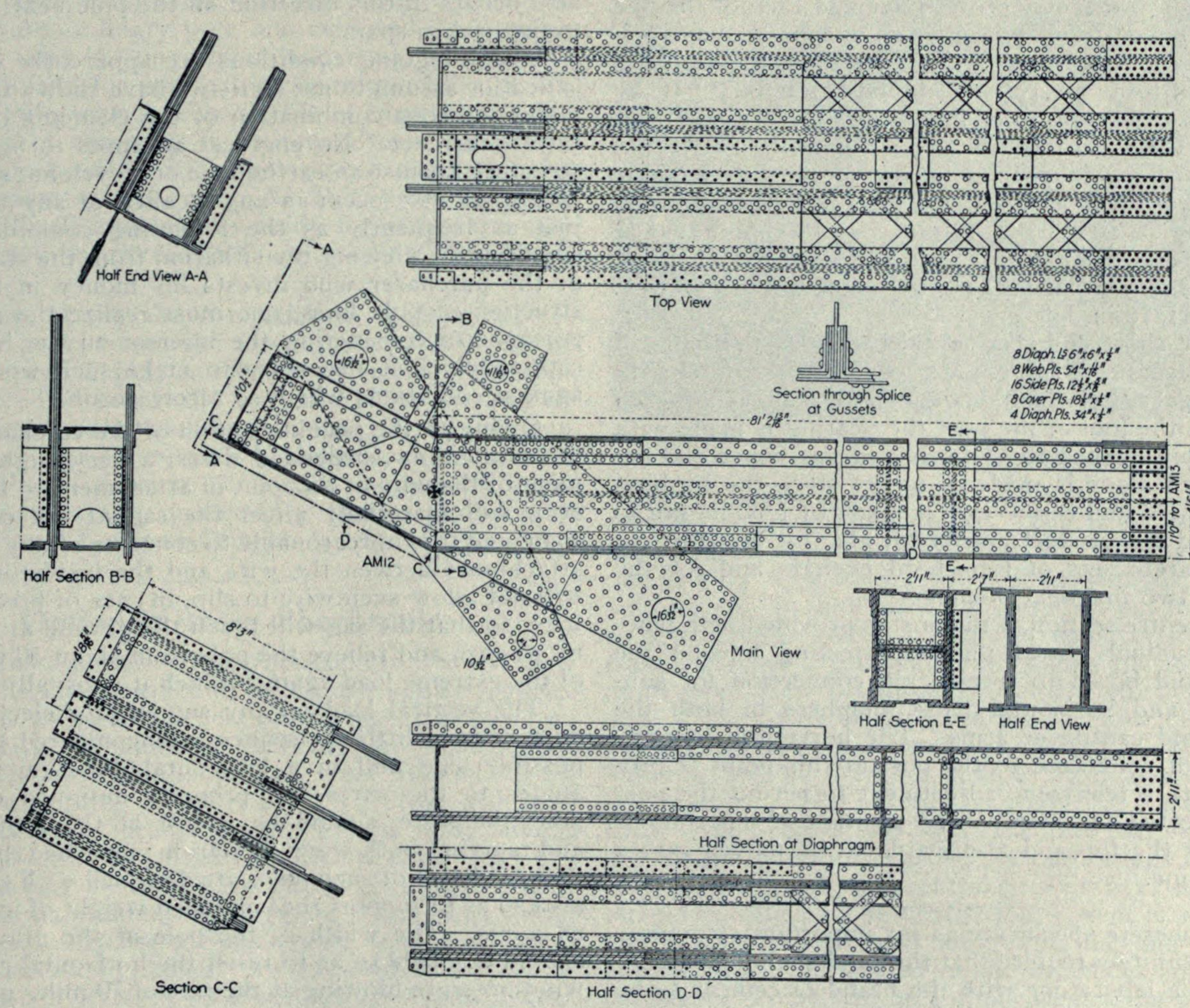
Location diagram of cantilever and anchor arms.



GENERAL ELEVATION OF MAIN TENSION DIAGONAL AM12-AU14



Details and field-rivetted splice of twin members of lower part of vertical post L12-M12.



Details of main compression diagonal member M12-M13, and of connections at upper end M12.

of 574 sq. in. The main body is symmetrical about the centre line, has four webs, and is shipped and erected in two halves. These duplicate sections are spaced 5½ ft. apart on centres and connected by field-rivetted flange tie plates. Each half member is made of a pair of built I-beams 4½ ft. deep and 2 ft. apart on centres with their flanges latticed. Their webs are also connected by transverse diaphragms and by tie-plates on the centre line.

At the lower ends the webs and flanges are spliced by field-rivetted flange and web splice plates to the lower part, M13-L14, of the same diagonal, and at the upper end four sets of reinforced gusset plates are shop rivetted to the webs and project beyond both flanges to receive the connection pins of the diagonal, horizontal and vertical members of the truss intersecting it at this point.

Main Vertical Post L14-U14

The main vertical post, 310 ft. high on centres, has a 9-ft. 2-in. by 9-ft. 10-in. cross-section with an area of 1,903 sq. ins. Including the eyebar connection detail at the top, and the detail at the lower end, which transmits the load to the pedestal, this post has a total weigh of 2,724,000 lbs. For convenience in fabrication, handling, shipping, and erection, it is made with twenty-six transverse and longitudinal field-rivetted splices. The middle section is 36½ ft. long and each of the other four intermediate sections 55 ft. long with maximum shipping weights of 120,000 lbs. each for the four pieces. The post is symmetrical about the longitudinal and transverse centre lines and each of the five intermediate sections is composed of four H-shape column sections connected to gether by field-rivetted latticing and tie plates. Each H-shape unit is 3½ ft. by 4½ ft. in cross-section and is made up of two built I-beam sections 3½ ft. deep.

Each of the four units in one of the intermediate sections of the posts has fourteen 8 x 8 x 13/16-in. flange angles, eight 19 x 9/16-in., two 19 x 5/8-in. flange plates and two 30 x 11/16-in. and six 37 x 11/16-in. web plates. The lattice bars are made of 8 x 13/16-in. and 8 x 11/16-in. bars.

In the short end sections of the posts the pairs of units are connected by wide cover plates parallel with the bridge axis, which engage both flanges of each unit. At the foot of the post the bearing is made with a 30-in. pin bushed to 45 in. but in the upper end detail, which alone is made of nickel steel, the bushing is eliminated and connection is made by a 30-in. pin to a rivetted nickel steel link bored also for the pins for four separate sets of top chord eyebars and for the pins for two diagonal members.

The centre section of the post is provided with pairs of longitudinal gusset plates projecting beyond the flanges and bored to receive pin connection for subdiagonal and horizontal truss members in both the anchor and cantilever arms. The horizontal longitudinal strut connected to the post at this point is provided with a telescopic adjustment to permit the post to be erected in a temporary position 15 ins. out of plumb at the top and afterwards to be moved into a vertical line.

All concrete specifications for important structures should definitely require that the sand shall be actually tested in a laboratory with the brand of cement to be used in the structure, and shall be rejected if it does not reach the standard strength in tension and compression.

Concrete Poles and the Possible Maximum Loads on Pole Lines

IT is widely conceded among engineers who are confronted with the task of providing a suitable substitute for the present timber pole that the concrete product is the only practical solution of the problem. The two foremost points in which the concrete pole is superior to that of wood are the facts that a properly constructed concrete pole is practically everlasting, and that almost all such poles can be designed so as to make them much stronger and far more stable than the timber product. Aside from the actual strength of wires, the stability of all supports for electric conductors is the main factor which governs the length of wire spans, and inasmuch as the stability of concrete poles can be made greatly to exceed that of wooden poles, the fact is probably established that extremely long wire spans will accompany the advent of concrete poles for general use.

Many engineers have published figures representing the possible theoretical loads on pole lines, the main factor in all such calculations being an assumed violet wind pressure acting against ice-covered wires. In addition to this the assumption is also made, that the above conditions may be accompanied with a temperature of 10 deg. below zero, and that the consequent contraction of the wires might cause them all to break in the same span. It is claimed in this connection, under the above conditions, with the wind blowing in a direction parallel to the wires, that the maximum load occurs in this direction on the pole next adjacent to the broken span.

The foregoing conditions are apparently very uncalled for assumptions; statistics have shown that such a simultaneous combination of the elements is a very rare occurrence. No engineer attempts to figure any structure against an earthquake or a cyclone; still such calamities may occur in any locality, at any time and just as frequently as the foregoing combination of conditions. Viewing the situation from the standpoint of the purchaser who invests his money in the construction of pole lines, one must realize the vast importance of considering the interest on the increased capital which is necessary to make such work proof against conditions which so rarely occur.

Owing to the peculiar action of the catenary curve in horizontally suspended wires, a very slight movement of the wire at its point of attachment to the cross arm, will materially affect the sag at the centre of span, and it is unreasonable to conceive of any suitable attachment betwen the wire and the insulator, which will not allow such wire to slip, in case of breakage of wire, so that the sag will touch the ground at the centre of span and relieve the pole from about 50 per cent. of the extreme load against which it is usually figured.

The vertical load on any support for electric conductors is of little consequence as compared with the possible side pull in a horizontal direction at right angles to the wires. A properly designed concrete pole, therefore, should be widest at the ground line and tapering both ways therefrom; provided, however, that the bases of such poles are designed with sufficient area so as to support the combined weight of ice-covered wires. The width of the pole at the ground line should be made so as to resist the horizontal action of wind pressure blowing at the rate of 70 miles per hour, at right angles to wires covered with ½-in. of ice.

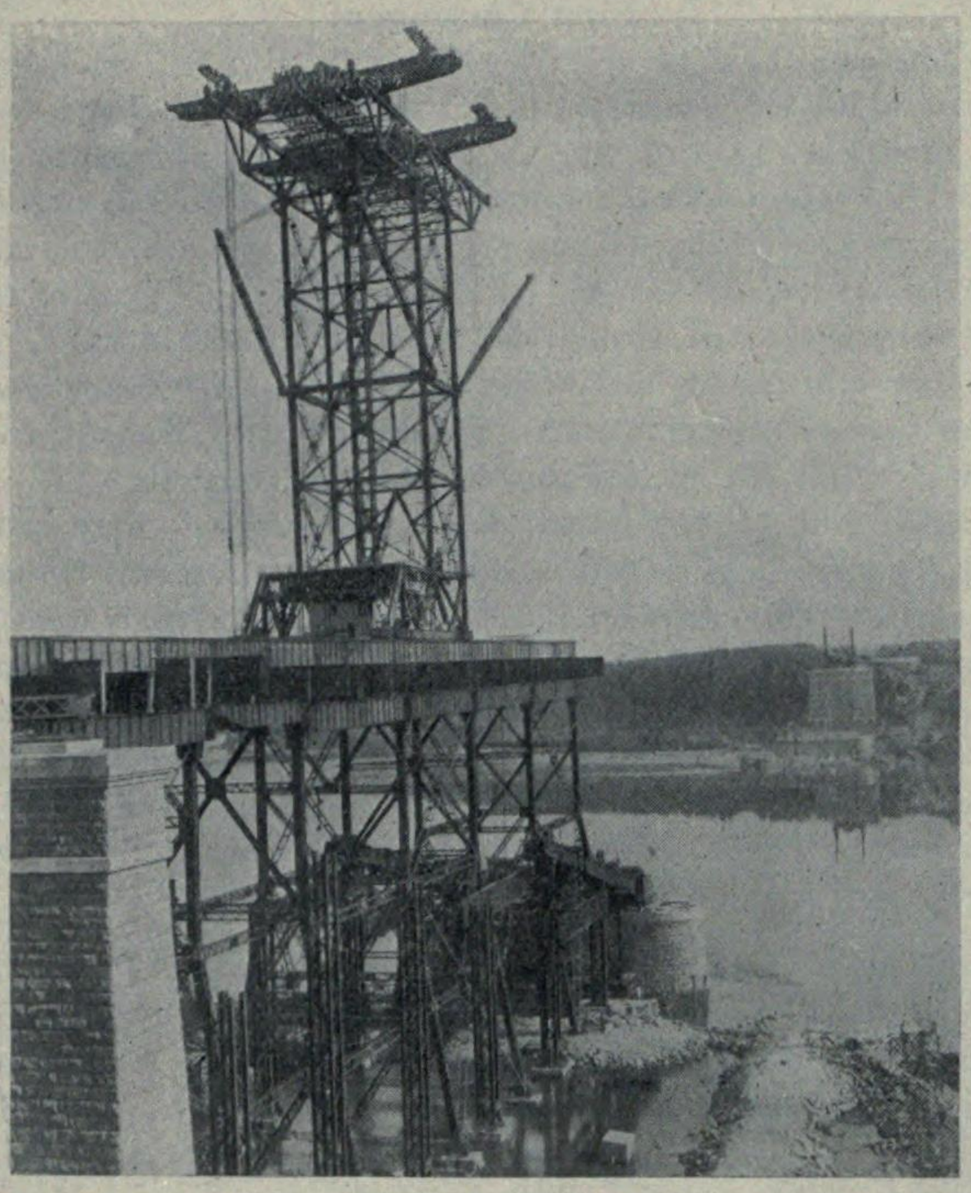
Many high tension transmission lines have been constructed with spans up to 1,200 ft. Such long

The Quebec Bridge, which has "the Longest Span Known to Bridge Construction"

Constructional Progress—How the Quebec Bridge Compares with the Celebrated Firth of Forth Bridge

Specially Contributed by H. P. Borden, Assistant to Chief Engineer, Board of Engineers, Quebec Bridge

AFTER several years' study and investigation, the new Quebec Bridge is approaching a stage where one may anticipate its ultimate completion within a short time. Work was started on the construction of the piers of this bridge in 1909, six years having been required to fully com-



General view of crossing, showing start on the erection of the north anchor arm. (Note the 1000-ton traveller in operation, and duplicate being erected on the south side.)

plete this work. Five piers in all were constructed—two main piers, two anchor piers, and one intermediate pier. The anchor piers, although about 150 ft. high, and containing about 17,000 cubic yards of masonry each, presented no engineering difficulties. The main piers, however, considering their volume, depth, and the conditions under which they were placed, probably constitute a record for this class of work, each pier costing in the neighborhood of one million dollars. No serious difficulty was encountered, however. One of the piers was carried down 50 ft. and the other 80 ft. below the bed of the river to solid foundations.

The span of the bridge is the same as that of the old bridge, namely, 1,800 ft. This enormous length of span enables Canada to claim the honor of possessing a bridge with the longest span known to bridge construction. The justly celebrated Firth of Forth Bridge in Scotland, which up to the present has claimed this honor, has a span of 1,710 ft., but it has two spans instead of one. It might be interesting here to compare briefly a few of the features of the two bridges:

The total over-all length of the Quebec Bridge is 3,239 ft., as compared with 5,349.5 ft. for the Forth Bridge. Both bridges have two railway tracks, the Quebec Bridge having two sidewalks extra.

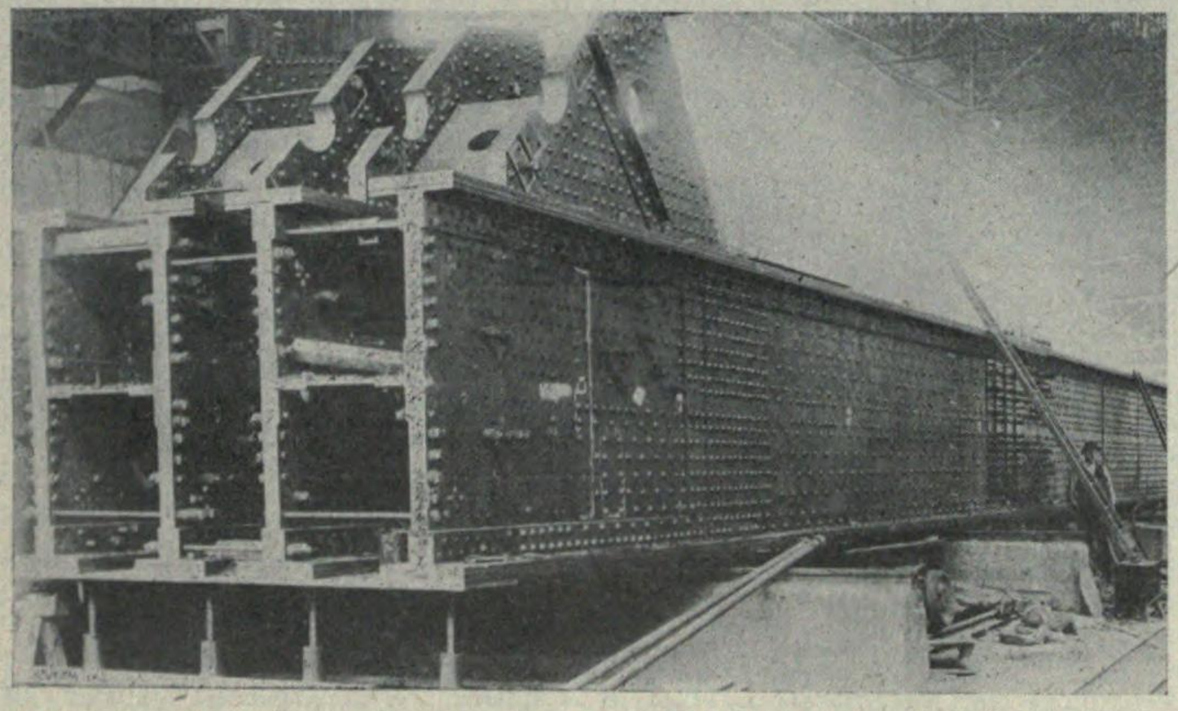
The Canadian bridge is designed to carry a live load per lineal foot, exclusive of its own weight, amounting to 11,000 lbs., as compared with 4,480 lbs. for the bridge in Scotland, the former weighing about 65,000 tons as compared with 57,000 tons in spite of the fact that the latter is some 2,110.5 ft. greater in length. The weight of the Quebec Bridge per lineal foot of cantilever only is 44,400 lbs., as compared with 21,360 lbs., the former having 4.03 lbs. of steel for every pound of live load, as compared with 4.77 lbs. of steel per pound of live load for the latter. The prescribed test load for the Quebec Bridge is 4 1/3 times heavier than that used for the Forth Bridge.

Thus it may be seen that while the Forth Bridge is considerably longer from abutment to abutment, yet the Quebec Bridge is not only greater in span but greatly exceeds the total weight of the Forth Bridge, due to the much heavier train loads for which it is designed.

On account of the unprecedented weight and size of members for this bridge, the St. Lawrence Bridge Company, the contractors for the superstructure, were compelled to design not only new shops, but in many cases, new and extremely heavy types of machines for the fabrication of this work. These shops have now been in operation for about two years, and at the present time have fabricated and shipped to the site about one-half the steel work required for this contract.

At the bridge site, special erection equipment also had to be provided for the handling and erection of the various members of the bridge. The heaviest piece to be handled weighed approximately one hundred tons. All equipment, both in the storage yards and in the bridge, was required to have a capacity of this amount.

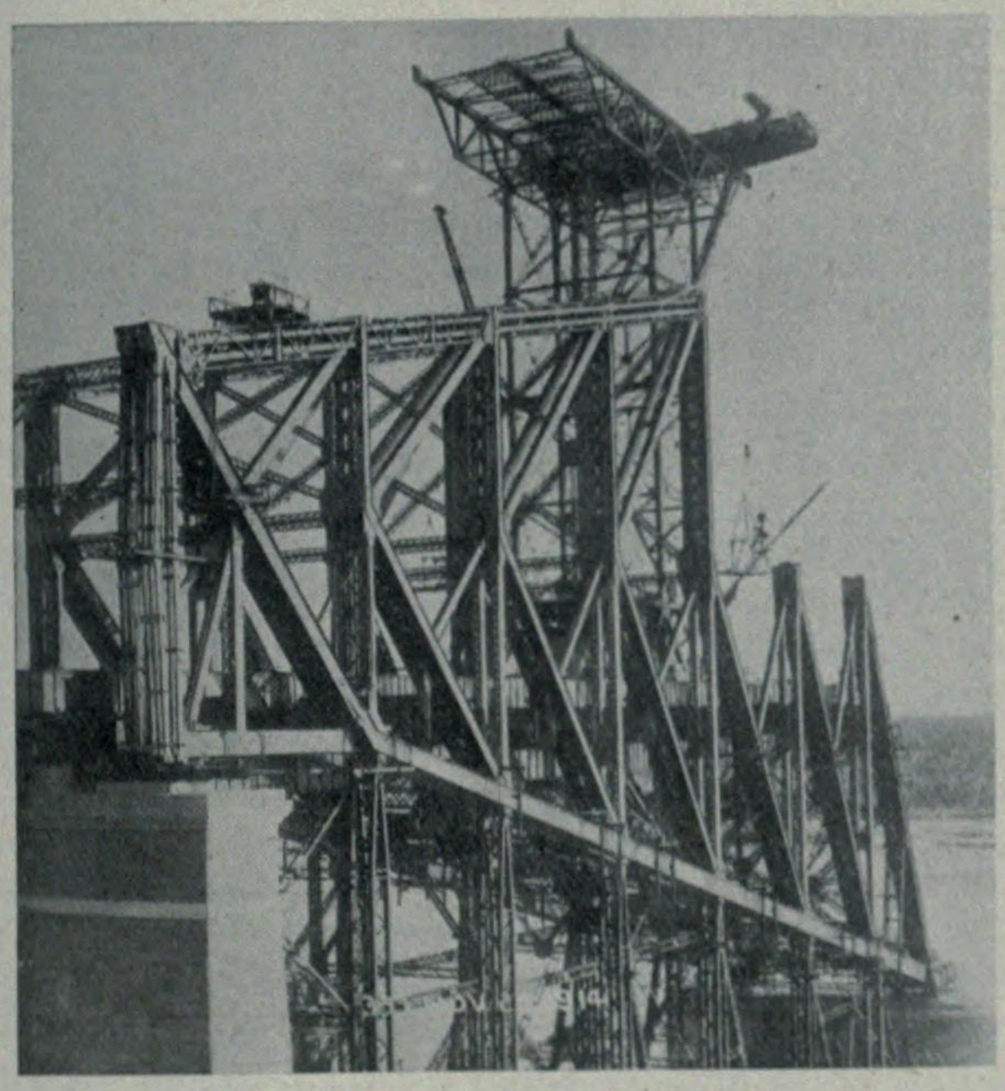
The erection traveller required for the erection of the cantilever bridge proper is a very elaborate piece of equipment, weighing in the neighborhood of 1,000 tons, standing 200 ft. high, and costing about $175,000. This traveller is equipped with two travelling cranes running on tracks at the top, and also with four hoist-



View of panel length of bottom chord, weighing 400 tons, as now assembled in the shop.

ing engines for operating booms at the four corners of the tower. All the machines on this traveller are operated by electricity, and most of them are controlled by one man at a control board on the lower bridge. This man is thus enabled to be at the lower level—where most of the work is going on—and can take his instructions directly from the foreman in charge.

During the past season very satisfactory progress has been made in the erection of the North Anchor Arm, practically the whole of this part of the bridge, amounting to some 15,000 tons, having been completely erected in place. This part of the structure is erected on elaborate steel falsework supporting the floor upon which the erection traveller runs and also supporting the trusses independently of the floor. This falsework is fitted with pneumatic jacks at the base, by which it can be adjusted to suit required conditions during erection. Owing to the limited capacity of the handling apparatus, as determined by practical considerations, practically all members of the bridge are shipped in two halves and spliced longitudinally in the field after erection. Instead of the pins at the

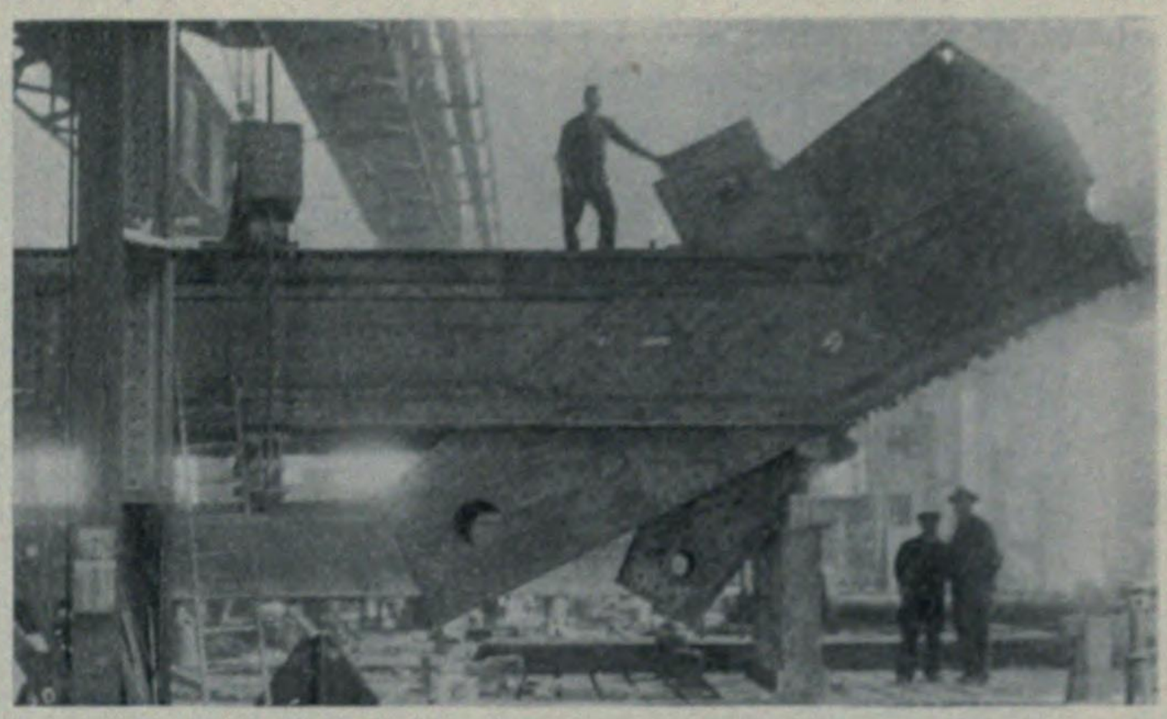


Construction of the north anchor arm.

panel points being continuous through all four webs, they are made in two halves, each half taking the stress from two webs only. This applies in all cases, with the exception of a few minor tension members. Thus it will be seen that each truss of this bridge is in fact two distinct trusses, with separate pins placed side by side and connected in the field with diaphragms and lattice bracing.

Another departure from ordinary practice is noted in the top chords, where the eyebars between main panel points are supported at the centre on small lattice trusses. This does away with the necessity of providing a redundant member at the middle of the panel to support the eyebars during erection.

Next spring the first thing to be done will be the erection of the main posts over the shoe on the main pier. These posts are probably the largest members ever manufactured, being 310 ft. long, centre to centre of pins, supported laterally at only one point during their entire length. The cross sections of these posts are really four separate box columns, one at each corner, being tied together by plates and lattice.

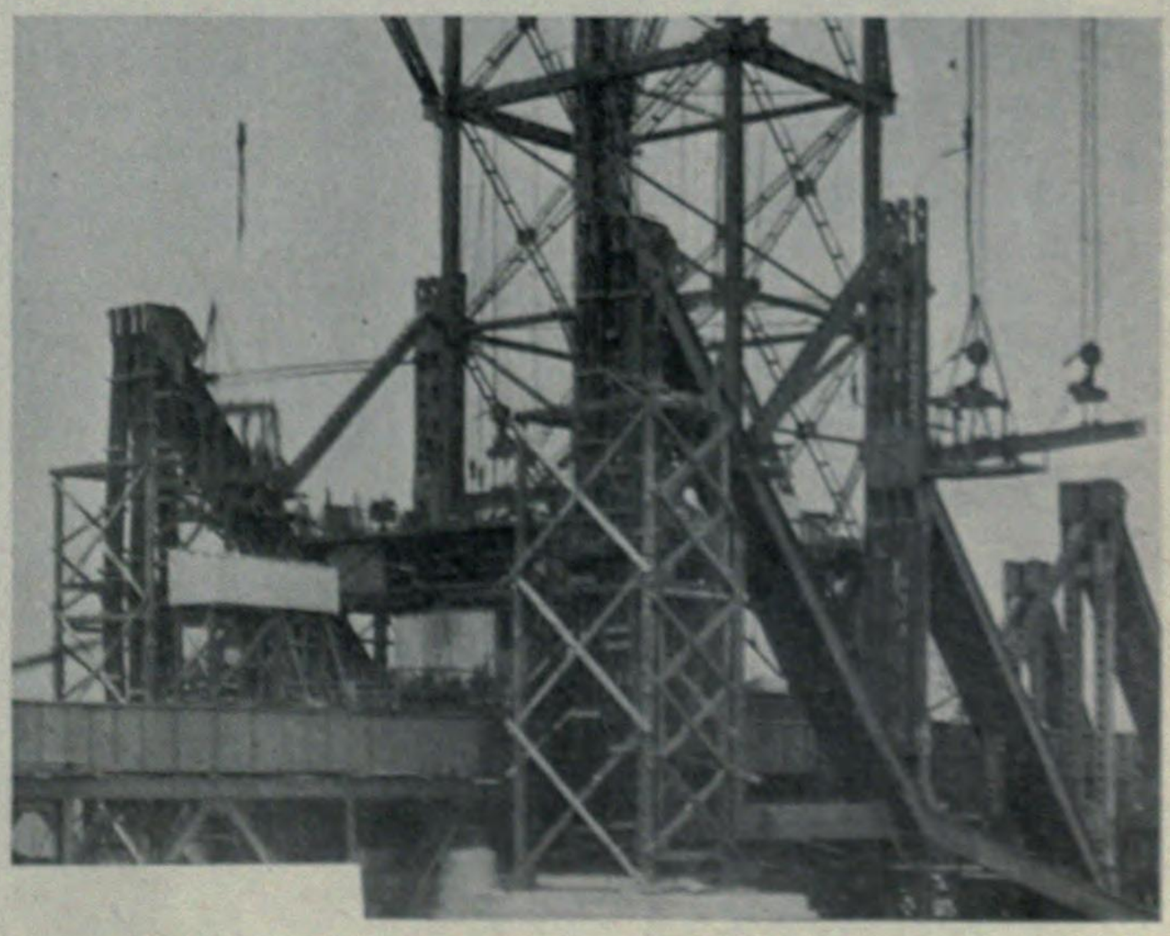


Enormous proportions of details of compression member where seven members intersect.

One of the most complicated details of the bridge is the link at the extreme top of this post, which is all nickel steel, and the point of intersection of seven members. This detail has webs 7¾ inches thick, and weighs approximately 140 tons. The four posts required for this bridge will cost, erected, in the neighborhood of one million dollars.

Steps are now being taken to erect a duplicate traveller and falsework on the south side of the river, and next year work will go on simultaneously on both sides of the river.

By the end of next season it is hoped that the north cantilever arm and south anchor arm will be fully erected. By the season of 1916 it is expected that the work of erecting the suspended span will be undertaken. This span, 640 ft. long, 110 ft. high, 88 ft. wide, and weighing about 5,500 tons, will be floated into place instead of being erected as a cantilever from the end of the cantilever arm. By this scheme of erection about one year will be saved in the erection of the bridge. It is expected that this span will be erected on the shore at some point in close proximity to the bridge site, and that at the proper time it will be transferred to large pontoons and floated into position. It will be lifted off the pontoons by means of heavy steel hangers at the ends of the cantilever arm and hoisted into position by means of powerful hydraulic jacks. From the fact that at this point there is



Heavy member of the truss in course of erection.

about a 16-ft. tide and an 8 to 10-mile current, the erection problem is rendered both interesting and difficult.

It is expected that the bridge will be open to traffic early in 1917.

The construction of this bridge is under the direction of the Board of Engineers of the Quebec Bridge, which is composed of Messrs. C. N. Monserrat (Chairman and Chief Engineer), Ralph Modjeski, and C. C. Schneider.

Why Canada Should be Optimistic

By W. J. Whiteside, Toronto

EVERY optimist in Canada should take a pessimist in charge. The cheerful man should gently lead the disciple of calamity to some quiet corner, and there impart to him as kindly as only the true optimist can, the knowledge that this country will still be distinctly visible on any good map of the world when peace is concluded in Berlin. The pessimist is not a thinker and his imagination flourishes only in grooves of gloom. It is necessary that he be trained to walk upright in the sunshine among the people who are adapting themselves to new conditions before he can be expected to shake off his adopted convictions and take his proper place in the daily toil of the nation. The national machinery in this country did not stop when the first German goose-stepped across the borders of Belgium. Canadians did not take to their cellars or cease to eat as usual. Neither did the products of the fertile fields of Canada disappear from the bins and the elevators or the live-stock perish on the hillsides. Few manufacturing plants of consequence had to close because of the inauguration of hostilities and those that did will be started again before long. Admittedly, the war has disturbed business, but not beyond the possibility of rapid and efficient adjustment, and those adjustments have in large measure been already achieved. As the first shock is always the hardest to bear, it is reasonably safe to assume that the problems of the future will be as capably handled and that day by day the nation will progress to a position of steadiness and contentment.

There were not lacking pessimistic prophets to preach that dark days were dawning when Canada's volunteers began to gather for service over-seas. Yet, because of that mobilization, factories throughout the country were soon running with full staffs, and, in many cases, running overtime, to furnish the equipment required. Boots, socks, underclothing, uniforms, rations, rifles and ammunition had to be acquired. As the Government has announced that men will be constantly in training here while the war lasts, it is likely that these self-same factories will continue to operate, as a result of the war, while the conflict lasts. In addition, quite out of a clear sky, came orders for saddles and harness from the Governments of Great Britain, France and Russia, in large quantities because the manufacturing plants of those countries could not produce the supplies needed quickly enough. The harness business is always rather dull in the fall and the demands of the armies of the allies were gratefully received. Canada is being called upon to furnish horses at good prices, beef at good prices, and other foodstuffs at good prices, and in bulk considerably greater than is customary in times of peace, so that Canada's portion of the war surely has not been an unmitigated evil.

The markets of a few manufacturers were upset by the Old World fighting, but they will find that their products may be diverted to other markets. As a matter of fact producers so placed are not numerous in Canada. The majority of our manufacturing plants are devoted to the production of goods essential to the daily routine of the people and the demand in the home market is sufficient to enable them to maintain operations.

The last Dominion census, that of 1911, is authority for thestatement that there were in Canada, in 1910, some nineteen thousand odd manufacturing plants. Of those, 6,985, or more than a third of the manufacturing plants of the Dominion—were devoted to the production of foodstuffs. As the people have to be fed, most of these plants should be able to carry on their operations as usual. The employees on the pay rolls of these factories in 1910 numbered 52,730. The wages paid totalled $14,492,568, and the cost of materials stood at $175,453,469, the whole constituting a considerable item, the spending of which is calculated to stimulate activity in other lines of industry.

In timber and wood products the census gives the number of plants as 4,999, employees 110,049, the wages paid $39,379,739 and the cost of materials $94,-052,429. Speculative building has largely ceased, but Canadian woods may be an essential feature of specifications for buildings going up for the Governments and for municipalities throughout the Dominion. There will possibly be a decrease of output in furniture. The lumber mills ordinarily enjoying an export business ought to be able to continue operations much as usual, though they will not have access to Germany and Austria, and there is ample opportunity for many of the other lumber men to seek outside trade as well.

The textile industry appears to be in an excellent position. The number of plants in 1910 is given as 1,444, the 72,672 employees were paid $26,703,826 in wages, and the cost of materials was $72,128,436. With the cutting off of supplies from Germany and Austria our Canadian plants should be called upon to furnish a wider range of goods than ever before for the domestic market, and what with the making of necessary clothing these factories are busy. It rests with the manufacturers themselves whether they are to hold the new domestic market when the war is over and trade routes are open all over the world.

In paper and printing the statistics show 773 plants. Employees numbering 22,894 received in wages $10,-866,721 and the cost of materials was $16,956,697. As the newspapers, to give the news of the war are going to issue more often than in times of peace, it stands to reason that men will continue to be employed cutting the spruce in the woods, floating it down the rivers or loading it upon trains for delivery to the mills, and that the pulp and paper plants will keep on with the business of turning out paper at least in quantities as plentiful as in peaceful days. For cardboard and papers other than that used by newspapers there is still a demand. At present there may be a slight

Erection Progress on Quebec Bridge

North anchor and cantilever arms completed — South anchor arm out to and including main post—Work to be completed during 1916

By H. P. Borden*

WHEN work on the Quebec Bridge closed down a year ago, the north anchor arm was completed out to the main pier with the exception of two panels of the upper web members and top chord. On the south side no steel at all had been erected between the main and anchor piers.

About the middle of April a start was again made on the erection of the steel on the north shore, and on May 3rd the erection of the main posts was begun. These posts rest on the main shoes over the main pier and are the largest single members in the bridge, being 310 ft. high, centre to centre of pins, and approximately 10 feet square. As the four posts required for the bridge weigh approximately 6,000 tons, costing in the neighborhood of one million dollars, or considerably more than the entire cost of many important bridges, some idea of the magnitude of these members may be obtained. Each of these members is composed of four separate columns latticed together in four directions, terminated by a tapered solid section at both top and bottom. In order to facilitate shipment and handling, each of these members was shipped in twenty-six separate sections and spliced together in the field. It was expected that serious difficulty might be encountered in the erection of these sections as they had to be put in place with splice plates attached to the ends and lowered with extreme precision to allow the webs and flanges of the adjoining section to be entered between the various plates and angles forming the splice. The efficiency of the electrically controlled hoists on the erection traveler, however, was such that this work was carried out with remarkable rapidity, both posts on the north side being erected and sufficiently riveted to allow the traveler to be moved ahead within one month from the time a start was made. Sufficient riveting was done on these members to take care of all erection stresses before any further steel was erected or the traveler moved ahead. This riveting was considered highly advisable rather than filling the holes with bolts and drift pins and riveting later as the work progressed, as it was found from past experience that once a strain was applied to a drifted joint it was absolutely impossible to remove these drifts except by drilling. The cramped space in the interior of these members also made riveting somewhat difficult, but with the use of specially designed jam riveters, which could work in a space down to 14 inches, very satisfactory work was obtained. While in some cases the heads of inside rivets were not perfect, yet, in all cases, tight rivets were obtained.

When the erection of the main post had proceeded to the desired stage, the traveler was moved ahead and the erection of the first panel of the cantilever arm was started. As the bottom chords have a field splice between main panel points, it was necessary to devise some support for these members for riveting this splice before it could be connected to the main panel point. This was accomplished by means of a "flying bridge" or heavy steel platform extending for one full panel length and for the width of the bridge. On this "flying bridge," which was supported by links to the structure above, the bottom chords were assembled and jacked up into their proper alignment, and the centre splices fully riveted up. As each panel was completed the "flying bridge" was moved ahead to the next panel. This work went ahead very rapidly, as all field splices and connections had previously been reamed out in place at the shop, thus avoiding any shop errors or the necessity of making any alterations or changes in the field. As each panel was erected, accurate measurements were taken to see that the alignment was correct. Owing to the extreme accuracy with which this work was manufactured and inspected in the shop, no difficulty of this nature was encountered, the alignment of both the anchor and can-

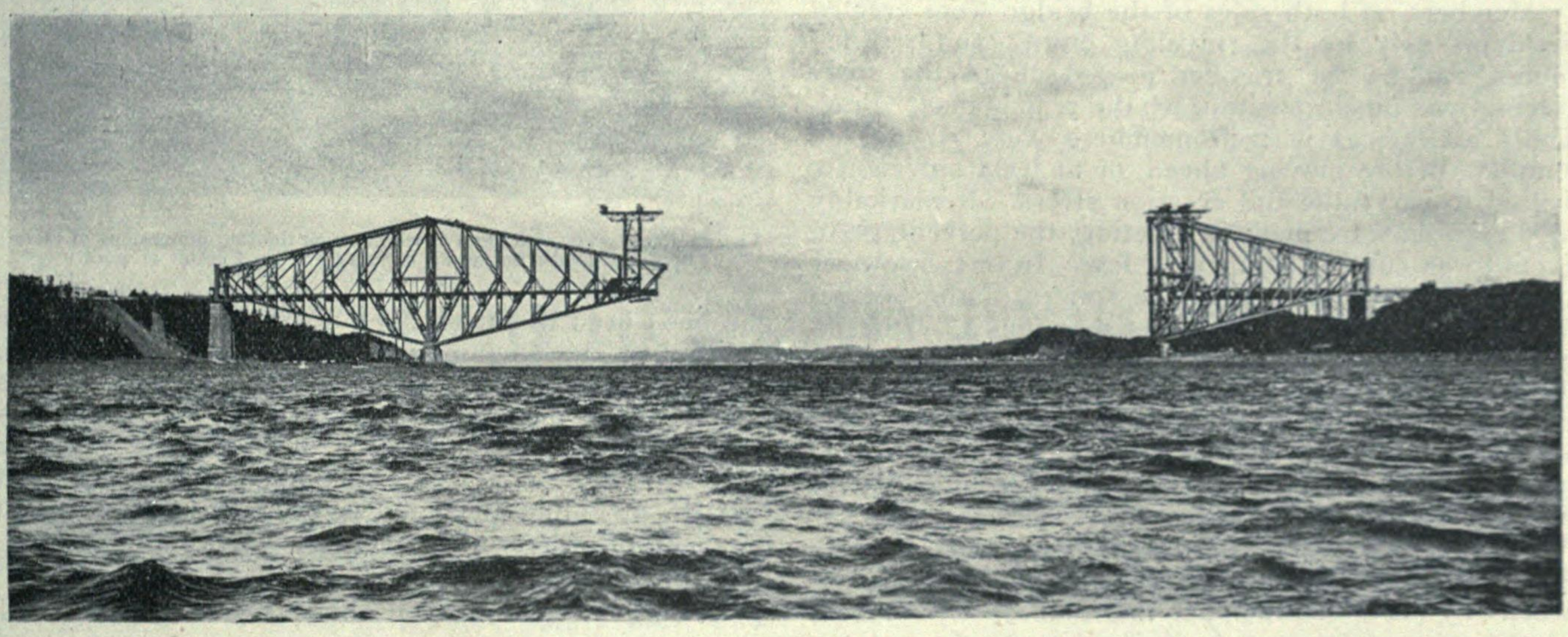


Fig. 1.—General view of Quebec Bridge to date—showing erection progress to the end of the season, 1915.

* Assistant to Chief Engineer–Quebec Bridge.

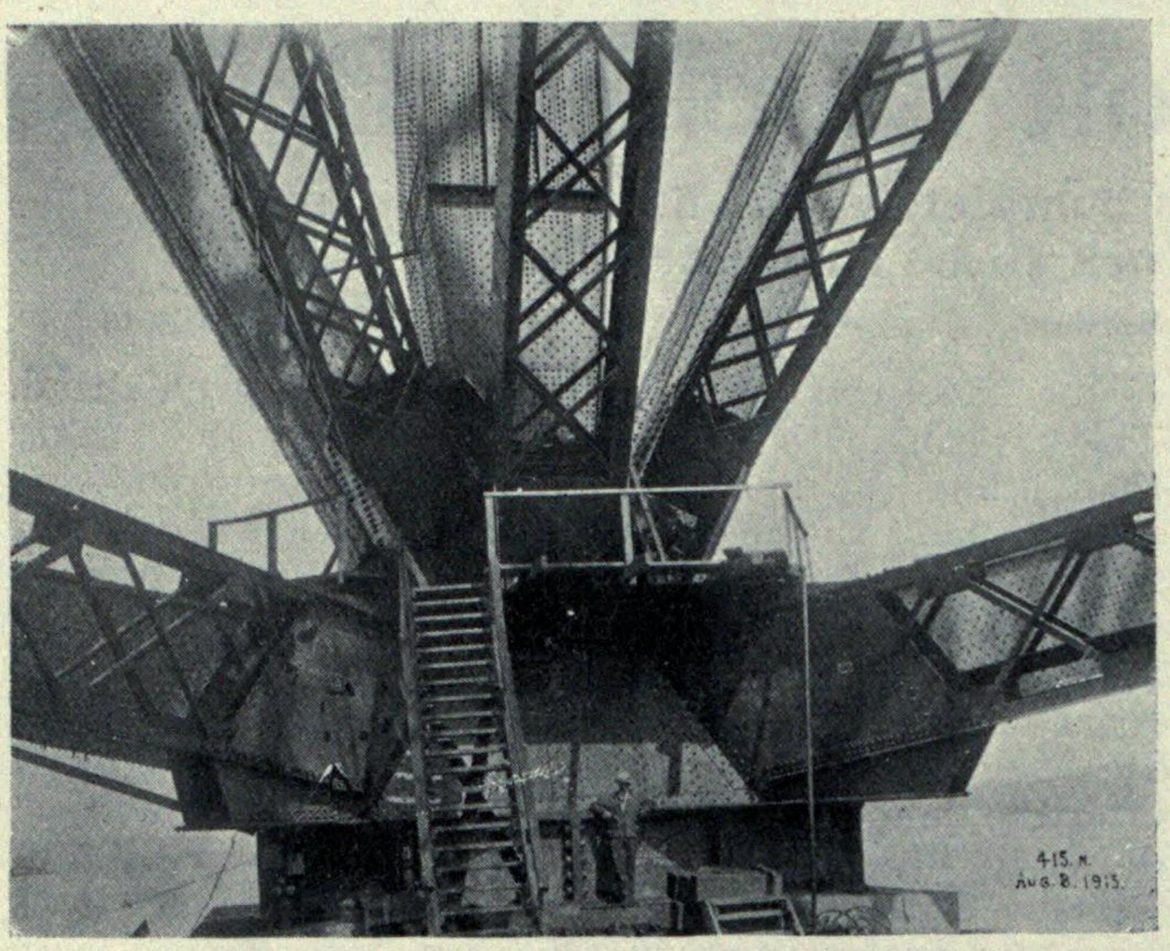


Fig. 2.—Intersection of ten members at the main shoe—Concentrated load on shoe about 55,000,000 lbs.

tilever arms throughout their entire length being absolutely correct.

Members on both sides of the bridge were erected simultaneously by the traveling cranes and stiff-leg booms, and as the traveler moved ahead the sway bracing was put in position by the rear booms. Practically all splices in web members were riveted up complete before moving ahead, or at least sufficiently riveted to carry the full erection stress. Remarkably good records were made in riveting, the percentage of rivets to be cut out being very low. In one case over 4,000 rivets were driven in the splices of the bottom chords, and only one loose rivet was found by the inspectors. This extraordinary record was due, naturally, to the experienced riveters employed on the work, but also to the fact that in reaming out the splices in the shop from 25 to 50 per cent. of bolts were used in bolting up the splice material, thus preventing drillings getting in between the web plates of the member. When the splice was taken apart, care was taken to clean out all drillings that might be found to exist between any parts of the splice material.

By the middle of November the cantilever arm was completely erected, being quite up to the progress laid out by the Bridge Company at the beginning of the season. The work of the traveler having been completed on this side of the river, it is now being taken down and will be re-erected at the site where the suspended span will be erected next year. On the south shore the erection of the falsework to support the anchor arm was started about the middle of April, this falsework being taken from the north shore where it

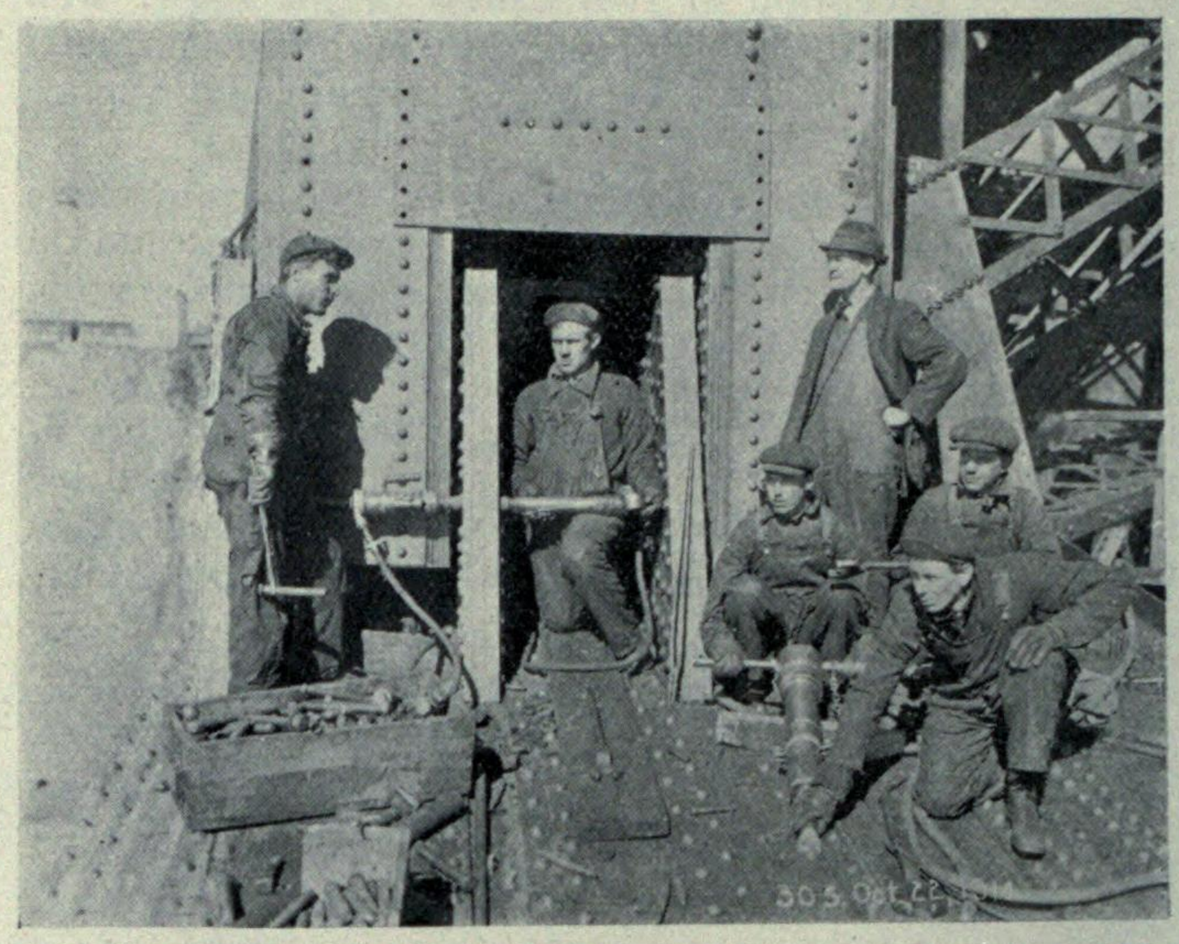


Fig. 3.—Panel point of bottom chord showing unusual dimensions of members—pneumatic bucker-up, hammer and rivet cutter at work.

had been used to support the north anchor arm. The erection of the anchor arm started on July 7th, and, owing to the experience gained on the north side, was erected much more rapidly, a gain of over six weeks being made in the completion of this work. By the middle of November the entire anchor arm had been erected, including the main posts, with the exception of a certain amount of riveting, which will be completed next year.

During the past season about 30,000 tons of steel

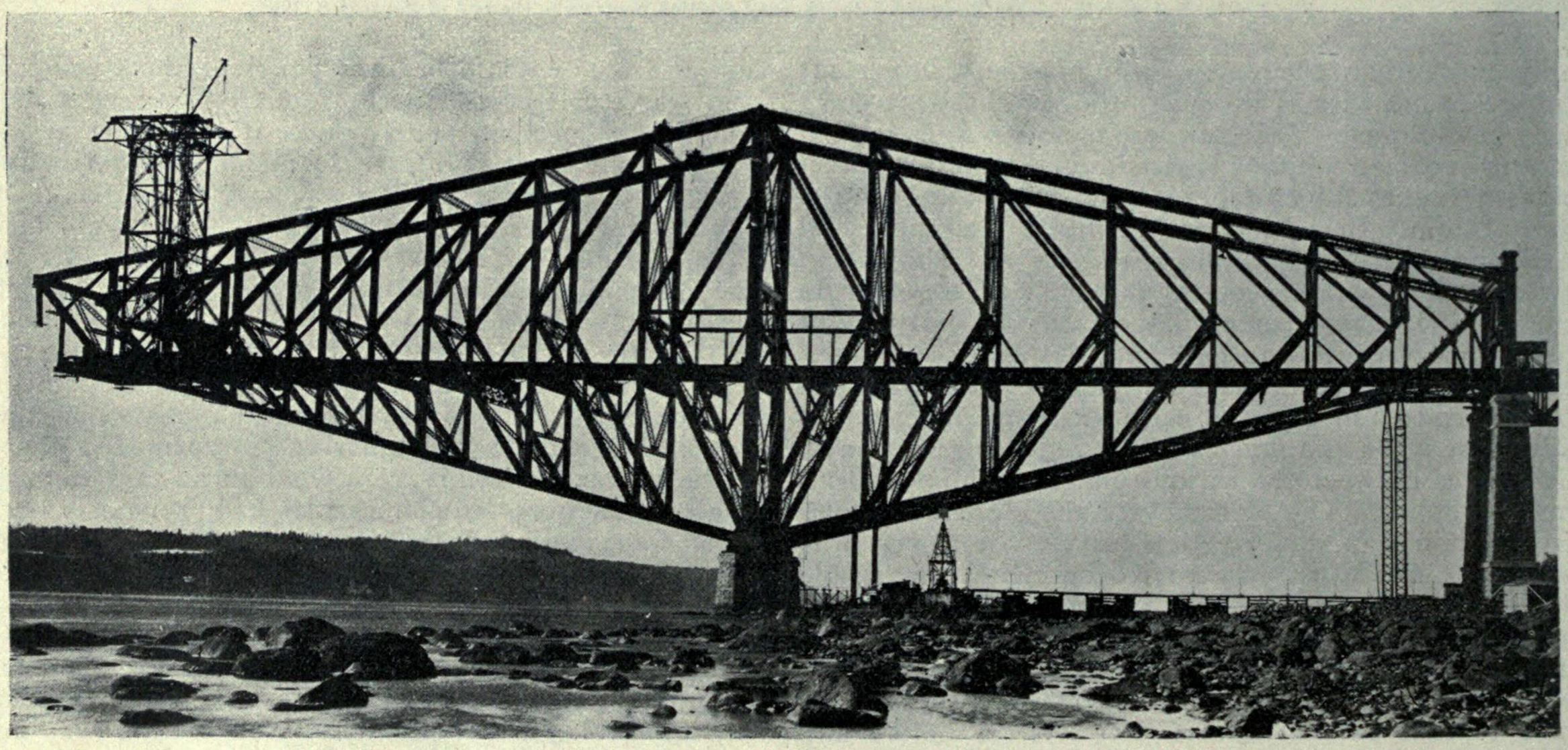


Fig. 4.—Completed north anchor and cantilever arm—Traveller being taken down to be used in the erection of the suspendspan.

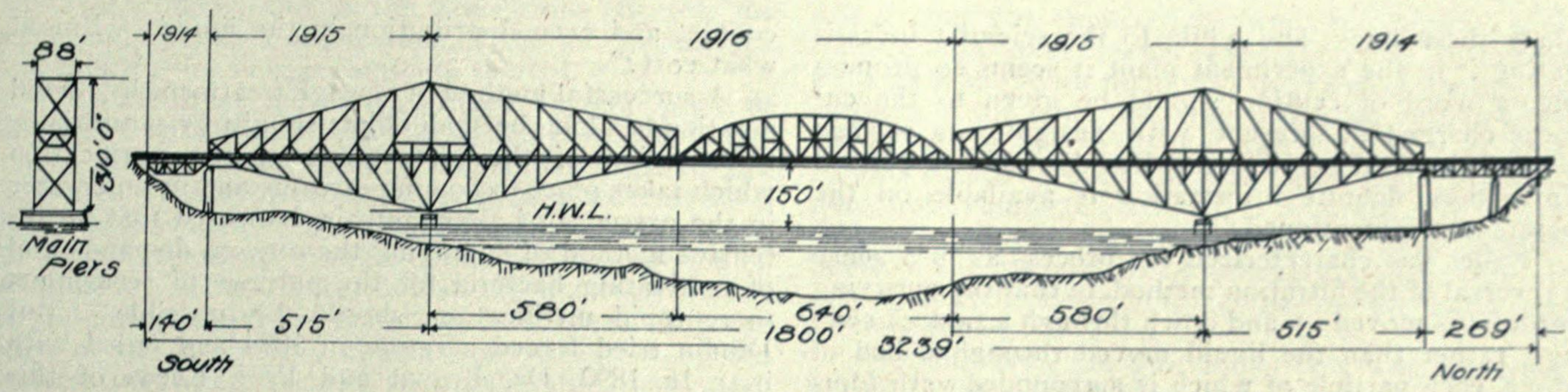


Fig. 5.—Quebec Bridge Progress—shows work done in 1914, 1915 and program for 1916.

was erected. In all about 45,000 tons has been erected out of the 65,000 tons, the estimated total weight of the bridge. The record day's tonnage in 1915 was 670 tons for the south shore traveler, although there were several days in which over 600 tons was erected by this traveler. An average of 350 tons per day was made in the erection of the south main post.

Next season the south cantilever arm will be erected, and it is expected that this work will be finished early in September. The suspended span will also be erected at Sillery Cove, a point some three miles below the bridge site. When completed it will be floated to the site on six pontoons 160 ft. long and 32 ft. wide, each having a working draft of 8 feet. This span, which is 640 ft. long, 110 ft. high at the centre, 88 ft. wide, and weighing about 5,000 tons, will then be attached to long hangers from the ends of the cantilever arms and jacked into place by means of heavy jacks placed on the erection girders at each corner of the cantilever arm. This operation should not take over twenty-four hours if everything works smoothly. By the end of 1915 practically all the steelwork of this bridge should be in place, and it will be possible for working trains to cross the river at this point.

The work is under the supervision of the Board of Engineers, Quebec Bridge, composed of C. N. Monsarrat (Chairman and Chief Engineer) and Ralph Modjeski; (Mr. C. C. Schneider, late member, deceased).

The contract is being carried out by the St. Lawrence Bridge Company, Limited, of which Geo. F. Porter is Engineer of Construction, W. B. Fortune, Superintendent, and S. P. Mitchell, Consulting Engineer of Erection.

The Aeration or Activation of Sewage

New method of sewage treatment sufficiently developed for adoption in full-sized plants—Experimental work at Brooklyn, N.Y., increases confidence in this system.

By G. T. Hammond*

The treatment of sewage by forced aeration, in the presence of activated sludge, is one of the most interesting developments in sanitary disposal methods of recent years. It is but little more than a year since the process was announced in England. Very extensive and careful study has already been given the subject, and numerous papers have appeared concerning it. At the present time, several full-size plants employing this method are building or under design by engineers who feel that what has already been learned about it experimentally justifies their confidence. There are, however, a great many things about it that are unknown, and all admit that much remains to be investigated, either in testing stations at a relatively small expense, or in full-size plants at possibly a larger cost, in order that we may obtain a satisfactory understanding of the many problems that have already presented themselves as to the nature of the phenomena and underlying principles of the method, and as to the essential features of the design of plants and apparatus for its employment.

Some of the problems that are engaging the attention of investigators are the effect of relatively low temperature in winter on the process; how the nitrogen in the sludge can best be built up; how much sludge will be formed under various conditions of operation, and whether a cycle or process of operation employing a series of tanks can be devised in such manner that all of the easily reducible organics will be removed from both sewage and sludge; how much sludge will be available for the manufacture of fertilizer, and whether all that is of value may not be required for use in the continuous flow plan of sewage treatment to diminish the time of aeration to a minimum.

Point of Equilibrium

There is probably a condition of equilibrium to be secured in the treatment under which just about so much sludge will be used by the process to obtain a required result, and just about such a surplus will have to be disposed of. How to adjust the method to the varying strength and quantity of the sewage as it flows to the plant, and the effect of varying strength of sewage on the expense of the treatment, also requires much study.

The efficiency of the method in regular service under the ordinary operation conditions that prevail in all American cities, its cost and economy, and its reliability as compared with other methods of sewage treatment now well known and giving good and cheap service, cannot but engage the careful study of conservative men, whose object usually is to provide the most economical method of treatment which shall offer the greatest promise of efficiency and reliability under existing requirements and circumstances.

Much remains to be learned of the new method

* Presented before section D of the American Association for the Advancement of Science at the Columbus Meeting December 29th, 1915.

reservoir, every fuel bunker, every waterfront industry, every factory, every wholesale assembling and distributing plant reaching out to marketing avenues, can be served to the highest degree of efficiency, economy, and despatch only by such an impartial public intermediary. A public belt line, giving equal access to all railways and steamships from all parts of the city reached by it, would afford new opportunities for development to outlying sections of the city, taking care of both carload and express package shipments.

In conclusion, Mr. Bridges expresses the hope that the nationalizing of railroads will take place, believing that in such a course there is a remedy for the difficulties that now apply to transportation problems, and more especially those problems that are concerned with the inter-relationships of rail and ship commerce.

Fall of Quebec Bridge Due to Broken Casting

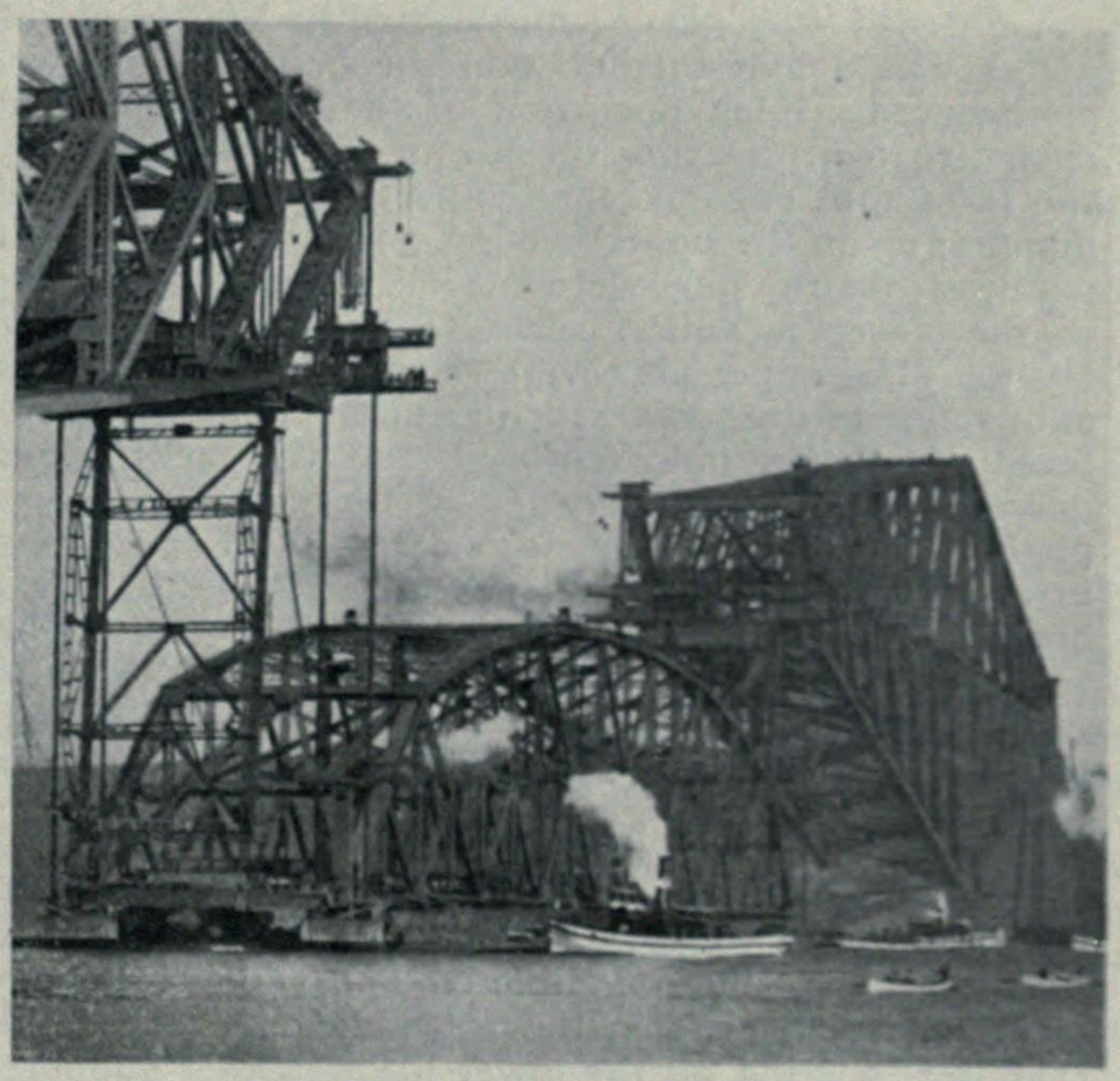
THE following brief description of the actual operations on the Quebec Bridge span, which was raised to a height of 12 feet before the failure of a cast steel bearing on the lower lifting girder at one of the corners, resulting in its fall, may now be accepted as the official explanation of the accident. In spite of a number of more or less hasty criticisms, it does not appear that any faults developed in the design of the bridge or the bridge span. Neither is there any apparent force in the contention that this method of erection can never be successful; there is no information to indicate that the span showed signs of buckling, due to its abnormal length and weight, during the three hours it hung suspended. Whether the minor detail fault which precipitated the whole trouble could have been avoided by a more rigid inspection or more eternal vigilance will possibly also remain a matter of dispute between those who accepted the responsibility of inspection and those who were mere onlookers.

At 6.50 a.m. the span arrived at the bridge site, and the mooring lines were connected up to the cast steel snubbing posts located at each of the four corners of the suspended span. These 1¼-in. steel mooring ropes, eight in number, four at each end of the span, were calculated to take a pull of 75,000 pounds each, and passed through sheaves at the lower corners of the mooring trusses, and from there up to a nine-part ¾-inch wire rope tackle, which led back to the drums of the derrick hoists, situated on the bridge floor at the ends of the cantilever arms. The span was pulled directly under its final position in the bridge by means of these 1¼-in. ropes and the derrick hoists. The hanger lifting chains which were to raise the span were then lowered and connected through the slotted holes at the lower ends to the pins at the top of the short hanger links connecting to the supporting girders under the end corners of the span. This connection was made at 7.40 a.m., when the current was practically at zero—that is, the tide had turned and the current was about to change from a westward to an easterly flow.

The mooring frames were made up of two steel trusses braced together, the bracing being designed to take a transverse pull from each end of the suspended span of 300,000 pounds. They were pin-connected to the cantilever arm floorbeams so that by means of the nine-part ⅞-in. wire rope tackle leading from the lower corners of the trusses to the connection to the floor between panel points CF5 and CF6 of the cantilever arm. and from there to the main hoists situated on the bridge floor, they could be raised so as not to obstruct the channel unnecessarily.

The hanger chains at each corner of the span were made up of four slabs to each chain, each slab being built up of two 30-in. by 1⅛-in. carbon steel plates. The slabs were manufactured and shipped in lengths of about 30 ft. centre to centre of end connecting pins. They were controlled after being suspended from the jacking girders located at the elevation of the bottom chords of the cantilever arms, by means of a two-part tackle connecting to the cantilever arm trusses at panel point CL2.

The hoisting apparatus at each corner of the span is illustrated in the figure herewith. A pair of supporting girders 6 ft. 11½ in. deep and 25 ft. long and braced together by bearing and pin connecting diaphragms and cover plates were placed under each corner of the span. The plate lifting chains were pin connected to these girders and also riveted to the same girders and passed up through a set of upper and lower jacking girders, to which they were altrnately pin connected as the jacks between the upper and lower jacking girders were operated. These jacking girders were



Quebec Bridge showing the suspended span floated into position between the two cantilever arms and connected to the hanger lifting bars. The load is still carried by the scows.

each made up of two plate girders 9 ft. deep and 22 ft. 6 in. long, connected together by cross-bearing diaphragms and cove plates. The upper jacking girders were the movable girders, and slid up and down in the stiff built guides, which were riveted into the lower jacking girders, passed up through the upper jacking girders, and connected to the stiff hangers which led on up to the upper supporting girders. These upper supporting girders were placed on top of the CU0 joints of the cantilever arms, and were of similar construction to the lower supporting girders. The load of the span was transferred to the upper and lower supporting girders by means of cast steel rocker bearings, designed so as to allow the span to sway in any

direction under the influence of external forces from current and wind which might have acted while the span was being hoisted.

The total load carried by the hanger chains while lifting the span was 5,147 tons. The supporting girders, hanger chains, jacks, and jacking girders and all their connections were designed throughout to carry this lifted load plus 20 per cent. impact.

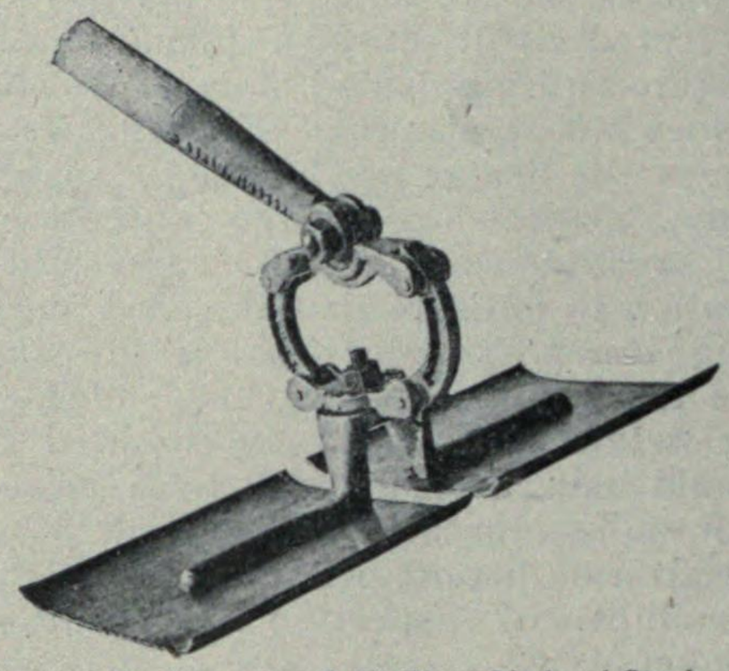
The work of hoisting was done by eight 1,000-ton hydraulic jacks, placed two at each corner of the span. These jacks were operated under a pressure of 4,500 pounds per square inch, the water being supplied to them by a pair of direct-acting double-plunger pumps, operated by compressed air and located on the centre line of the bridge floor at the ends of the cantilever arms. Valves placed in the feed pipe lines in front of the pumps controlled the water supply sent to each corner of the span, and by this means and with the aid of an indicator, which showed any difference in elevation between the two sides of the span, the span was kept approximately level. Another set of valves with a similar indicator attachment was located in front of each set of jacking girders and controlled the water supplied to each separate jack and by means of which the jacking girders were kept horizontal.

The Collapse of the Span.

At 8.30 a.m. the tide had dropped sufficiently to make the pins bear at the ends of the slotted holes in the hanger links, and the links themselves had straightened out. At 9 a.m. the tide had fallen about a foot and a half further, and the first jacking was commenced. Each operation of the jacks lifted the span two feet. During the lifting, or upward stroke, the 12-in. pins engaged the hanger chains through the diaphragms in the upper jacking girders. At the finish of the stroke the pins were entered in the diaphragms of the lower jacking girders to engage the hanger chains. The upper pins were then removed, the jacks and upper girders lowered, the upper pins again entered, the lower pins removed, and the jacks again operated. The first operation of the jacks was completed in 15 minutes; the second and third operations in about 13 minutes each. At the end of the third operation the span had lifted clear of the scows, the scows had drifted away and were taken care of by the waiting tugs, leaving the span supported entirely by the hoisting apparatus on the ends of the cantilever arms. The fourth stroke was completed, after which an intermission of about an hour was allowed, in order that the working men could get their breakfast; and, upon their return, the jacks were again operated. The sixth stroke had been completed, and while the upper jacking girders were in the act of being lowered **the cast steel bearing on the lower lifting girder supporting the span at the southwest corner failed.** The span slipped off the support at this corner, the sway and lateral bracing then collapsed, precipitating the span into the water. As it fell it turned over to the west, and plunged to the bottom of the river, where it lies, a mass of twisted steel, 200 feet below the river surface. As the load of the span was suddenly released from the ends of the cantilever arms these arms whipped back, vibrated and swayed to such an extent that a number of the workmen, engineers, and visiting members of the engineering profession assembled to view the hoisting of the span, were thrown off their feet. These vibrations lasted for some seconds, then gradually subsided, leaving the anchor and cantilever arms in the same condition as they were before they had taken the weight of the span. Check elevations have since been made, and it has been established, after examination, that these arms are apparenly uninjured in any manner, after having been subjected to a more severe test than would have been possible under ordinary service conditions.

A Double-Action Split Float

The accompanying illustration shows a divided or "split float," as it is more commonly called, produced commercially as a result of an increasing demand on the part of concrete road builders. The difficulty which was experienced by road builders in getting the concrete on both sides of the joints in a true plane resulted in home-made split floats of wood, many of which are now in use. The tool shown in the accompanying illustration is of steel, and, while the general trade has not yet entirely accepted the idea of steel for a float where a float finish rather than a trowel finish is wanted, the experience of some users with just such floats has been most satisfactory, and their use is increasing. This float has the double action, which facilitates its manipulation. The tool is made of cold pressed steel, 6 in. wide by 12½ in. long, with a ½-in. opening in the centre so that the joint may be straddled. The bridging over this opening has an upward bend of 1½ in., giving ample room to take care of the surplus of felt strips used in the expansion joints. The tool is built to permit the use of a long handle. It is manufactured by the Abram Cement Tool Company.



A Double action Split Float Made of Steel.

Progress on Halifax Ocean Terminals

(Continued from page 942)

It is interesting to note in connection with the new railroad pier, No. 2, which has just been completed, that huge reinforced concrete piles, 77 ft. long and weighing 46,000 pounds, were employed and in driving them the largest steam hammer ever built was used, which, with its follower and guide, weighed 28,000 pounds. Its ram is 4,000 pounds in weight, and develops 3,916,000 foot-pounds per minute.

Railroad Excavation.

The total excavation in connection with the new railroad entrance to the harbor site involved an excavation of about 1,750,000 cubic yards, and the deepest cut was about 60 ft. It was impossible to balance the cuts and fills, so most of the work was in cut, the spoil being carried north to the freight yard and south to the breakwater and back-fill for the quay and pier wall.

The Canadian Pacific Railway during the fiscal year just ended carried 1,255,561,198 passengers one mile, against 1,164,488,630 last year. The grain carried this year was 276,788,209 bushels.

heated by steam, and new concrete covered with tarpaulins and kept warm with steam until well set. A steam coil placed in the bottom of the gravel pile proved very satisfactory and in very cold weather was assisted by pipes driven into the pile from the surface. In protecting the stop-log platform, which is a 15-in. slab, with a 15-ft. span, building paper was put down on the new concrete, on which was spread 3 inches of wood shavings, and 3 inches of manure. This made sufficient covering and left a smooth surface with no discoloration.

Concreting at 30 Degrees Below Zero

During the process of this work, the temperature dropped several times to around 30 degrees below zero, but little trouble was experienced from frozen concrete. Over the sluices, which were left in the dam to take the flow of the river during construction, spray froze in heavy sheets, which required much dynamiting to dislodge.

Under the contract the city agreed to unwater the pond to facilitate the construction, but found it impracticable to do so. This necessitated the construction of cofferdams during the winter in the headgate section in order to allow continuous operation of the power plant. Divers were necessary, the maximum head of water at these cofferdams being 25 feet. About 300 linear feet of cofferdam was constructed.

The contractors on the work were MacBean & Williams, of Montreal, who executed the contract under the supervision of Mr. Thos. Tremblay, city engineer of Sherbrooke, and Mr. M. A. Sammett, consulting engineer, of Montreal. The concreting equipment was furnished by the Pneumatic Concrete Placing Company of Canada, Limited.

Fabrication and Shop Work for Quebec Bridge

Extraordinary Size of Bridge Members and Machine Tools Called for Entirely New Shops—Specially Built Machines

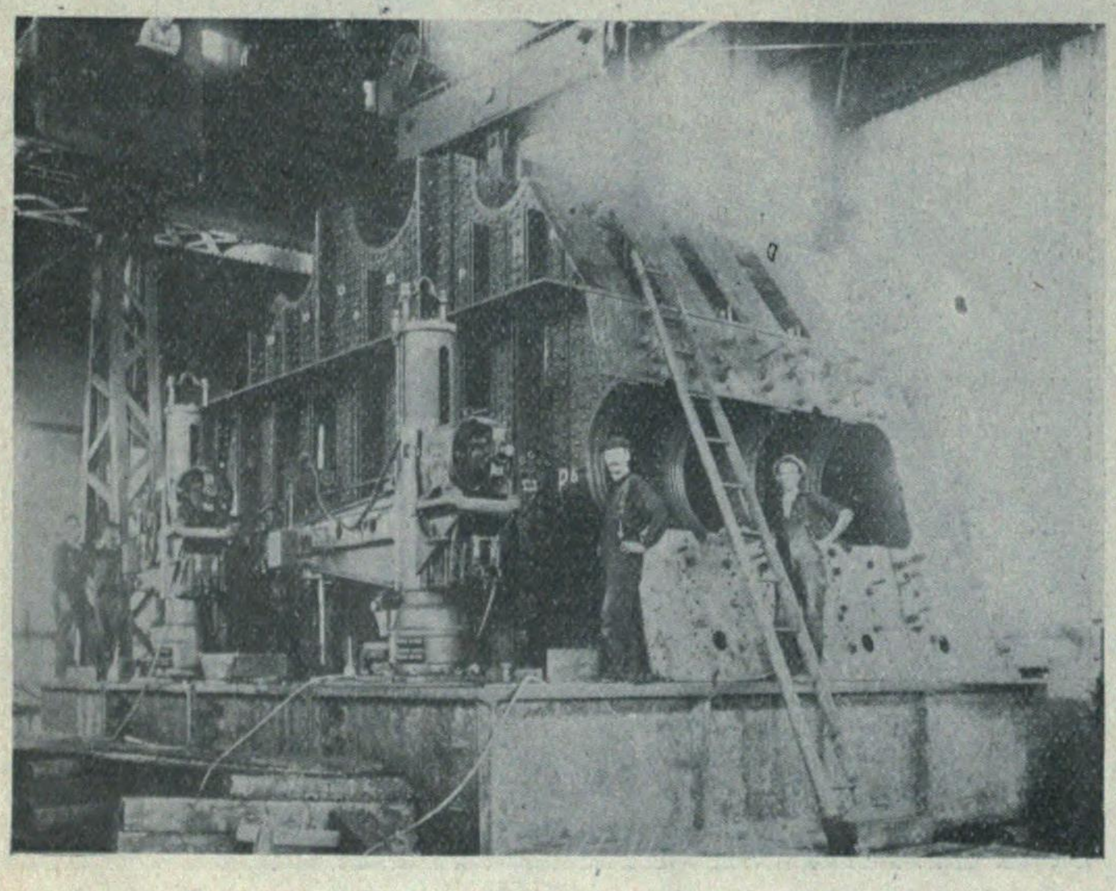
THE fabrication of the superstructure and the shop work of the Quebec Bridge were described by Mr. Phelps Johnson, president of the St. Lawrence Bridge Company, at the meeting of the Canadian Society of Civil Engineers, Montreal, on December 20. This was the third of the series of talks on the Quebec Bridge, and as on the previous occasions, the address was in the form of a commentary on a series of slides.

Mr. K. W. Blackwell, a past president, was in the chair, and prior to introducing Mr. Johnson, referred to the death of Mr. J. Hobson, who was a great engineer, and who had done splendid work, especially in railway engineering. He hoped the Council would send a message of condolence to the family.

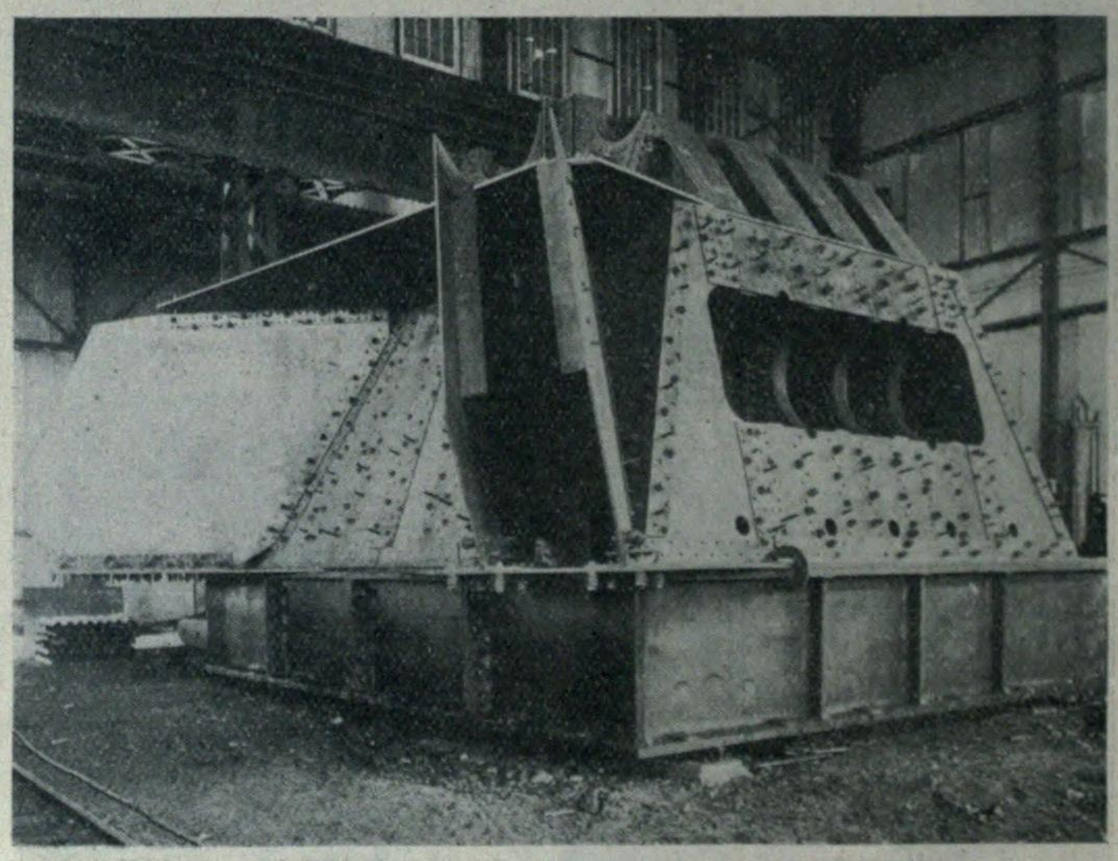
Mr. Johnson, in describing the work, commented on its great accuracy, and the immensity of the undertaking. He explained that although the Dominion Bridge Company, Lachine, and the Canadian Bridge Company, Walkerville (who combined to form the St. Lawrence Bridge Co.), had fine shops, it was decided to build an entirely new shop at Rockfield, near Montreal. This was owing to the fact that many of the members of the bridge were extremely large and heavy and called for tools of greater capacity than any in existence. The position of the Rockfield shop had decided advantages, as it enabled the material to be conveniently sent to both sides of the river. The shop was a fine specimen of workmanship and was very well equipped. In this connection Mr. Johnson paid a compliment to Mr. Ladd for the manner in which the work was fabricated and for his ingenious way of meeting problems, notably in the matter of drilling.

Mr. Johnson then described how the shops were designed, the method of dealing with material, and the various operations. One shop was 660 feet long, and was divided into two sections. The shop was equipped with two 70-ton cranes for the heavy work and two 35-ton cranes for the lighter members. The heavy members were dealt with on one side of the shop and the lighter material on the other.

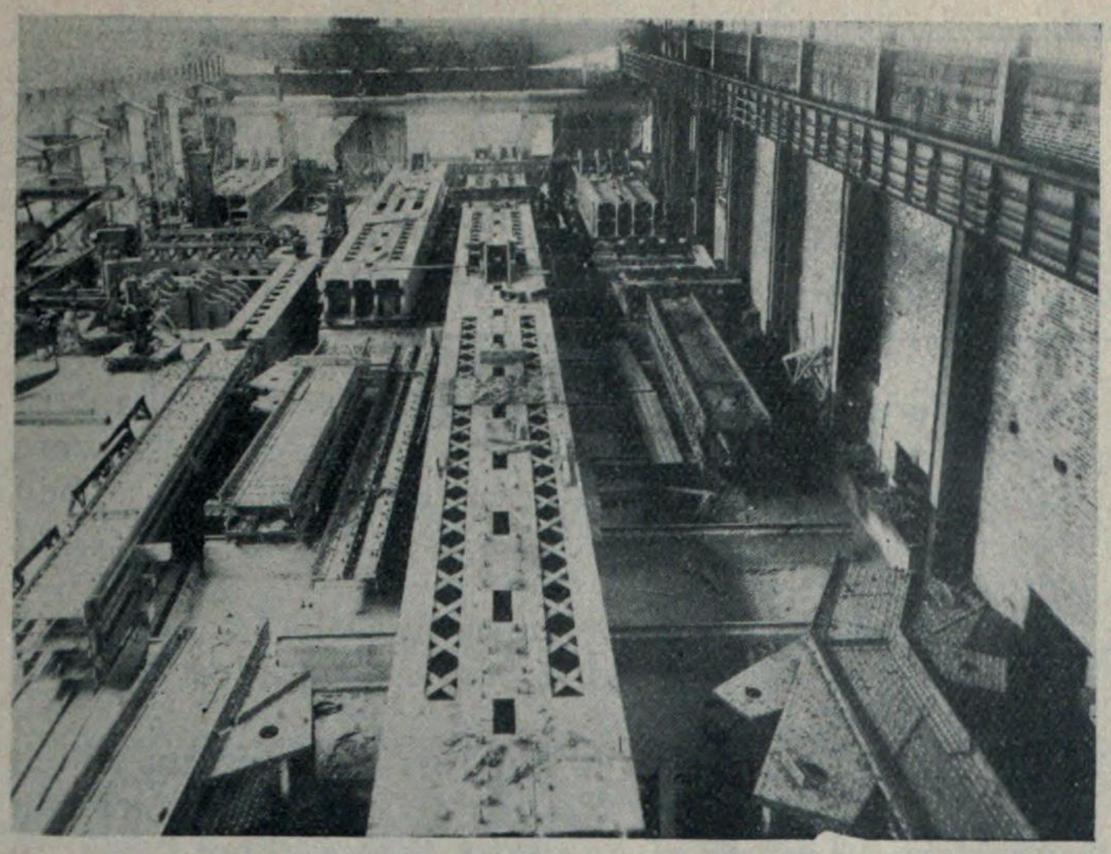
Fifty per cent. of the tools were Canadian made, some came from the old country, and others were



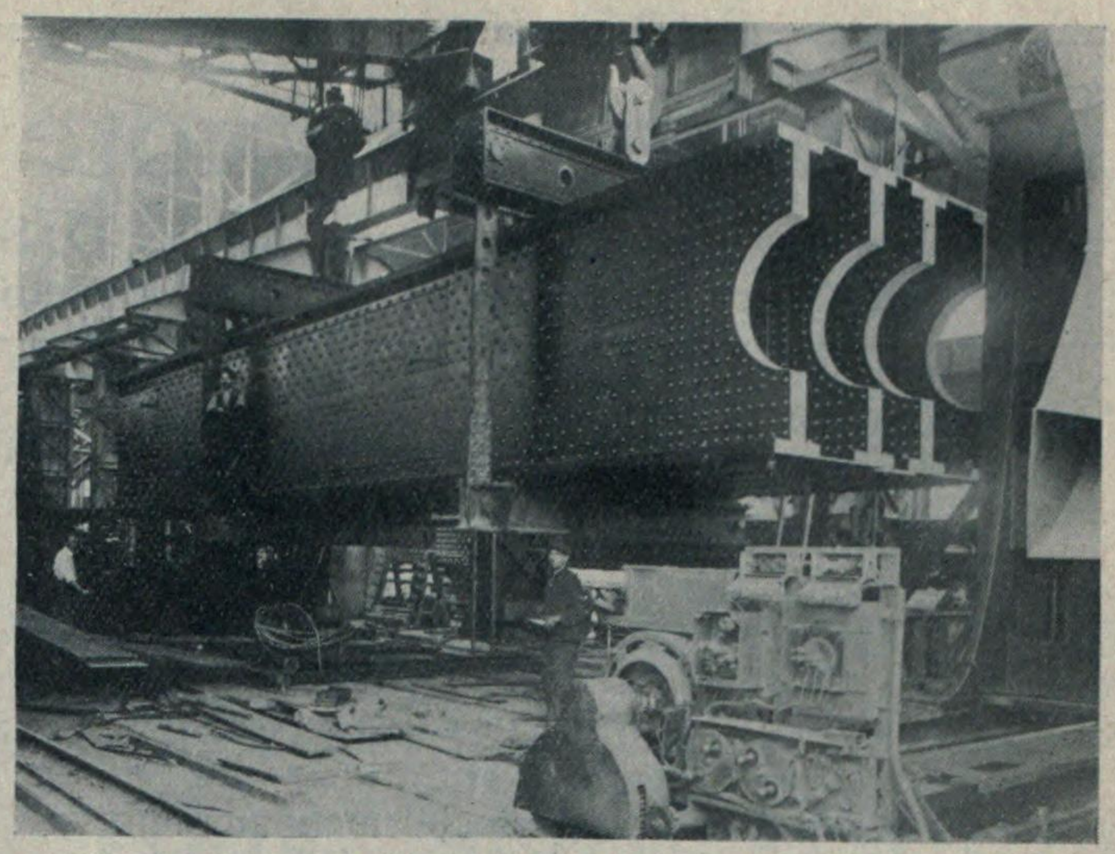
Reaming and assembling main shoe in shipping shed.



Shoe assembled before shipment.



Shop where heavy members were riveted, faced and bored.



Bottom chord of cantilever arm, section next to shoe, showing pin boring.

American. A series of pictures showed drills, made expressly for the work, horizontal and vertical planers, large borers, and riveters. The latter were stated to be very powerful, and were so designed as to give the full effect at the end of the stroke. There was ample stock used in the rivets. In showing pictures of the shoes, Mr. Johnson said that the steel castings were the largest made in Canada, and were of different descriptions. The large boring machine was specially built for the work. In planing, as much time was occupied in setting up the work as in doing it. The main posts weighed 1,200 tons, made up of four sections. All the heavy work was done on concrete skids carried down to rock.

Replying to questions, Mr. Johnson said that the rivets were of carbon steel.

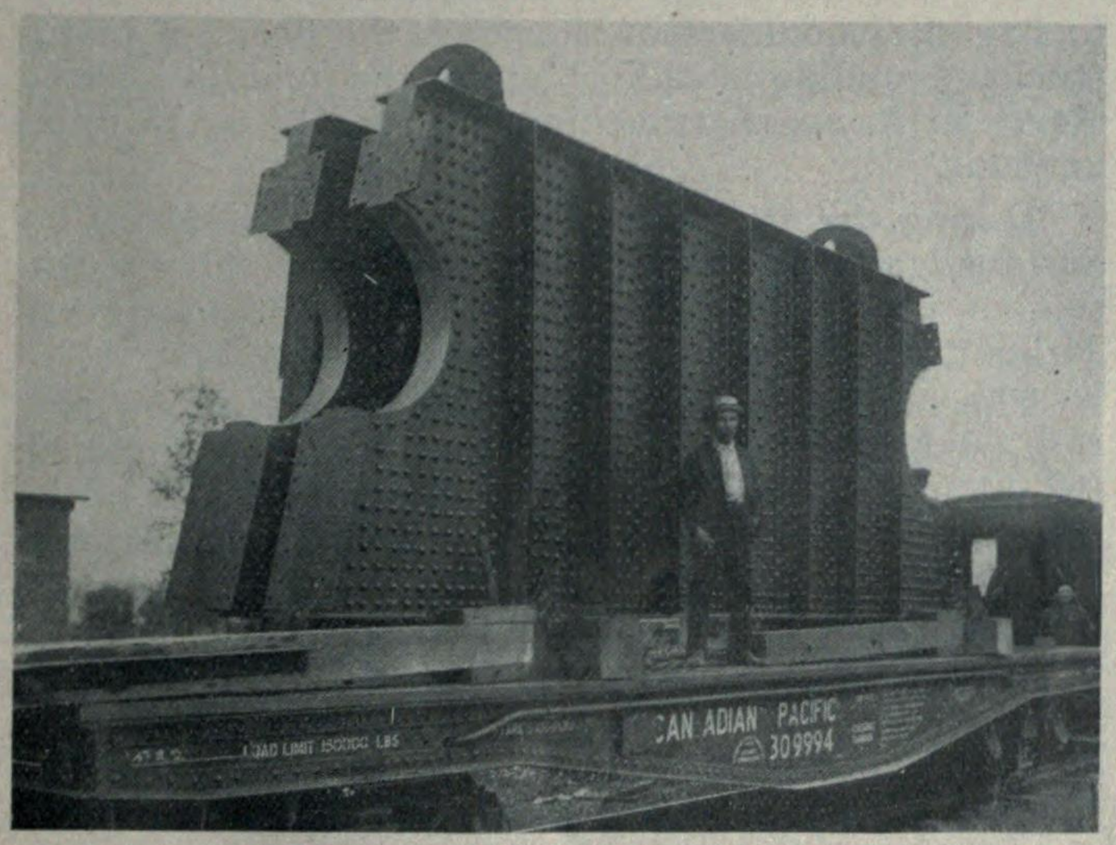
The Chairman spoke of the microscopic accuracy of the work, and it was satisfactory to know that so many of the special tools were designed and produced in Canada.

Brig. Gen. Sir Alexander Bertram, in moving a vote of thanks to Mr. Johnson, stated that he (Sir Alexander) had had much to do with the machining work. A great deal of rock had to be quarried in order to place the machines on the proper level, and thus secure absolute accuracy in the boring work.

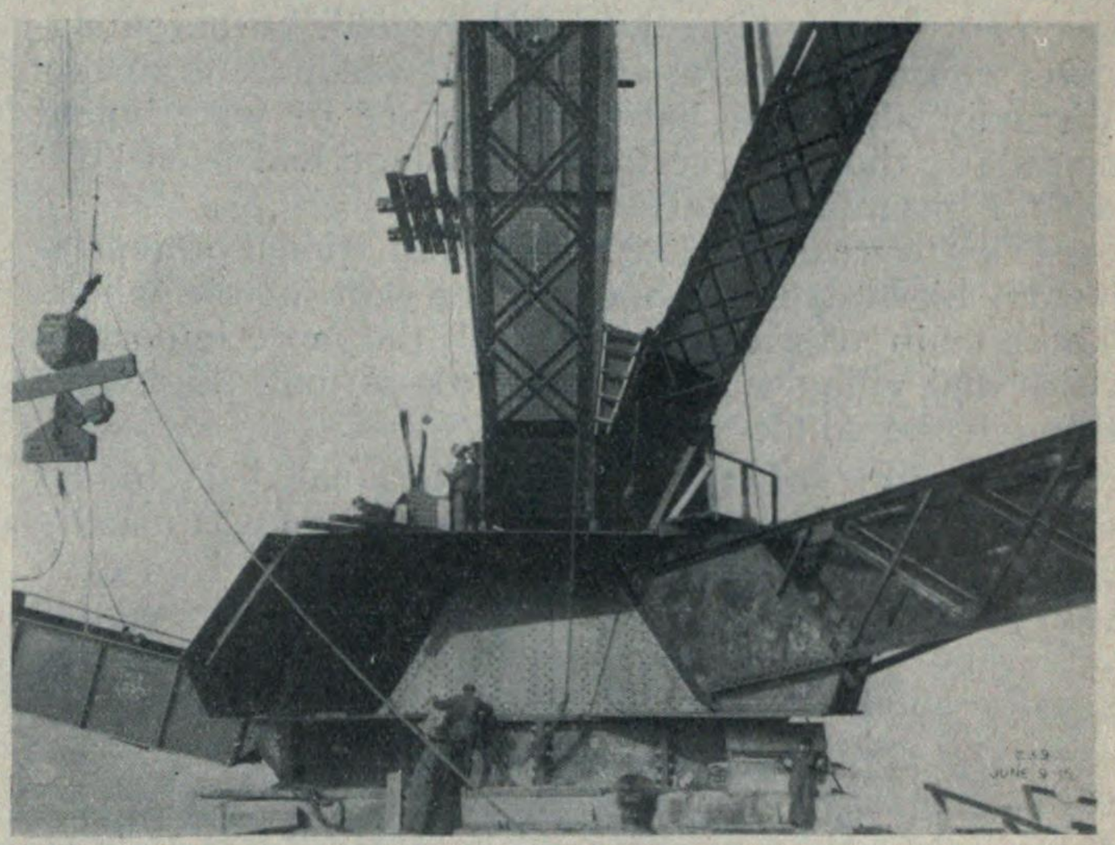
Senator J. P. B. Casgrain seconded the vote, and gave details of the inside history connected with the decision to abandon the proposed two 23-ft. roadway drives proposed in the original plans. He had a considerable influence in this decision, which saved four and one-half million dollars.

Dominion Bridge Company's Profits For Past Year

For the year ending October 31st, the profits of the Dominion Bridge Company totalled $1,186,436, a decline of $1,575,844, due, it is stated, to unremunerative contracts for shells and other munition work. Referring to the successful completion of the Quebec Bridge, Mr. Phelps Johnson, the president, states that the company will receive about $1,500,000 as its share of the profits accumulated in the seven years the work has been in progress and also benefit by the return of a good portion of the cash capital investment in the work. The company has secured contracts for marine boilers and engines totalling about $1,700,000, at prices which it is believed will prove satisfactory. The company has also secured contracts for fabricating ships' plates and frames which will keep the structural departments in Lachine and Toronto busy for seven months.



Middle section of main shoe loaded for shipment.



Main shoe showing connections made to cantilever arm side.

Tower Travellers of Gantry Crane Type Used to Erect Quebec Bridge

Details of Devices that Handled and Placed Steel for the Entire Structure—Each Traveller Equipped with Two Large Capacity Cranes and Four Derricks

By A. J. Meyers*

TO erect the main bridge material, tower travellers of the gantry crane type were used. The height and range of travel of these machines and their equipment of cranes, derricks, and auxiliary hoists were such that all the members of the cantilever systems were handled from the carrying trucks on the main bridge floor and placed into final position in the bridge, sometimes in pairs and sometimes singly, entirely by this means. These travellers, of which there were two—one for use on the north shore and the other for use on the south shore—were carried between the main bridge trusses on runways, located at the elevation of the bridge floor. On the anchor arms these runways were carried on special staging, placed between the falsework bents which supported the anchor arm trusses. On the cantilever arms they were carried entirely by the permanent bridge floor and the trusses of the cantilever arms.

The inside type of gantry crane traveller adopted was given the preference over the outside gantry crane traveller and over the top chord traveller sometimes used in the erection of cantilever bridges, because this inside type offered distinct advantages both in economy of erection material and ease of operation. The girders used for the runways were mostly part of the permanent bridge floor, and, having once been placed, did not have to be handled again. The entire control of the traveller equipment was located practically at the centre of operations, greatly facilitating supervision and the transmission of orders while handling the heavy truss members.

General Description of Traveller

As shown in Figures 1 and 2, the body of each traveller was a structural steel tower, about 190 ft. high over all, divided vertically into six tiers, with horizontal bracing on floors at the tier division points. The horizontal cross-section of the middle portion of the tower was a rectangle, 54 ft. by 37 ft. on side measurement and the vertical bracing in each tier of this middle portion was double intersecting on all four sides of the tower. The base or lowest tier of each traveller was made up of two Warren trusses, 23 ft. 3 in. deep, running longitudinally, parallel to the trusses of the main bridge and projecting to the rear to a total length of 90 ft. This tier was braced transversely with portal and lateral bracing, designed to allow derrick cars and material trains to pass on the two railway tracks underneath the main tower. These cantilever base trusses supported the main tower, and were carried on four six-wheeled trucks, running on double lines of rails, 6 ft. 6 in. centre to centre for each truck, the centre to centre distance of double tracks being 54 ft. and the length of wheel base on each track being 65 ft. 11 in.

The top or uppermost tier of each traveller consisted of a pair of trusses of the sub-vertical Warren truss type, running longitudinally and cantilevered out beyond the main tower, a distance of 57 ft. front and rear. These trusses were 18 ft. deep and 155 ft. long. They were braced transversely in vertical and horizontal planes, and served as runways for the two travelling cranes above. From the base of the traveller runway rail to the top of these upper travelling cranes the completed traveller was 210 ft. high, and weighed in working condition 920 tons.

Two Travelling Cranes and Four Derricks

Each traveller was equipped with two upper travelling cranes, each crane having a longitudinal travel on the top chord of the upper trusses of 119 ft. 3 in. These cranes were cantilevered out transversely beyond the tower of the traveller a distance of 29 ft., giving a total length of crane of 112 ft. between the end stop channels for the auxiliary gantry cranes, and they were designed with two 55-ton hoists each, which could work separately, in pairs, or all four together, in handling the heaviest bridge members. At each extreme end of a crane was located a small auxiliary gantry crane which travelled with the main crane and formed part of its equipment. These small gantry cranes were designed for a maximum lift of 10 tons on two 5-ton block and falls, and were used for handling the pin-driving and riveting cages.

Approximately 100 ft. up from the base of the traveller runway rail, seats for four 70-ft. 20-ton derrick booms were located, one seat at each of the four corners of the main tower. The ordinary working length of these booms was 70 ft., but in case of necessity the two front booms could be lengthened to 90 ft., in which case the seat of the boom was lowered 36 ft. to the floor below, provision having been made to accommodate the booms at these points.

As shown in Figures 1 and 2, the derrick hoists and operating machinery were placed on the second and third floors of the traveller. These floors, where the control for the hoisting and operating machines for the whole traveller was located, were the working floors for the operators. The controller house, which contained the switchboards, main hoist magnetic controllers, and resistances, was situated just underneath floor 2, to the rear of the traveller. Communication between the top and bottom of the traveller and the several intermediate floors was attained by means of an electrically-operated elevator and stairway encircling the elevator shaft, located in the centre of the rear face of the traveller, and also by a system of field telephones which thoroughly connected up the different fields of operation.

Transferring Load to Trucks

Each supporting truck of the traveller had six truck wheels, three for each rail, spaced at 4 ft. 6 in. centres longitudinally, giving a wheel base for each truck of 9 ft. The details of one truck are shown in Fig. 5. When the traveller was in motion along the bridge floor the two top travelling cranes rested to the extreme rear of the upper trusses, giving a condition of almost equal distribution of traveller dead weight upon

* Chief Draftsman, Board of Engineers, Quebec Bridge.

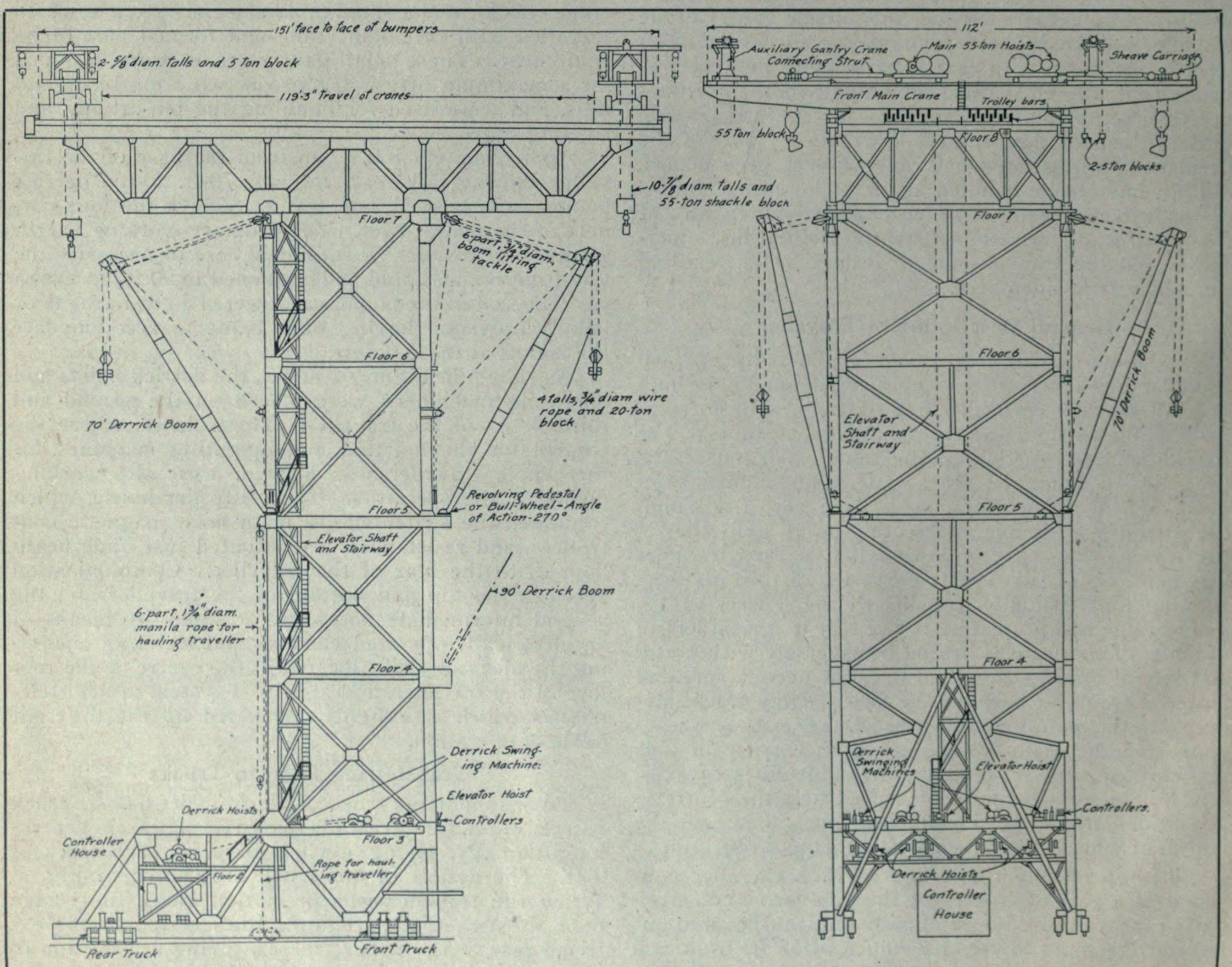
the four trucks. The reaction taken by one front truck under these conditions was 486,000 pounds. This 486,000-pound truck reaction was transferred from the bottom chords of the trusses through a 6 in. diameter pin to a longitudinal box girder, located between the web of the truss chord, with built vertical hangers riveted into the ends. These hangers distributed the load to transverse box girder beams through two 6 in. diameter pins at right angles to the pin connecting the truck to the bottom chord of the trusses. The transverse box girder beams were riveted to four vertical diaphragms projecting up from the two longitudinal box girders which transferred the reaction to the truck wheels.

That portion of the reaction taken by each one of the six truck wheels was transferred from the box girder to the wheels by means of four helical car springs. These springs each carried a load of 21,000 pounds while the traveller was in motion, but were designed to take a load of 30,000 pounds each before they would compress to their solid height. The use of these car springs and having the 6-inch connecting pins arranged at right angles to each other, as shown, insured that the truck reaction would be taken concentrically and symmetrically, and would be distributed equally over the six truck wheels, even if the traveller runways were somewhat uneven or out of level—a condition which could not be avoided.

Upper Runways Kept Horizontal

On account of the floor of the bridge being on a grade, which varied in inclination to the horizontal as the bridge was erected panel by panel, it was necessary to make provision for keeping horizontal the plane of the top chord of the upper trusses, which carried the main travelling cranes. This was accomplished by making the connection between the bottom chords of the lower trusses and the rear trucks of the traveller adjustable, by using, as shown in Fig. 5, two 5-inch diameter vertical bolts to transfer the reactions from the traveller to the trucks. The distance from the centre line of the bottom chords of the lower trusses to the base of traveller runway rail could be changed by moving the top travelling cranes to the extreme front of the traveller, thus reducing the dead load reaction on the rear trucks to a minimum and enabling the cast steel nuts at the upper ends of the 5-inch diameter bolts to be turned and the rear end of the traveller raised or lowered as desired, in order to bring the runway for the upper crane girders into a horizontal plane.

Provision was also made at the rear end of the bottom trusses to anchor the traveller to the floor girders whenever the traveller was lifting the heavier bridge members with the travelling cranes in their forward position, and whenever the traveller was lifting with these cranes to the rear, shims were driven between



Figs. 1 and 2—Each traveller is a six-tier tower with two top travelling cranes and four derricks.

the ends of the trusses at the rear and the supporting floor girders so as not to overload the rear truck springs. Under all working conditions the truck springs, both of the front and rear trucks, were locked at a height of spring which allowed the springs to take only a reaction equal to that which they carried while the traveller, with the top travelling cranes to the extreme rear of the upper trusses, was moving from one operating position to another. The front and rear reactions from the loads lifted were always taken care

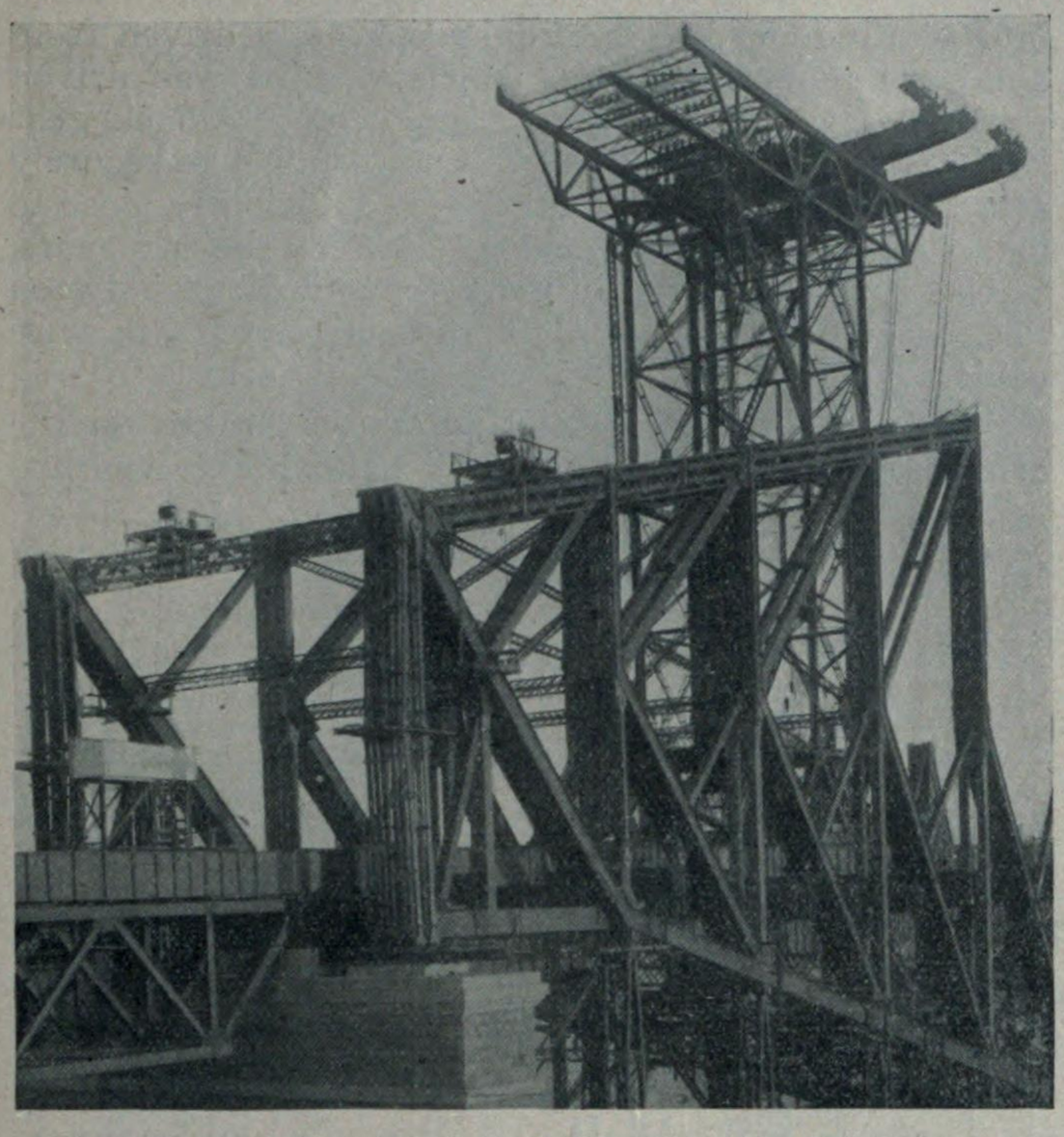


Fig. 3—View showing traveller on its last trip to the main pier, placing the upper web members and the upper bracing of the north anchor arm.

of by shimming between the traveller bottom trusses and the supporting floor girders or by anchoring the rear of the traveller against lifting.

Four 70 ft. Booms Handle Small Material

About 100 ft. up from the base, on the fifth floor of the traveller, were located the four 70-ft. 20-ton booms. These booms were used for handling the smaller material, such as sway and lateral bracing and floor material, and also pin-driving and riveting cages. They were built of four 6 x 6 x ⅜ in. angles, latticed, the outside dimensions of the cross-section at the centre of the boom being 3 ft. x 2 ft. 6 in. back to back of angles. Both ends of the booms were tapered to a bevel of 1½ in. in 36 in. At the upper end three sets of sheaves were provided to accommodate the four-part ¾-inch diameter wire rope tackle of 20-ton lifting capacity, and one set of sheaves to accommodate the six-part ¾-inch diameter top lifting tackle which operated the boom. At the lower end the booms were pin-connected to a revolving pedestal or bull wheel, having a horizontal angle of turning of 270 degrees, allowing the booms to operate in any position from the horizontal to the vertical, on two adjacent faces of the traveller. The front booms and their revolving pedestal were moved to seats on the fourth floor, 36 ft. 9 in. lower down, whenever it was found necessary, in placing material, to increase the reach of the boom from 70 ft. to 90 ft., by inserting a boom section 20 ft. long in the middle of the length.

Derricks Operated Electrically

These derricks were operated by four electric hoists, located on the second floor of the traveller. Each hoist was driven by a 51 h.p. 220 volt d.c. motor, with drum type controller and resistance necessary for hoisting, having a speed of 295 r.p.m., and geared to give a lifting speed under full load of 37 ft. per minute. These hoists were designed for a rope pull of 10,000 pounds with eight layers of ¾-inch wire cable on a drum. The two drums were each 15 in. diameter and 31 in. long, and were furnished with a differential brake band and a patent automatic brake on the pinion shaft strong enough to hold the maximum load. Each hoist had four spools 12 in. in diameter and 15 in. long, each spool being loose on the shaft and provided with sliding steel jaw clutch, operated by hand lever with latch and quadrant.

Each revolving pedestal or bull wheel of a boom was operated by 5 h.p. 220 volt d.c. motor, 700 r.p.m., located on the third floor of the traveller, and geared to give a rope speed of 25 ft. per minute with a maximum pull of 6,000 pounds in the rope. This motor was fitted with a mechanically-operated brake on the extended armature shaft. The use of this brake was to block the machine at night or when not in use. The motor was furnished with a reversible controller and the necessary resistance.

Pair of Travelling Cranes Handle Heavy Members

Travelling longitudinally, with the top chords of the upper trusses of the traveller as runways, was a

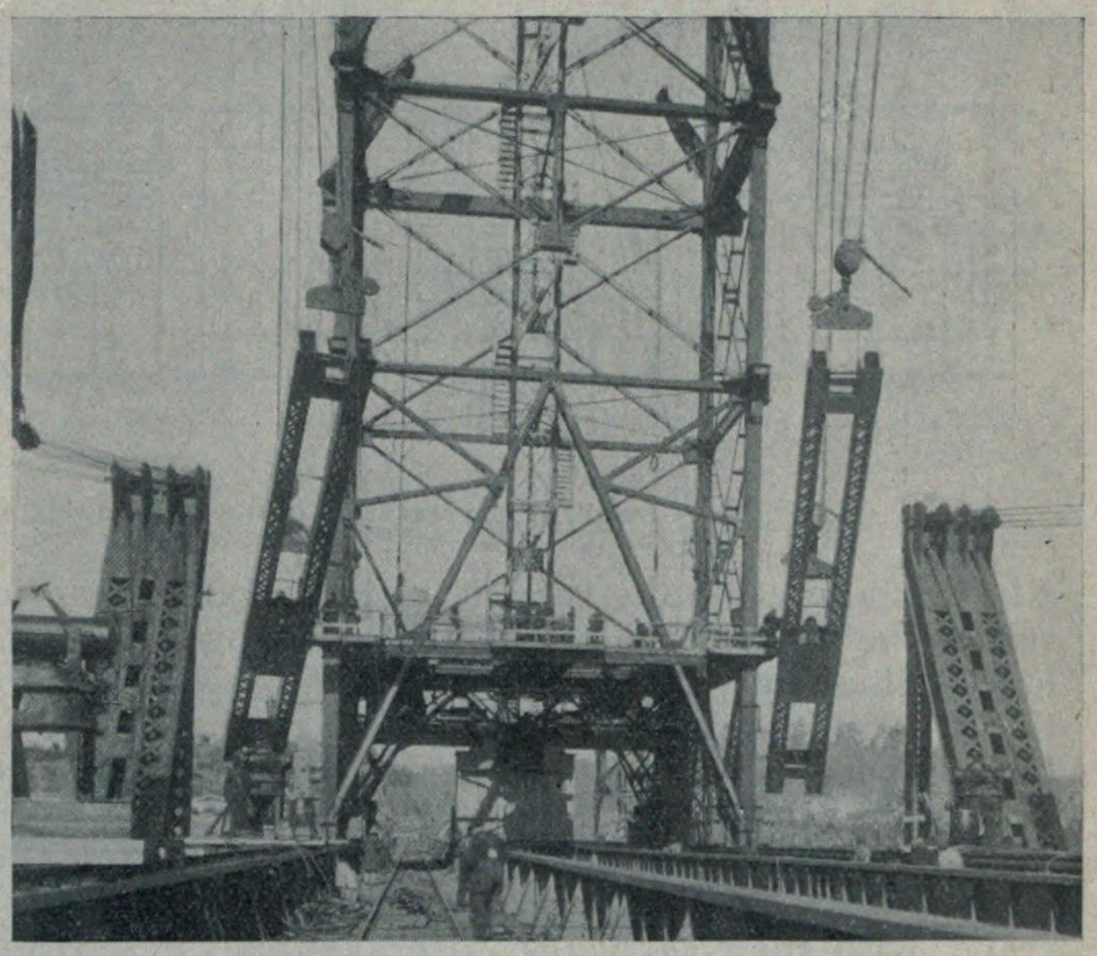


Fig. 4—Traveller hoisting and placing the corresponding members of the east and west trusses of the north anchor arm at the same time.

pair of transverse cranes, equipped to handle the heaviest members in the bridge, as shown in Fig. 6. Each of these cranes was built of two single webbed plate girders 5 ft. 6 in. deep and 113 ft. 4 in. long, spaced 8 ft. 6 in. centre to centre, and braced together for that portion of the crane, beween the runway trusses, with top and bottom laterals and vertical cross frames. Beyond the runway trusses the main girders cantilevered out on each side of the traveller a distance of 29 ft. 8 in., or far enough to command the vertical planes of the main bridge trusses.

These cantilevered portions carried between the main crane girders two runway girders 36 in. deep by

25 ft. long, spaced symmetrically about the longitudinal axis of the cranes and 3 ft. 11 in. apart, and framing into two cross plate girder diaphragms, one at the end of the crane girders and the other at the point of runway support. On these smaller girders were placed the runway rails for the sheave carriage of the 55-ton hoist. These sheave carriages travelled longitudinally on these runway girders when handling material from the loading cars on the main bridge floor to the final position in the main bridge trusses. These girders were braced to the main crane girders by intermediate cross frames, but a space of 2 ft. 10 in. between the girders was left clear for the full length of 25 ft., to allow for the longitudinal travel without obstruction of the 55-ton block and tackle of the main hoists.

Two 55-ton Hoists

The two main 55-ton hoists were symmetrically placed about the centre line of the crane girders, and were mounted on a carriage which travelled on cast steel rack rails running along the top flange of the main plate girders. The distance of travel longitudinally was limited to the section of the crane girders between the centre line of the traveller tower and the longitudinal runway trusses. The sheave carriage for the 55-ton block and tackle was connected to the main hoist carriage by a latticed channel strut, pin-connected at both ends, and moved longitudinally with the main hoist carriage at a fixed distance from it. This arrangement enabled the two main hoists of each crane, with their carriages, to be kept always within the two points of runway support for the cranes, giving greater stability to the design. Six 24-in. diameter sheaves were placed in the sheave carriage to accommodate the ten-part ⅞ in. diameter wire rope tackle for the 55-ton block vertically below.

The 55-ton capacity block and tackle of each main hoist was operated by one 75 h.p. 220 volt d.c. motor, with a speed of 550 r.p.m. Each hoist was designed to lift a gross load of 120,000 pounds at a speed of 12 ft. per minute, through a double five-part tackle, both ends of the hoisting wire rope being wound on the drums, thus making a rope speed of 60 ft. per minute.

Impossible for Load to Run Away

The controller system was of the magnetic switch type and arranged for dynamic braking, with a minimum lowering speed of 12 ft. per minute. The armature shaft had an automatic disc brake capable of holding the maximum load. It was, therefore, impossible for a load to run away, as, in lowering, the motor worked through a resistance greater than the load carried by the crane. The burning out of a fuse applied the full force of electrical resistance, preventing all motion. In order to guard against attempting to lift loads greater than those calculated upon, special fuses were provided which would blow out when the load reached its maximum. The hoisting drum was divided into two independent sections, separately driven from a second reduction shaft, which in turn was driven through a single pair of cut gears off the back gear shaft of the hoisting motor. One drum was securely attached to the axle; the other was sufficiently loose to insure equal division of the load between the two gears. Each drum was 36 in. in diameter and 31 in. between flanges, and capable of holding five layers of ⅞ in. wire cable.

In case of failure of the automatic brakes on the armature shaft, a hand-operated band brake was furnished on the extension of the back gear shaft of the motor. This brake was of sufficient capacity to stop and hold the maximum load lifted. It was operated by a lever with a locking attachment so that the hoisting block could be locked fast at any point independent of all other brakes.

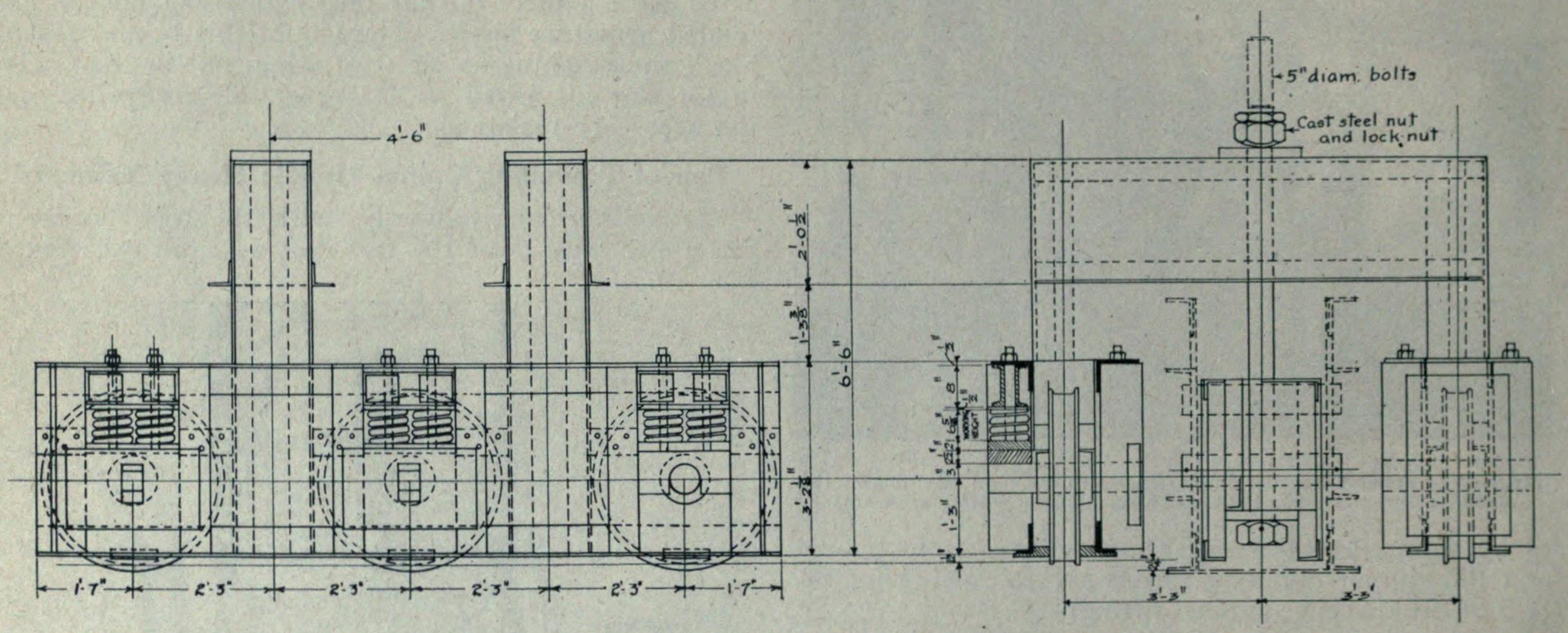


Fig. 5—Details of one rear truck of traveller showing method of adjustment to keep top crane runway horizontal.

A 5 h.p. 230 volt d.c. motor, with a speed of 800 r.p.m., was used to move the hoist and sheave carriage along the rack rail. The propelling gear moved the sheave carriage with the maximum load suspended at a rate of 10 ft. per minute, and was capable of holding the hoist carriage against an endwise thrust of 30,000 pounds, due to fleeting loads from the centre of the traveller, but was not capable of moving the carriage against this thrust.

The main shackle blocks, 55-ton capacity, weighed 1½ tons each. They were designed to be self-lubricating. In their highest position these main blocks were 193 ft. above the base of runway rail for the traveller. To prevent over-winding, each main hoist was provided with a Youngstown limit stop, which interrupted the lifting motor current and applied the brake immediately when the block reached the limiting position.

At each end of the main travelling cranes was lo-

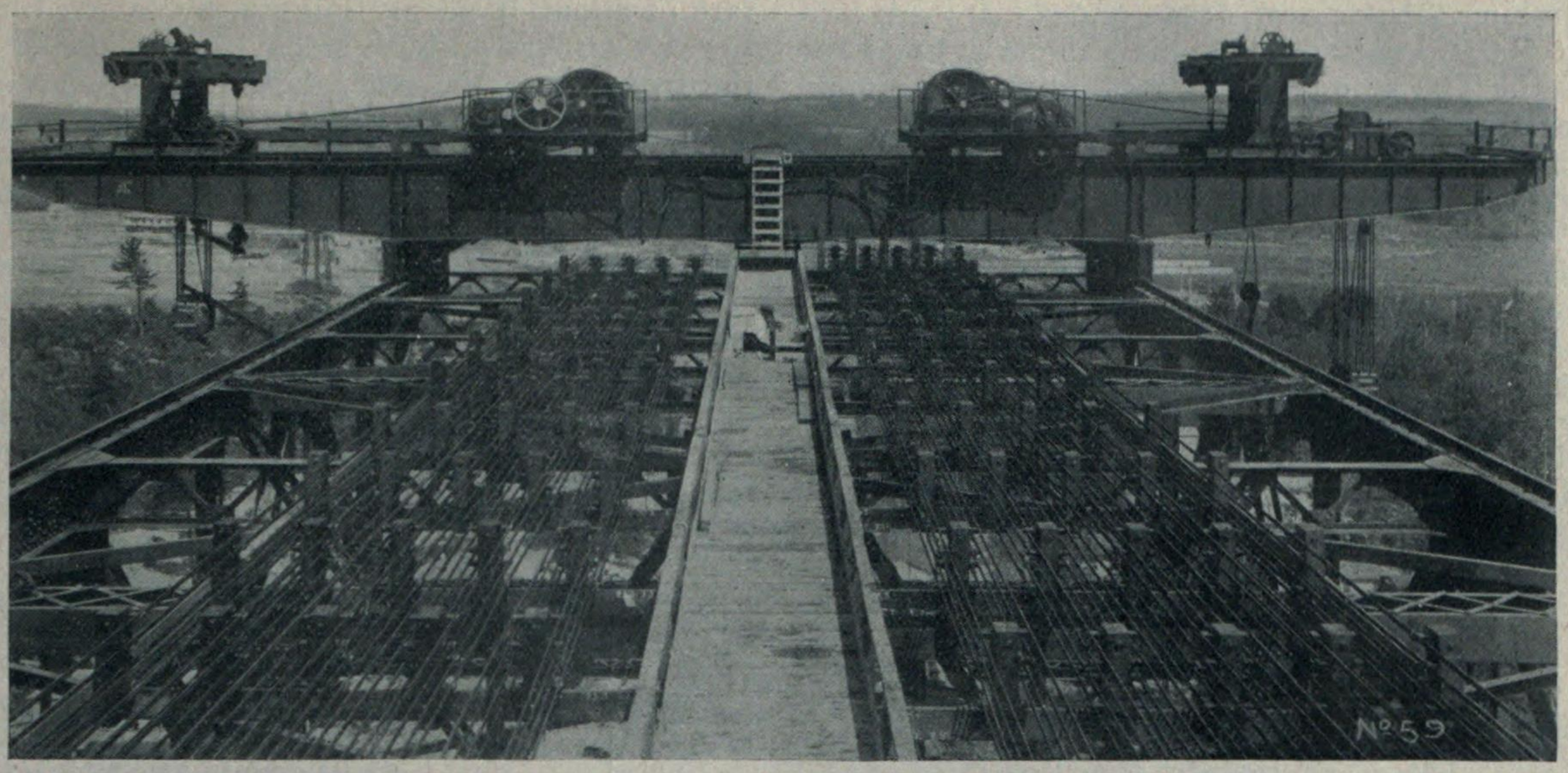


Fig. 6.—View of travelling crane on top runway trusses, showing trolley bars and arrangement of hoisting machinery. These are electrically operated by controllers placed where the operator has full view of the loads being elevated and within easy reach of the foremen issuing instructions.

cated a small auxiliary crane of the gantry type, having an overhang from one support of 2 ft. and from the other support of 9 ft., for the purpose of handling pin-driving and riveting cages. These auxiliary hoists spanned over the sheave carriages for the 55-ton falls, and travelled on eyebeam runways placed on the top flanges of the cantilever section of the main crane girders, having locking wheels underneath the top flange of the eyebeams to keep the gantry in place and to take the uplift from the maximum lift of 10 tons at the end of the 9-ft. arm. Each auxiliary crane was equipped with two 5-ton blocks, which had a transverse travel from end to end of channel runways of 20 ft. normal to the axis of the main travelling crane. They were moved longitudinally on the eyebeam runways by hand power. The 5-ton blocks with two-part 5/8 in. diameter wire rope tackle were controlled by hoists located in the centre of the main crane girders on platforms carried between the bottom flanges. Each hoist had two 16 in. diameter drums, and each drum was operated by a 30 h.p. 220 volt d.c. motor, with a speed of 575 r.p.m., and geared to give a rope speed under full load of 150 ft. per minute.

Crane Trucks

Each main travelling crane was carried on four trucks having two 30 in. diameter wheels per truck, spaced at 4 ft. centres with 3 in. thread, the total length of wheel base on one runway rail being 12 ft. 6 in. The trucks were made of a double web box plate girder 30 in. deep and 7 ft. 6 in. long. Each crane was driven by a 220 volt 16 h.p. d.c. motor, having 725 r.p.m., and

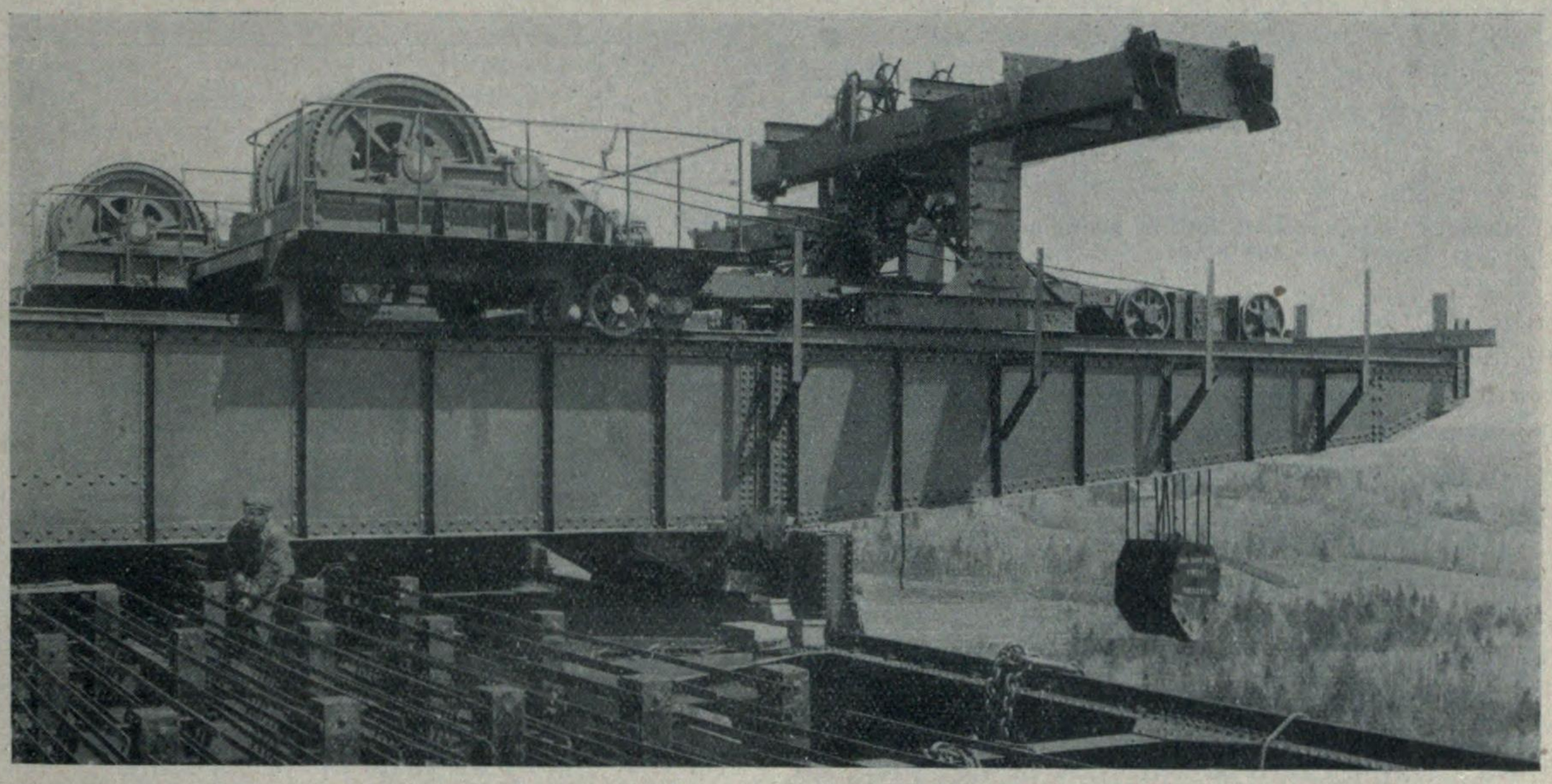


Fig. 7—Showing main 55-ton hoist, auxiliary gantry crane and sheave carriage.

geared to give a traversing speed of 25 ft. per minute when climbing a 1 per cent. grade under full load, estimated at 500,000 pounds, including the weight of the crane itself. The motor was located between the main girders at the centre on a platform on the level of the bottom flange, and the driving power was transmitted symmetrically to the trucks on each rail by gearing and a 3½ in. diameter shaft. Provision was made in this shafting to take down any section without having to remove any other section. Only two truck wheels at each end of a crane were driven. These driving wheels were keyed to their axles, which carried gears on an extension, the other wheels turning loose on their axles.

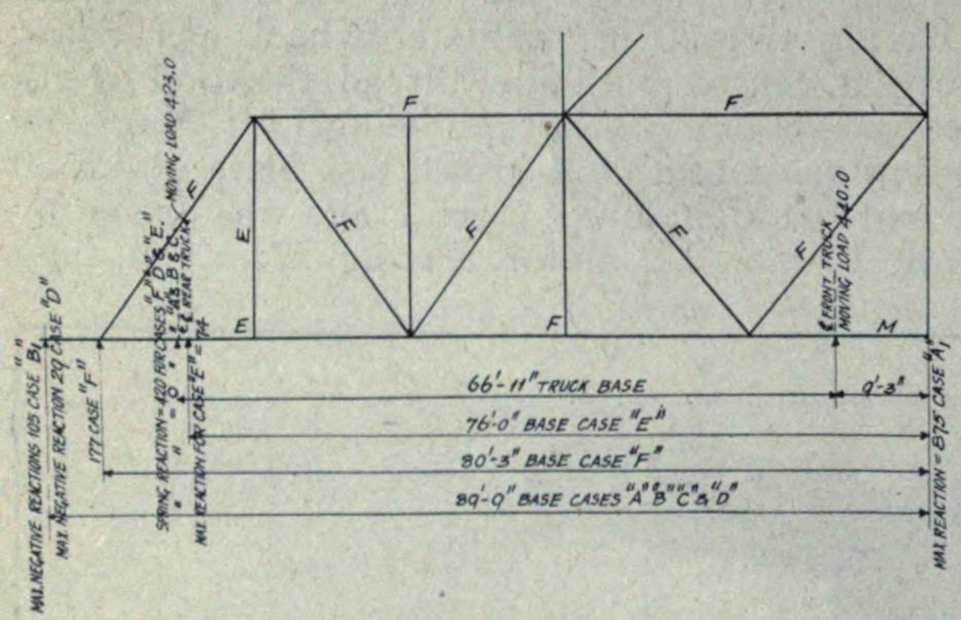
While the main cranes were in motion along the runways the contact for the electrical current for the numerous motors was maintained, as shown in Figures 2, 6 and 7, by a system of 20 lines of 1½ x ⅜ in. trolley bars, four tiers deep.

Electric Lift to Connect Floors

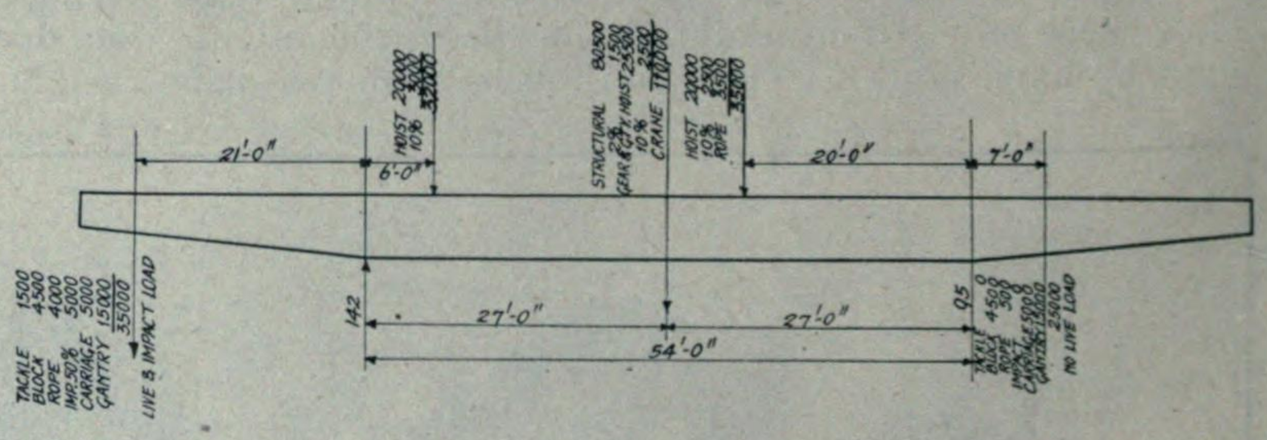
The electrically-operated elevator which gave ready access to the different floor levels and working platforms of the traveller was driven by a 15 h.p. d.c. motor, running at 575 r.p.m., and geared to give a full load lifting speed of 75 ft. per minute. The passenger car was supported by two falls of ⅝ in. wire rope, winding one part on a 14-in. drum, and the whole of the machinery was located at the foot of the shaft on the third floor of the traveller. The controller was located in the car, and was arranged for dynamic control. The motor was provided with a solenoid brake.

The traveller was moved a long the bridge floor at a rate of about 10 ft. per minute, by taking hold of the runway girders on both sides of the traveller either to the front or to the rear, depending upon the desired direction of motion, with a 1¼ in. diameter wire rope, which passed through sheaves located in the bottom chords of the lower trusses just below the rear face of the tower. These 1¼ in. ropes ran vertically up and connected to a six-part 1¾ in. manilla rope tackle, one at each rear leg of the traveller tower. The 1¾ in. rope was continuous from the tackle on one side of the traveller to the tackle on the other side of the traveller, and was overhauled by the drums of the derrick hoists located on the second floor. By this arrangement of tackle the pull at the two sides of the traveller was always the same, no matter if one or two hoists were working.

Wheel loadings for maximum stresses and reactions of travellers. Letters on truss refer to loading giving maximum stresses.



Maximum reactions; letters refer to loading giving maximum stresses and reactions.



Method of loading cranes to obtain wheel loadings shown above; loads in pounds.

Weight of Traveller Was 920 Tons

The total weight of one traveller, including its complete equipment of derricks and cranes, was 920 tons. The amounts of this weight contributed by the different component parts of the traveller were:

	Tons.
Runway trucks	65
Bottom supporting trusses and bracing	120
Main tower frame, floors, and bracing	170
Wood in floors, etc.	30
Top crane runway trusses and bracing	165
Elevator shaft and stairway	19
Main travelling cranes	210
Auxiliary gantry cranes	36

Derrick booms and tackle	50
Wire and manilla rope (except for main cranes)	8
Electric wiring	3
Derrick hoisting engines	32
Miscellaneous machinery on operating floor 3	12
Total	920

Shims Take Live Load Reactions

When the traveller was being moved from one working position to another, both top travelling cranes were moved to the extreme rear positions and anchored. For this condition of loading the reaction on one front truck was 486,000 pounds, and on one rear truck 450,000 pounds. When the travellers were in operation the weight of the main top travelling cranes was treated as a live load along with the loads lifted by these cranes. Under these working conditions shims were driven at the front and rear of the traveller between the lower trusses and the supporting runway girders and floor-beams. When placing these shims the main travelling cranes were moved into such positions so that the final reactions from the dead weight of the traveller, exclusive of the weight of the main cranes, was 486,000 pounds on one front truck, 36,000 pounds on the front shim reaction, and 165,000 pounds on the rear shim reaction. The rear truck springs were locked at this working height, but the front truck springs were left free, because no negative reaction could possibly reduce the reaction on the front truck below the 486,000 pounds which it carried under moving conditions. Under working conditions the rear of the traveller was anchored to the runway girders in order to take a negative reaction when the main cranes were working in the extreme forward position.

Features of Design

Although in the actual erection of the largest bridge members the members were lifted and placed by the travellers in pairs, one for each truss at the same time, giving a condition of symmetrical loading for the traveller, the traveller itself was designed to lift only one of these heaviest members for one truss at one time, this unsymmetrical condition of loading giving considerably larger stresses and reactions on the side of the traveller carrying the load than would maintain with the symmetrical loading.

The positions of the main travelling cranes and the wheel concentrations for maximum lifts in these positions are shown in Fig. 8. These positions give the maximum reactions and stresses for the traveller and its members. Cases A1 and A2 might have existed when the first section nearest the main pier of the bottom chord of the cantilever arm was erected. This member weighed 160,000 pounds, the weight when lifted being equally distributed between the two cranes and on one side of the traveller. Cases B1, B2, and B3 were for the assumed maximum capacity of lift on one 55-ton block and tackle—that is, 110,000 pounds on one side of the traveller. Case C occurred when lifting the heaviest section of the main shoe, weighing 130,000 pounds, on one side of the traveller, 65,000 pounds being taken by each crane. Cases D and E occurred when placing the compression diagonal members of the anchor arm. In both cases the full weight was taken by the front crane, 65,000 pounds for case D, and 60,000 pounds for case E. Case F occurred when erecting the end compression diagonal of the anchor arm the whole weight of the member—113,000 pounds—being taken by the rear crane.

Impact Proportions

In proportioning the runway girders, supporting floor-beams and staging, 20 per cent. impact was added to the reactions from the load lifted and from the weight of the lifting blocks and tackle. In proportioning the members of the traveller tower and trusses 50 per cent. impact was added to the reactions from the same causes.

Stresses and reactions from longitudinal and transverse wind acting on the traveller were calculated on the assumption of a wind pressure of 30 pounds per square foot on the exposed area of two parallel faces. No wind was assumed to be acting when members were being lifted and placed.

The members of the traveller when being manufactured in the shop were made of such a length that, under the dead weight of the traveller, the front and rear ends of the top runway trusses would be 6.21 inches and 5.95 inches respectively above their geometrical position. This camber was so chosen that the crane track at the loaded end would be approximately level under maximum deflection during operation.

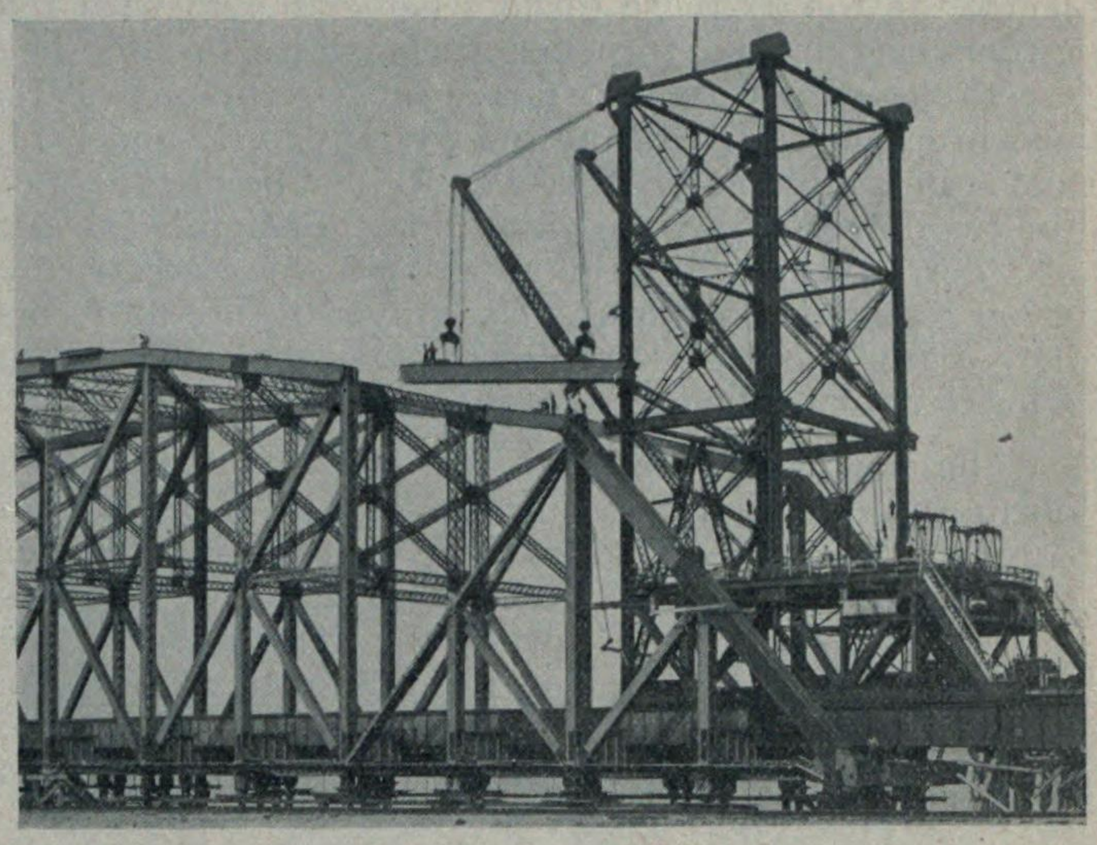


Fig. 9—Traveller completing erection of suspended span. The top runway trusses and main travelling cranes were not needed for this work.

In designing the traveller the unit stresses allowed were: For compression on carbon steel, 16,800 pounds per square inch, for members with l/r less than 50, and 21,000—84 l/r for members with l/r greater than 50. For tension stress on carbon steel and for extreme fibre stresses in bending in girders and beams 21,600 pounds per square inch was used, and for shear in the webs of plate girders and beams 12,000 pounds per square inch. Wherever nickel-steel was used these allowed unit stresses were increased by 40 per cent.

Nickel-Steel Reduced Weight

In order to reduce the weight of the completed traveller as much as possible nickel-steel was used for the main material in the main traveling cranes and the top runway trusses. The material in the main tower and the lower supporting trusses and all the bracing was of carbon steel.

The largest stress in the tower columns was 1,299,000 pounds, demanding a carbon steel section of 79 square inches. This member was made up of two 24 x ¾ in. plates and four angles 8 x 6 x 13/16 in. latticed. In the runway trusses at the top of the traveller the largest stress in the top chords which carried the runway rail for the main cranes was 1,344,000 pounds

than the traditional specification requirement for width not less than one-twentieth of the span. A spacing of 37 ft. was adopted; earlier, a spacing of 40 ft. had been considered.

To assure long life of bridge, a large future increase of loading was counted on. The train load was assumed at 7,500 pounds per foot of track, and the engine driving-axle loads at 90,000 pounds. These figures represent a margin of at least 25 per cent. over present-day traffic weights. They may be regarded either as regular design loading for normal service stresses or as emergency loading by which to test the design for safety under limiting conditions.

Big Problem Was to Keep Down Weight

The important problem in the detail designing was to hold down the weight to an absolute minimum.

It was Mr. Cartlidge's strong conviction that all the weight economy obtainable by the use of eyebars as tension members should be obtained. In carrying this into effect, even the sub-hangers, which carry the intermediate floorbeams, were detailed as eyebars. The hip vertical is also made an eyebar member, but for erection service it was given some value as a strut by riveting a transverse plate diaphragm longitudinally between the bars.

Most characteristic of the bridge is the use of long (72 ft.) eyebars in the bottom chord. There is no connection between these bars and the floorbeams at the subpanel points, but a simple stirrup at the end of the floorbeam supports the bars. By this arrangement secondary stresses due to distortion of the subpanel triangle under load are eliminated, while at the same time the weight of a pin and two sets of eyebar heads is saved.

The economy secured through use of the eyebars is represented by the sum of 10 to 15 per cent. saving of section in rivet holes and details and 5 to 10 per cent. increase in unit stress allowable in eyebars over built members. Thus, about 25 per cent. of the weight of tension members in the trusses was saved, comparing with built members of nickel-steel, and about 35 to 40 per cent. when comparing with members of silicon steel. Because the eyebars were so important for economy, they were used even where serious difficulty was encountered in making room for the end connections. Diagonal U4-L6 was a case where the substitution of a built member would have simplified the joint details considerably, but eyebars were retained.

Contractors Objected to Eyebars

When the erection problem was worked out by the contractor, the eyebars in the web system and the long bottom-chord eyebars were objected to because of the delay resulting from the awkwardness of handling such long, flexible members. But the engineers adhered to their plans, and, as already stated, the only use of built members in tension is in the diagonals of the four middle panels and the bottom chord in the end main panel.

To save weight of lattice and other detail metal in compression members, the top chord and the posts were detailed of H-section, using a central transverse diaphragm. For example, the middle top-chord member consists of two webs 42 x 1¾ in., four angles 8 x 8 x 1⅛ in., four flats 10 x 13/16 in., and a diaphragm with web 32 x ¾ in., and four angles 6 x 6 x ⅝ in. All of this metal is effective cross-section, and, while top and bottom lattice is also used, it forms a much smaller proportion of weight than would otherwise be needed.

Partly because of the presence of the diaphragm, very thick plates in the side ribs of the top chord were thought permissible—as the 1¾ in. plates just noted. Some difficulty developed in the shop in securing acceptable plates of these dimensions, especially with regard to straightness, or freedom from waviness at the edges. It is now believed to be better practice to use plates not thicker than 1 in. to 1¼ inches.

In the floor occur one or two interesting weight-saving details. There is only one stringer lateral system, between the two centre stringers; occasional struts in the plane of the upper flange extend over to the outer stringers to brace them. There is no traction bracing. Longitudinal forces pass from the stringers into the subpanel floorbeam, and this must transmit them (by bending) to the middle of its length, where the diagonals of the main bottom lateral system are attached to the lower flange. These diagonals clear the lower flanges of the stringers, but are hung from them by stirrups.

Quebec Bridge Designs Discussed at C. S. C. E. Meeting

YET another phase of the design and construction of the Quebec Bridge was dealt with by Mr. George H. Duggan at the meeting of the Canadian Society of Civil Engineers, Montreal, on January 10. Mr. Duggan, chief engineer of the St. Lawrence Bridge Company, spoke on "Tendering Designs of the Quebec Bridge." He first outlined the steps taken to form the board of engineers, to collect data, and to prepare trial designs. The board made the most careful investigations into the engineering features of great bridges in many countries. Mr. Duggan explained in detail the differences in design between the Forth Bridge, the Quebec Bridge which collapsed, the design by Mr. H. E. Vautelet, the ex-chairman of the Quebec Board of Engineers, which was not adopted, the official design ultimately decided on, and the design of the St. Lawrence Bridge Company now carried out. The company made thirteen bids on the official design and on their own, and spent many months working out the details of both plans and investigating the use of nickel and carbon steel before tendering.

Mr. Duggan also pointed out what he considered weak elements in Mr. Vautelet's design and also in the official plan, emphasizing the phases of erection in relation to the travellers proposed to be installed. He showed that, owing to different conditions, it was impossible to adopt the same methods of erection as in the case of the Forth Bridge, and gave reasons for the non-adoption of features in that bridge and in the first Quebec Bridge.

A considerable portion of Mr. Duggan's address was devoted to explanations of why various plans were adhered to, directing special attention to the value of the K truss. He stated that they considered seriously the adoption of the truss in the central span, but found certain difficulties which made it advisable not to use it for that portion of the work. He concluded by an appreciation of the services of various members of the staff of the bridge company.

Clearing Snow from Country Roads

Snow may be removed from roads by using a road-drag in reversed position, so that it will push the snow into the side ditches.

Lieut.-Col. Monsarrat Tells Toronto Branch, C.S.C.E., of Quebec Bridge

LIEUT.-COL. MONSARRAT, chairman and chief engineer of the board of engineers responsible for the final success of the Quebec Bridge, addressed the Toronto branch of the Canadian Society of Civil Engineers (Engineering Institute of Canada) on Tuesday evening, February 12, in the Chemistry and Mining Building at the University of Toronto. Col. Monsarrat delighted his audience by his simple, though comprehensive, description of the details which led up to the final successful conclusion of this, the greatest piece of bridge engineering of modern times. He touched briefly on the history of the project and the circumstances which resulted in the Dominion Government deciding to go ahead with the work, the disappointments of 1907 and 1916, and, finally, the almost superhuman precautions which ended so auspiciously on September 17, 1917. The lecture

Lt.-Col. C. N. Monsarrat.
British and Colonial Press Photo.

was illustrated by views of the work in its various stages.

At the conclusion of the address Professor Haultain moved, and Mr. G. A. McCarthy seconded, a hearty vote of thanks.

Asphalt Production

STATISTICS just completed under the supervision of J. D. Northrop, of the United States Geological Survey, Department of Interior, indicate that the year 1916 was one of prosperity for the asphalt industry in the United States. The quantity of natural asphalt, including bituminous rock, grahamite, gilsonite, wurtzilite, and the natural paraffin, ozokerite, produced and sold at mines and quarries in the United States in 1916 was 98,477 short tons, valued at $923,281, a gain of 22,726 tons, or 30 per cent. in quantity, and of $396,791, or 75 per cent., in market value, compared with 1915. All branches of the asphalt industry shared in the general prosperity, and the gains in output included, except for grahamite, each of the principal varieties of natural asphaltic material produced in the country.

The quantity of manufactured asphalt produced in 1916 from crude petroleum of domestic origin increased only 3½ per cent., as compared with that produced in 1915, and the quantity of similar material manufactured in the United States from Mexican petroleum increased 47 per cent., as a consequence of which the net gain over production in 1915 was nearly 20 per cent.

The total sales in 1916 of manufactured asphalt derived from domestic petroleum amounted to 688,334 short tons, valued at $6,178,851. Of this quantity 404,000 tons, valued at $3,158,603, consisted of road oils and fluxing material, and 284,325 tons, valued at $3,020,248, consisted of solid or semi-solid products utilized for paving.

California led all other states in the production of manufactured asphalt, its output from sixteen refineries in 1916 amounting to 257,300 short tons, valued at $1,958,946, and consisting of 108,288 tons of road oils and fluxes, valued at $633,579, and 149,702 tons of paving residuals, valued at $1,325,367.

The total sales in 1916 of manufactured asphalt derived from Mexican petroleum amounted to 572,387 short tons, valued at $6,081,851. Of the quantity sold, 295,682 tons valued at $2,486,938 consisted of road oils and fluxes, and 276,705 tons, valued at $3,531,913, consisted of residuals utilized for paving.

Quebec Government Has Given Authority for Construction of Storage Dams

THE Quebec Government, in pursuance of its policy of developing the water-powers of the province, has passed several bills authorizing the Quebec Streams Commission to construct further storage dams—this authority, however, being subject to the consent of the Lieutenant-Governor-in-Council. Thus dams may be built on Lake Kenogami, a branch of Lake St. Jean; on the Chicoutimi and Sable Rivers; the St. Anne and Sauvanne Rivers; the Jacques Cartier River, and elsewhere. The expenditure authorized is $4,000,000, but it does not follow that these works will be carried out immediately. The commission has made studies and plans of the possibilities of water storage on numerous rivers. Under another bill, power is given to purchase railways, camps, a power plant, shops, machinery, etc., used by the St. Maurice Construction Company, in carrying out the contract for the building of La Loutre dam on the St. Maurice River. The price is not to exceed $500,000. The purchase is subject to the Shawinigan Water and Power Company, Brown Corporation, and Laurentide Company, Ltd., agreeing to reimburse the commission $1,000,000 over the price payable under a previous contract for supplying water by the damming of the St. Maurice. The payment of the $1,000,000 is to be spread over forty years. The St. Maurice Construction Company also agrees to renounce all claims for extra work incurred in the construction of La Loutre dam, a sum of $298,807 being mentioned particularly in the bill. The amount of $1,500,000 for the La Loutre work previously authorized is raised to $2,500,000.

Westinghouse, Church, Kerr & Co., Inc., engineers and constructors, Montreal and New York, have issued another of their characteristic illustrated cards, depicting the first refined potash plant in the United States—that of the Mineral Products Corporation, at Marysvale, Utah, where 30 tons of potash are produced daily.

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Canada's Engineers—P. L. Pratley

If any one class of engineer should be picked out as worthy of special credit for the economic development of our country, it would be the bridge builder. Canada is a land where the predominating problems concerned in its development are those of transportation. Railways and highways, thousands of miles of them, spread across the country, linking up the remote corners of a vast area into one integral unit, and wherever a railroad or a highway penetrates, there bridges are essential. We have them of every type—the tiniest culvert to the leviathan Quebec—each of them, nevertheless, a product of engineering skill and ingenuity and a tribute to the ability and energy of the bridge builder and designer.

It is fitting, then, that as the subject of this week's sketch, we should select one of Canada's well known bridge designers, Philip Louis Pratley, M. Eng., M. Inst. C. E., M. E. I. C. Mr. Pratley was born in Liverpool, England, in 1884 and received his education at the Liverpool Institute and the University of Liverpool, entering as "Council Scholar." He graduated as Bachelor of Engineering, with first class honors, becoming a "Rathbone Medalist" and "University Scholar" and obtaining the Master's Degree after the requisite practical experience. With the intention of taking up mining, he devoted his vacations to working in the lead and zinc mines of North Wales. He also had some training in building construction with his father, a building contractor in Liverpool. Following his graduation from the university, Mr. Pratley served in the bridge shops of Francis Morton & Co., Garston, Lancashire, Eng., until coming out to Canada as designing draftsman with the Locomotive & Machine Company, of Montreal, (now defunct). He joined the designing staff of the Dominion Bridge Company in May, 1906, and, after experience in detailing, checking and designing, he went to the Government Board of Engineers for the Quebec Bridge, as calculating and designing engineer, concerned particularly with the intricate mathematical work in connection with primary and secondary stresses in the various designs which were studied and figured, these including both cantilever and suspension types. On the formation of the St. Lawrence Bridge Company, Mr. Pratley was appointed to their staff as designing engineer and, in that capacity, had charge of all stress sheets and material diagrams for the various designs submitted by them. After the submission of tenders, he returned to the Government Board and took part in the examination and checking of the designs handed in to them. In December, 1910, he was offered and accepted the position of Assistant Designing Engineer to the Dominion Bridge Company, in 1913 succeeding to the full charge of the estimating and designing department as Designing Engineer.

Mr. Pratley has had many large and important bridges pass through his hands. The principal individual structures are, perhaps, the Lachine Bridge, on the C. P. R.; the St. John, N. B., Arch; the Port Nelson Bridge, on the Hudson Bay Line; the Kildonan Bridge, on the C. P. R., near Winnipeg, and a series of bridges on the C. N. P. R. in British Columbia. In addition to bridge work, he has given attention to the construction of steel buildings of all descriptions, industrial plants, mine structures, etc. The Creighton Mine head frame and crusher house, belonging to the International Nickel Company, perhaps the biggest in America, and the head frames at the Dome and Hollinger gold mines in the Porcupine area are important examples of this latter class of work. Under Mr. Pratley's direction are also carried out investigations of existing bridges and structures, estimates of quantities and costs, designs for tenders and for construction and sketches and details for manufacture and erection. In 1917 Mr. Pratley was given charge of the engineering work in connection with a special war venture, the building of marine boilers. As engineer of the boiler department,

Mr. P. L. Pratley

he has designed and superintended the manufacture of boilers for the British Admiralty and the Canadian, French and United States Governments. This work is now almost finished, being substantially an emergency undertaking.

He is a member of the Engineering Institute of Canada and member of the Institution of Civil Engineers and author of two papers to the latter institution; one on the Boucanne River Viaduct, (1913), and the other the St. John Arch, (1920), just being published. Mr. Pratley is an enthusiastic advocate of a universal language for purposes of engineering and science in general, and, in this connection, is a member of the Universal, British, and North American Esperanto Societies, and vice-president of the Montreal Society.

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met, $8,000,000 more will have to be appropriated. Apparently the province is not prepared to advance this sum, and the proposed legislation throws the responsibility for financing on the municipalities themselves.

International Town Planning Congress

Delegates, appointed by the Governments of Great Britain, France, Belgium, Italy, Holland, Denmark, Norway, Sweden, Switzerland, Spain, Serbia, Greece, Egypt, India, South Africa, Australia, Canada, the United States, and the republics of South America, will be present at the International Town Planning and Housing Congress to be held in London during June of the present year.

The proceedings of the congress will occupy nine days, special trains being made available so that the delegates may have an opportunity to inspect the progress that has been made in housing schemes.

A Housing Commission, consisting of Mayor W. S. Davis, Messrs. M. J. Butler and W. S. Savage, has been formed at Oakville, Ont., and work will commence as soon as government funds are available. The Commission has already 23 applications for houses on hand.