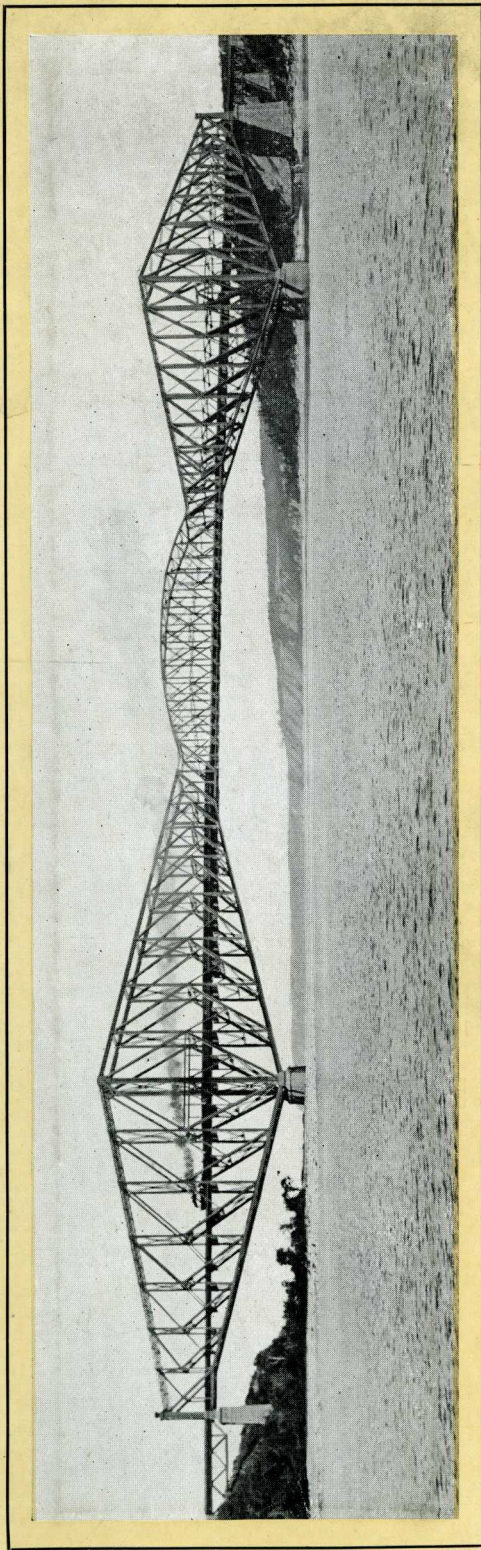


THE
QUEBEC BRIDGE

CARRYING THE
TRANSCONTINENTAL LINE OF THE CANADIAN GOVERNMENT RAILWAYS
OVER

THE ST. LAWRENCE RIVER
NEAR

THE CITY OF QUEBEC, CANADA.



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OVER
THE ST. LAWRENCE RIVER
NEAR
THE CITY OF QUEBEC, CANADA

The Bridge was Built for the Department of Railways and Canals

DOMINION OF CANADA

1910 - 1918

| | | | | | | | | | |
|---|---|---|---|---|---------------------------------|---|---|---|-----------|
| Rt. Hon. Sir Wilfrid Laurier, P.C., G.C.M.G. | - | - | - | - | Prime Minister | - | - | - | 1906-1911 |
| Rt. Hon. Sir Robert L. Borden, P.C., G.C.M.G. | - | - | - | - | Prime Minister | - | - | - | 1911-1918 |
| Hon. Geo. P. Graham | - | - | - | - | Minister of Railways and Canals | - | - | - | 1906-1911 |
| Hon. Francis Cochrane | - | - | - | - | Minister of Railways and Canals | - | - | - | 1912-1917 |
| Hon. John D. Reid | - | - | - | - | Minister of Railways and Canals | - | - | - | 1918 |

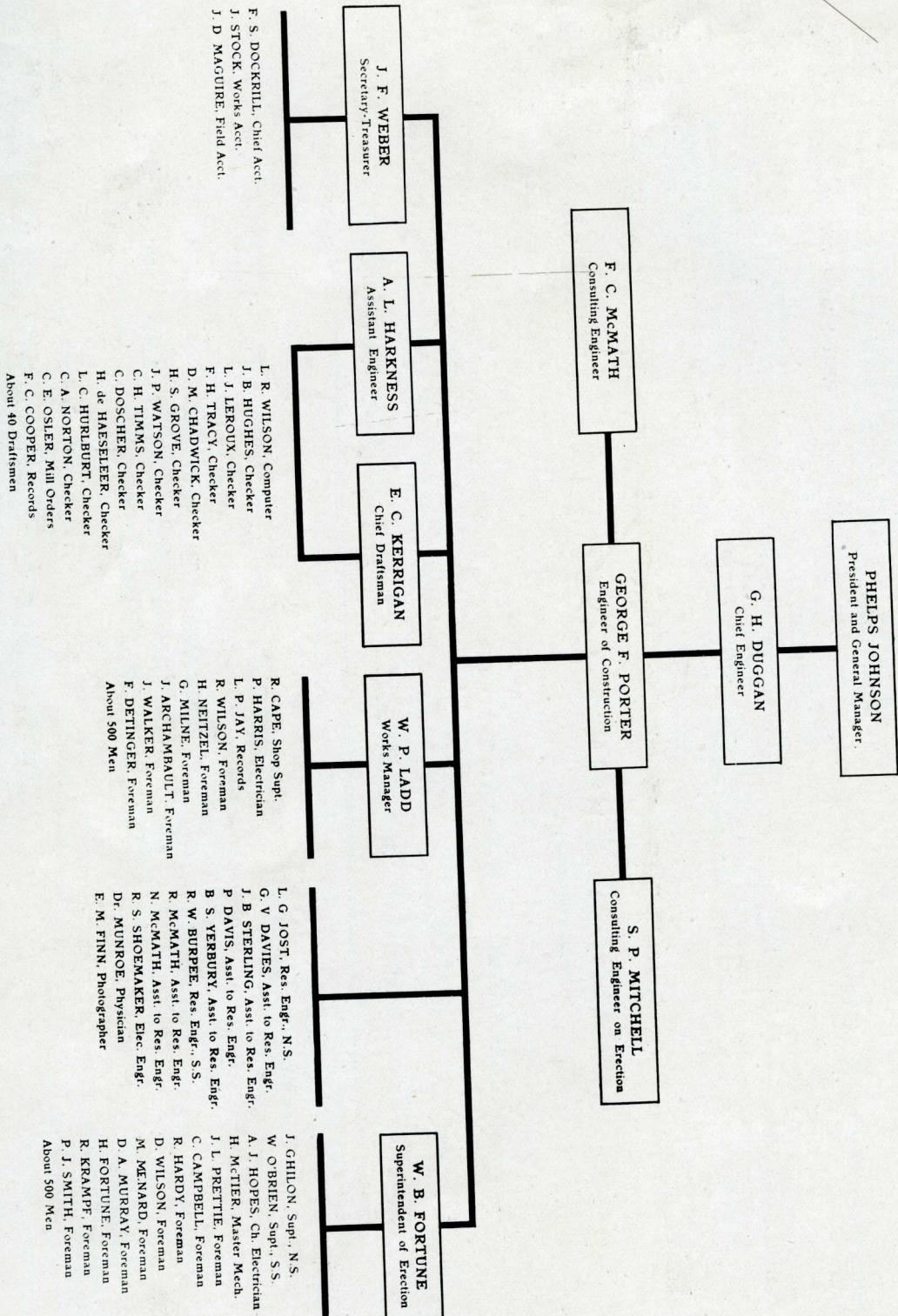
THE SUPERSTRUCTURE WAS DESIGNED, MANUFACTURED AND ERECTED BY THE
ST. LAWRENCE BRIDGE COMPANY, LIMITED
 A COMPANY SPECIALLY INCORPORATED IN THE JOINT INTEREST OF THE
DOMINION BRIDGE COMPANY, LIMITED, of Lachine, P.Q. and
THE CANADIAN BRIDGE CO., LIMITED, of Walkerville, Ont.

WITH A VIEW TO COMBINING THE ORGANIZATIONS & RESOURCES OF THE TWO COMPANIES FOR THE EXECUTION OF THE WORK

THE SUBSTRUCTURE (FOUNDATIONS AND MASONRY) WAS CONSTRUCTED BY
 M. P. & J. T. Davis, *Contractors*
 S. H. Woodard, *M.Am.Soc.C.E. Engineer*

| | | | |
|---|---|---|--|
| The Advisory Board of Engineers appointed to recommend a design and specification to the Minister upon which the contract would be awarded: | | The Engineers representing the Government were: | |
| Ralph Modjeski, <i>M.Am.Soc.C.E.</i> | - | Chicago, Ill. | |
| Chas. MacDonald, <i>M.Can.Soc.C.E.</i> | - | Gananoque, Ont. | |
| M. J. Butler, <i>C.M.G. M.Can.Soc.C.E.</i> | - | Montreal, P.Q. | |
| H. W. Hodge, <i>M.Am.Soc.C.E.</i> | - | New York, N.Y. | |
| H. E. Vautelet, <i>M.Can.Soc.C.E., Chairman</i> | - | Montreal, P.Q. | |
| The Supervising Board of Engineers during the construction of the work: | | | |
| Ralph Modjeski, <i>M.Am.Soc.C.E.</i> | - | Chicago, Ill. | |
| C. C. Schneider, <i>M.Am.Soc.C.E.</i> | - | Philadelphia, Pa. | |
| H. P. Borden, <i>M.Can.Soc.C.E.</i> | - | Montreal, P.Q. | |
| C. N. Monsarrat, <i>M.Can.Soc.C.E., Chairman</i> | - | Montreal, P.Q. | |

ORGANIZATION OF ST. LAWRENCE BRIDGE CO., LIMITED



THE Bridge is notable not only as having the longest and by far the heaviest single span yet built, but for the use, the first time in an important structure, of what has become known as the "K" system of web bracing, which is believed to have important advantages over the Pratt or the Warren web system generally used in cantilevers.

It is statically determinate as regards stresses.

The deflection is uniform, without local irregularities, and secondary strains are negligible.

Each web member carries only about one-half of the total shear.

Diagonal web members have economical inclination.

Main panels are short, resulting in more numerous and smaller increments of chord stress than in trusses with long panels.

All web members of the trusses transmit live as well as dead load stresses.

The support for an intermediate floor beam in each main panel is readily provided without injurious bending of any main member.

The truss members at their connections meet at favorable angles and simple and satisfactory connecting details are easily arranged.

The assembly in erection is the adding of simple undivided triangles one to another, each self-supporting as completed and requiring but a minimum of temporary supporting members.

The use of the "K" web system was conceived and proposed by PHELPS JOHNSON. The design was developed by G. HERRICK DUGGAN. The detailing and erection was under the direction of GEORGE F. PORTER.

Before the final decision to adopt the "K" system of bracing was reached, practically all other web systems were studied. The decision to use the "K" bracing was largely

influenced by considerations connected with the erection of the structure and, particularly by the conclusion that there would be no necessity for leaving any compression joints partly open and unriveted, until the deformation of the truss, due to the addition of dead load as the erection progressed, was sufficient to close the joints.

This conclusion was found to be fully warranted and in erection the abutting faced ends of all compression joints were easily brought to a full bearing and rivetted before succeeding material was placed.

The engineers of the Company had long been convinced that the initial cause of failure of the Phoenix Company's Bridge was the high intensity of pressure and consequent distortion and displacement of material at the bearing edges of the lower chord sections of the anchor arm. These chords had been assembled with partly open joints, which were expected to gradually close as the cantilever arm and the suspended span were built out, and the consequent increased stresses and changes in the lengths of the truss members brought the chord sections to full bearing. Before the closing of the joints was complete the chords must have been subject to practically the full stress intended to be borne by their full section, resulting in a very great intensity of pressure upon the limited areas actually in contact.

CAPACITY

The Bridge was designed to carry two railway tracks spaced 32 feet 6 inches centre to centre and on the outside of each of these tracks was provided a 5-foot concrete sidewalk.

RAILWAY LIVE LOAD:

2 Coopers' Class E60 locomotives, followed by 5,000 lbs. per lineal foot on each track.

SIDEWALK LIVE LOAD:

500 lbs. per lineal foot for each walk.
500 lbs. per lineal foot of snow on bridge.

WIND LOAD:

30 lbs. per square foot of the exposed surface of two trusses and $1\frac{1}{2}$ times the elevation of the floor; plus a moving load of 300 lbs. per lineal foot applied 9 feet above the rail.

IMPACT:

Trusses, 20 per cent of Ry. Load.
Floor Beams, 75 per cent of Ry. Load.
Stringers, 100 per cent of Ry. Load.

UNIT STRESSES:

| | | |
|---|--|-------------------------|
| Tension: | | Lbs. per sq. in. |
| Eyebars | | 20,000 |
| Riveted Members | | 18,000 |
| Including Secondary Stresses | | 24,000 |
| Compression: | | |
| Short Members with $\frac{1}{r}$ 50 and under | | 14,000 |
| Long Members with $\frac{1}{r}$ over 50 | | 17,500-70 $\frac{1}{r}$ |
| Including Secondary Stresses | | 18,000 |

The above unit stresses are for carbon steel. For nickel steel increase by 40 per cent.

Quality of Steel:

| | | |
|---------------------|------------------|------------------|
| | Carbon Steel | Nickel Steel |
| | lbs. per sq. in. | lbs. per sq. in. |
| Ultimate Strength | 62,000-70,000 | 85,000-100,000 |
| Minimum Yield Point | 35,000 | 50,000 |
| Elongation in 8 In. | 1,500,000 | 1,600,000 |

| | | |
|---------------------------|----------|----------|
| Minimum reduction of area | Ultimate | Ultimate |
| | 44% | 40% |

Each track is carried on through plate girder spans with wooden ties resting on 24" I-Beam stringers spaced 7 feet centres. The upper flanges of the girders are reinforced with heavy 15-inch channels for protection in case of derailment.

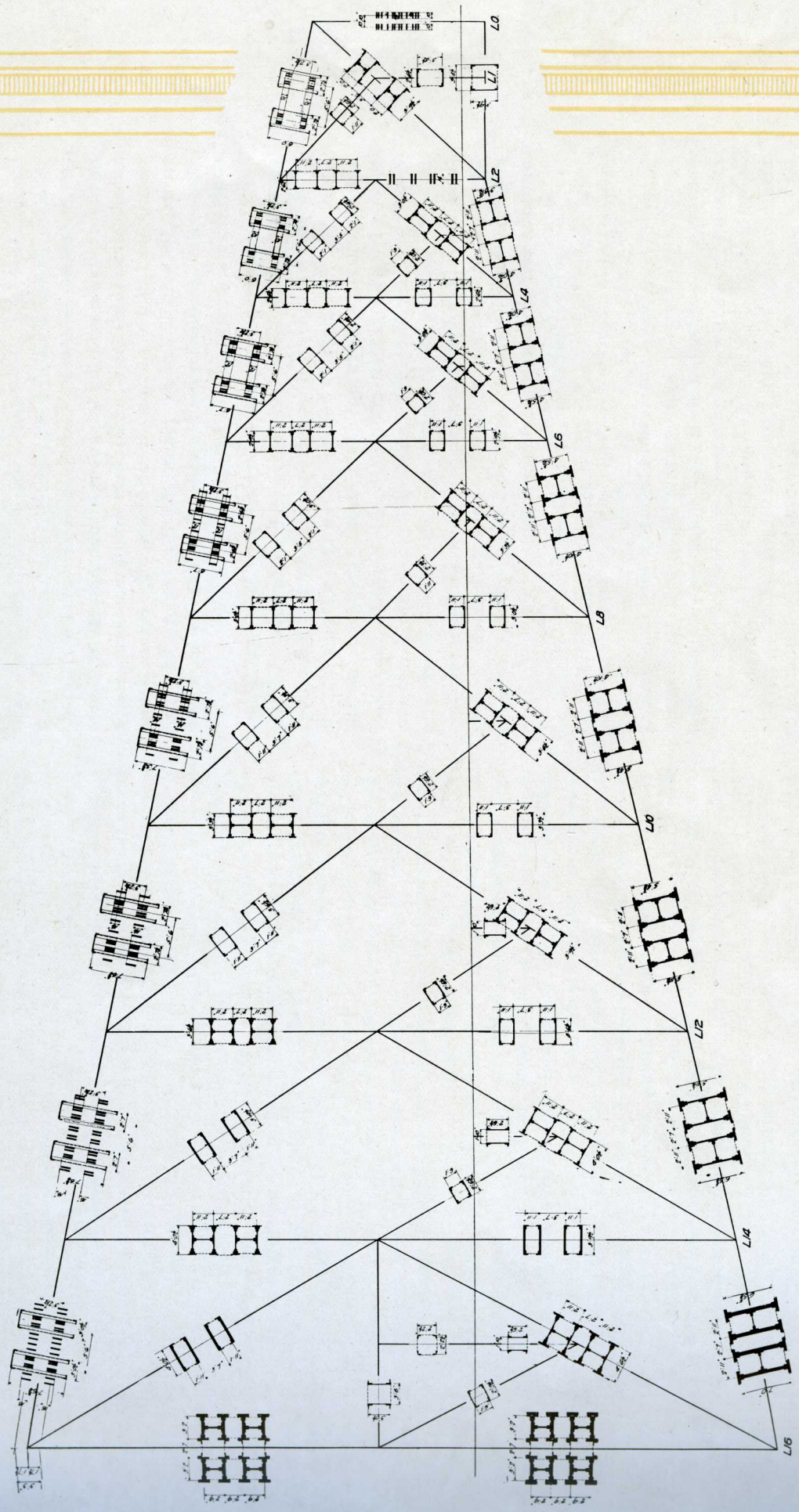
The floor beams, with the exception of those of the suspended span and at the L¹ and L² panel points of the cantilever and anchor arms, are hung on pins on the centre line of the trusses, the pin holes in the floor beams being pushed to give large bearing surfaces and to prevent cutting friction, this construction being adopted for the purpose of equally loading the truss members and to prevent the deflection of the long floor beams bending the members. See Plates 18 and 26.

The main truss members of the cantilever structure are made of four ribs consisting of symmetrical I sections for compression members, and channel sections for tension members, built up of plates and angles. The compression ribs are connected in pairs by longitudinal diaphragms on the centre lines and lattice and the plates connecting the flanges thus forming two H sections, which were again connected in the field by the plates on centre lines and flanges.

The tension ribs were assembled in pairs with flanges turned in and connected by lattice and tie plates on the flanges only.

Each member was, however, completely assembled in the shop, for the purpose of finishing the ends, boring pin holes and drilling splicing material. Most of the pins connecting the web system were in two lengths. This construction practically divided each main truss into two complete trusses placed side by side and field connected together which facilitated the transportation and erection of the large members.

All the webs were parallel through the trusses, but the lower chords were tapered in elevation from a depth



3—Cross sections of important members of the cantilever arms
 NOTE: The cross sections of the members of the anchor arms are similar

inches outside diameter, each 4 feet 10 inches long, weighing 13,750 lbs. The sleeves were adopted to reduce the bearing on the surface of the pin to about 7,000 lbs. per square inch, as it was desired to eliminate the bending stresses in the end lower chord that would occur during erection if the chord could not deflect without too great restraint at its junction with the shoe. The bearing of sleeves on pins was lubricated with paraffin, which special experiments had shown to give a very low coefficient of friction under this pressure.

TABLE SHOWING DIMENSIONS AND WEIGHTS OF SOME OF THE PRINCIPAL MEMBERS

| Member | Mark | Area Sq. Ins. | One Panel One Truss | | | Largest Piece Shipped | | | Largest Piece Erected | | |
|-----------------|---------------------|------------------|------------------------|----------|-----------------------|-----------------------|----------|-------------|-----------------------|----------|-------------|
| | | | Dimens., Feet | Lin. Ft. | Total Wt., Tons | Dimens., Feet | Lin. Ft. | Wt. Tons | Dimens., Feet | Lin. Ft. | Wt. Tons |
| Comp. Diag. | AU ^{0L2} | 563 | 4 x 8.8 | 95.5 | 150 | 4 x 8.8 | 65.5 | 92 | 4 x 8.8 | 65.5 | 92 |
| Upper Chord | AU ¹²⁻¹⁴ | 1120 | 7.5 x 8.5 | 86.6 | 224 | 7.5 x 2.6 | 86 | 10 | 7.5 x 2.8 | 86.0 | 56 |
| Lower Chord | AL ¹²⁻¹⁴ | 1902 | 7 x 10.1 | 86.5 | 416 | 7 x 4.7 | 47.4 | 93 | 7 x 4.7 | 47.4 | 93 |
| Ten. Diag. | AM ^{15U14} | 392 | 4 x 7.4 | 168.2 | 154 | 4 x 2 | 103 | 53 | 4 x 2 | 152 | 77 |
| Comp. Diag. | AM ^{10L14} | 623 | 4.5 x 10.1 | 184.3 | 280 | 4.5 x 4.5 | 88.7 | 72 | 4.5 x 4.5 | 88.7 | 72 |
| Upper Chord | CU ¹⁴⁻¹⁶ | 1088 | 7.5 x 8.5 | 85.7 | 218 | 7.5 x 2.8 | 85 | 11 | 7.5 x 2.8 | 85 | 55 |
| Lower Chord | CL ¹⁴⁻¹⁶ | 1631 | 7.0 x 10.1 | 86.3 | 340 | 7.0 x 4.8 | 49.3 | 88 | 7.0 x 4.8 | 49.3 | 88 |
| Com. Vert. | CM ^{14U14} | 428 | 4.0 x 9.6 | 127 | 130 | 4 x 4 | 69.5 | 54 | 4 x 4 | 69.5 | 54 |
| Tens. Vert. | CL ^{14M14} | 296 | 3.8 x 7.4 | 146 | 90 | 3.8 x 1.8 | 134 | 44 | 3.8 x 1.8 | 134 | 44 |
| Tens. Diag. | CM ^{14U16} | 377 | 4 x 7.4 | 167 | 147 | 4 x 2 | 102.3 | 50 | 4 x 2 | 146.8 | 73 |
| Comp. Diag. | CM ^{14L16} | 619 | 4.5 x 10.1 | 185.8 | 283 | 4.5 x 4.5 | 90 | 73 | 4.5 x 4.5 | 90 | 73 |
| Main Vert. Post | AL ^{14U14} | 1903 | 9 x 10 | 310 | 1207 | 3 x 4.3 | 57.7 | 52 | 3 x 4.3 | 57.7 | 52 |
| Main Floor Beam | C.F. ¹¹ | | 10 x 1.8 | 90.3 | 62 | 10 x 1.8 | 90.3 | 62 | 10 x 1.8 | 90.3 | 62 |

| | | | | | |
|---|--------|---|---|------|-------|
| Total steel in one Anchor Pier, including Anchor Bars | Tons | 740 | Total steel in Floor System complete, including Floor of Suspended Span | Tons | 8,730 |
| Total steel in one Anchor Arm, exclusive of Floor | 14,900 | Total steel in Suspended Span, including Floor System | 5,510 | | |
| Total steel in one Cantilever Arm | 10,430 | Total steel in Eyebars, including Anchor Eyebars | 7,770 | | |
| Total steel in Track Girders | 2,400 | Total steel in Pins | 1,700 | | |
| Total steel in Floor Beams | 4,330 | Total steel in Structure, including Approaches | 66,480 | | |

Nickel steel was used in the trusses of the suspended span and the cantilever arms except carbon steel in eyebars of upper chord and in the first compression diagonals and all the vertical compression members of the cantilever arms. All pins in the suspended span and about one-half those in the other parts of the structure are nickel steel.

The proportion of nickel steel in the structure is 27 per cent. The rivets in heavy members were $1\frac{1}{8}$ inches diameter.

With the exception of locomotives and locomotive cranes, electric power was used throughout for erection purposes. Power houses were established on both sides of

the River. On the North side were installed four electrically driven air compressors each of 530 cubic feet capacity and two motor generator sets of 250 K. W. to transform A. C. to D. C. current for operating the travellers. A similar transformer set was installed on the South side, but only three 530 cubic feet air compressors. Current was carried to the traveller by heavily insulated cables wound on drums and connected to a switchboard situated in a house supported on the inner track girders at the rear of the traveller and which moved with the traveller. The current was distributed to the motors from this switchboard. The upper hoists on the travellers were magnetically controlled from a working platform on the traveller.

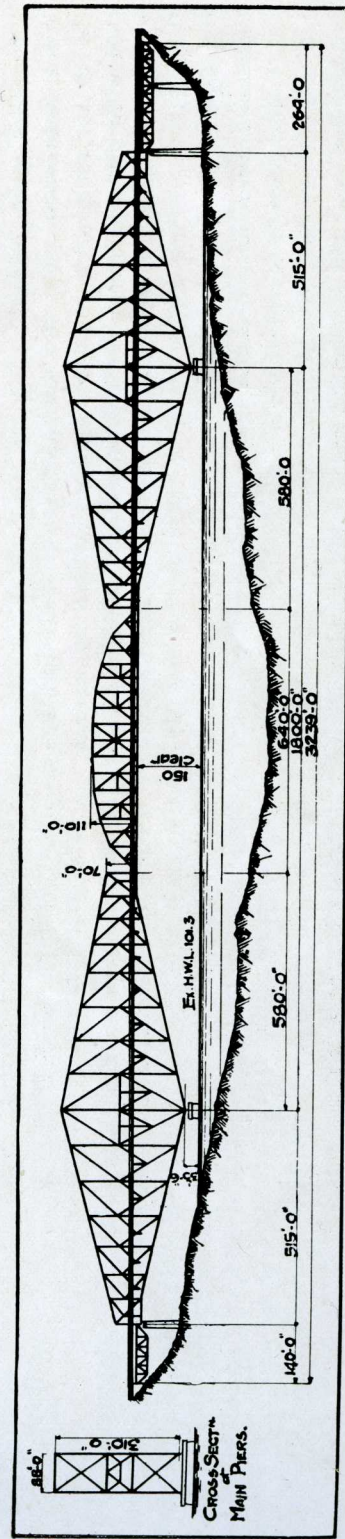
SUMMARY OF PROGRESS DATES

| | | | |
|--|--------------|---|---------------|
| Contract for Substructure awarded to M. P. & J. T. Davis | 10 Jan. 1910 | South Anchor Pier completed | 28 Nov. 1913 |
| Contract for Superstructure let to St. Lawrence Bridge Co. | 4 Apr. 1911 | South Approach Span erected | 30 July 1914 |
| North Abutment completed | 24 Oct. 1913 | South Main Pier completed | 1 July 1914 |
| North Anchor Pier completed | 14 Nov. 1913 | South Anchor Arm erected | 8 Nov. 1915 |
| North Main Pier completed | 7 May 1914 | South Cantilever Arm erected | Sept. 1916 |
| North Approach Spans erected | 11 Nov. 1913 | Suspended Span swung on supports at Sillery | 20 July 1916 |
| North Anchor Arm erected, except Pier Post and First North Vertical Post | 4 Dec. 1914 | Suspended Span lost while being hoisted to position | 11 Sept. 1916 |
| North Anchor Arm completed | 8 June 1915 | Suspended Span (new) Hoated from Sillery to Site | 17 Sept. 1917 |
| North Cantilever Arm erected | 13 Nov. 1915 | Suspended Span connected in final position | 21 Sept. 1917 |
| South Abutment completed | 28 Nov. 1913 | First Train over the Bridge | 17 Oct. 1917 |
| | | Bridge open for regular Train Service | 3 Dec. 1917 |

ERECTION PROGRESS

The following table shows the quantity of steel erected in each of the seasons of 1914, 1915, 1916, together with the average and best rates made:

| | Tons Erected | Number Weeks To Erect | Average Tons Erected Per Week | Largest Number Tons Erected | | |
|----------------------|--------------|-----------------------|-------------------------------|-----------------------------|------------|--------------|
| | | | | In one Week | In one Day | Date |
| SEASON 1914: | | | | | | |
| North Anchor Arm | 13,636 | 29 | 470 | 1039 | 411 | Nov. 22, '14 |
| SEASON 1915: | | | | | | |
| South Anchor Arm | 19,165 | 30 | 638 | 1823 | 670 | Oct. 6, '15 |
| North Anchor Arm | 5,038 | 10 | 504 | 1140 | 340 | May 13, '15 |
| North Cantilever Arm | 12,542 | 25 | 502 | 1025 | 387 | June 10, '15 |
| For Season | 36,745 | 35 | 1049 | .. | .. | .. |
| SEASON 1916: | | | | | | |
| South Cantilever Arm | 12,642 | 26 | 486 | 1101 | 499 | May 26, '16 |
| Suspended Span | 4,701 | 9 | 522 | 898 | 219 | July 12, '16 |
| For Season | 17,343 | 26 | 667 | .. | .. | .. |



THE STORY

THE story of the Bridge is briefly told in the following editorial which appeared in the Engineering News - Record of New York under date of September 27th, 1917:

"In the engineering world the name Quebec has for half a generation been associated with a great prospective engineering triumph. Twice the hopes of success have been dashed, but never in the heart of the true engineer was there doubt that the enterprise would be brought to a successful completion.

"Now the great hopes are realized. The greatest of cantilevers stands across the St. Lawrence.

"Just ten years ago the south half of the first bridge crumpled under its own weight, dragging a hundred men to their death. The investigations and discussions that followed destroyed that first project to its very roots. But new leaders were found, new ideas developed. On the wreckage of the old there arose the finest creation of bridge-building that any generation has seen.


"What courage was required to attack the work anew can be realized only when one recalls the extent of the defects revealed in the old design. True, these discoveries were warnings for the succeeding designers, but impressed with the terrible nature of the first experience their work could not but be haunted by visions of what had happened in that dark August of 1907. The new structure from the start gave evidence of the masterly hands responsible for it. A new truss design was developed, the shopwork was of marvelous precision and finish, the erection novel and courageous.

"Yet, despite the most careful study and precautions, a second accident marred the record of the structure, when last year the suspended span, while being hoisted,

"fell into the river. One might think that in the face of this second discouragement the engineers and contractors responsible might have wavered in their determination to proceed. But he who thought so failed to reckon with the mettle of the men in charge. The wires had not finished sending the story of the lost span to the world when announcement was made that it would be rebuilt and erected by the very method employed last year. The promise of that announcement has now been fulfilled. What changes there have been from the previous erection plan are only in details. They are described elsewhere in this issue.

"Before closing the final chapter in the design and erection of this remarkable structure, it is proper to record the debt that bridge-builders owe to the work at Quebec. It has advanced greatly our knowledge of the problems of large compression members and of tension bars. The effects of distortion in trusses were explored farther than before and means devised for dealing with such effects. Much knowledge has been added to our store of experience on the assembly of heavy members, while new standards were set as to degree of precision and finish in shopwork. Then there is, beyond all this, a great gain in our general grasp of the problem of very large bridges as to practicability and cost.

"But these are the gains of the profession as a whole. To the individual engineer the great value of the achievement lies in the inspiration emanating from the courage of the men who have erected on the failure of 1907 and the loss of 1916 this greatest of bridges—and in so doing not only have erected a monument to themselves and their courage and ability, but have vindicated the profession before a doubting world."



LATE 4 shows, to the same scale, the elevation of the Quebec Bridge and all the great cantilever bridges heretofore constructed. It will be seen that the Quebec Bridge with its span of 1,800 feet exceeds the span of the Forth Bridge by 100 feet, and that these two are in a class by themselves—the next longest, the Blackwell's Island Bridge, being less than two-thirds the span of the Quebec Bridge.

Although the difference in span between the Quebec and Forth Bridges is not great, the Forth Bridge was far from being a precedent for the structure at Quebec. The weights of locomotives and all railway loads had increased so much since the earlier Bridge was built it was necessary to proportion the Quebec Bridge for about $2\frac{1}{4}$ times the live load provided for in the Forth Bridge. Again, it was not practicable to adopt many of the unique and excellent features of the Forth Bridge or the method of its construction.

The rolled material for the Forth Bridge was fabricated at the site and fitted to the bridge piece by piece in a manner analogous to steel shipbuilding and thus did not require especially heavy machinery or lifting appliances for placing the material in its final position in the bridge.


This method of manufacture and erection permitted the use of large open panels with diagonals at an economical inclination, the use of battered and horizontally tapering trusses, and of circular compression members, all tending towards economy of material. Conditions in Canada did

not permit manufacture at the site or placing the material in position in the manner used at the Forth Bridge and all the cantilever designs submitted for the Quebec Bridge were based on assembling the rolled material into members of as large dimensions as could be transported from the shops and erected in the bridge.

It was natural that the project of building a bridge across the St. Lawrence River at Quebec should have been of great interest to many bridge engineers, it being foreseen that it would be a longer and heavier span than any hitherto built and that the increase in span and capacity to very near the limiting length of the cantilever type of bridge would bring with it new and important problems to be solved. When tenders were first called for its construction by the Quebec Bridge & Railway Company in 1899 most of the prominent bridge engineers of America were in some measure connected with the competition.

A contract for the foundations and masonry was let to Messrs. William Davis & Sons and a contract was made with the Phoenix Bridge Company of Phoenixville, Pa., for the construction of the superstructure on a design prepared by the Phoenix Company.

The masonry was satisfactorily completed and work on the superstructure proceeded until the South anchor arm, cantilever arm and nearly half of the suspended span were erected when on the 29th August, 1907, all of this portion of the superstructure suddenly collapsed.



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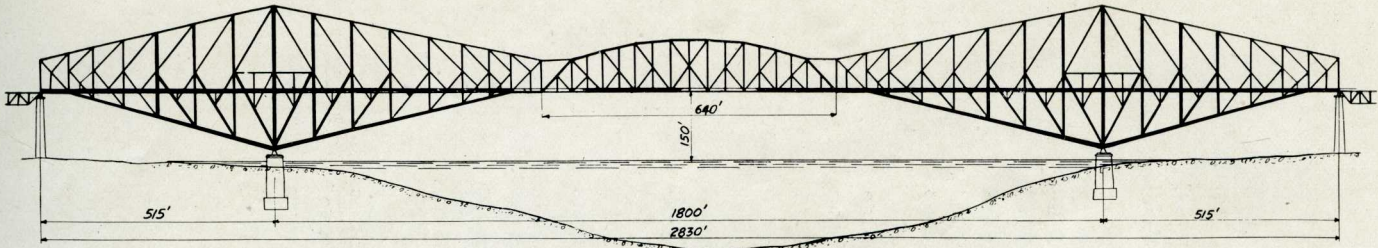
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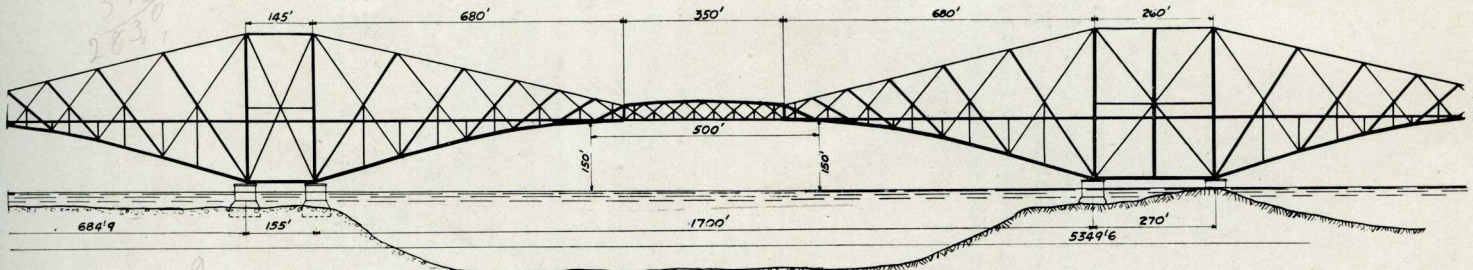
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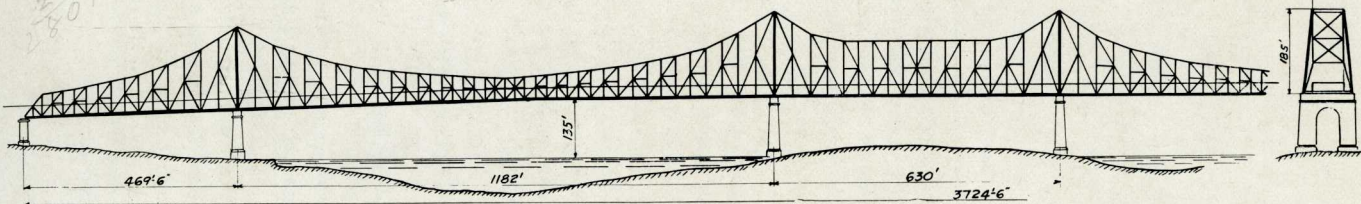
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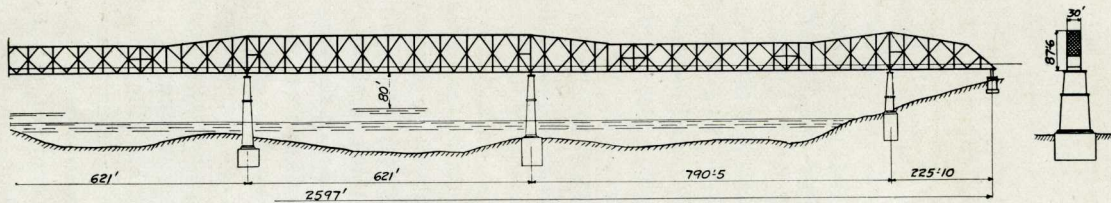
THE QUEBEC BRIDGE



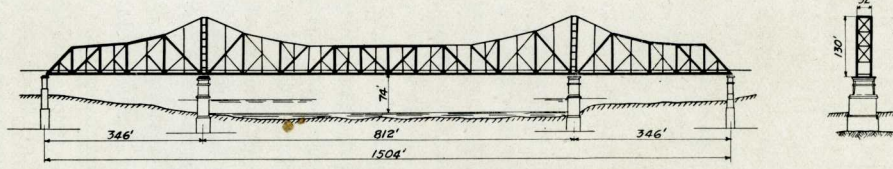
THE FORTH BRIDGE (One of the two Main Spans)
(NEAR EDINBURGH, SCOTLAND)



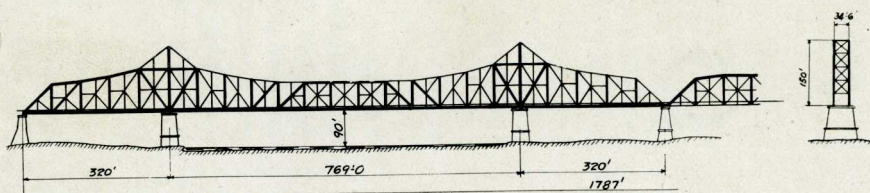
BLACKWELLS ISLAND BRIDGE
(NEW YORK, N.Y.)



THE MEMPHIS BRIDGE
(MEMPHIS, TENN.)

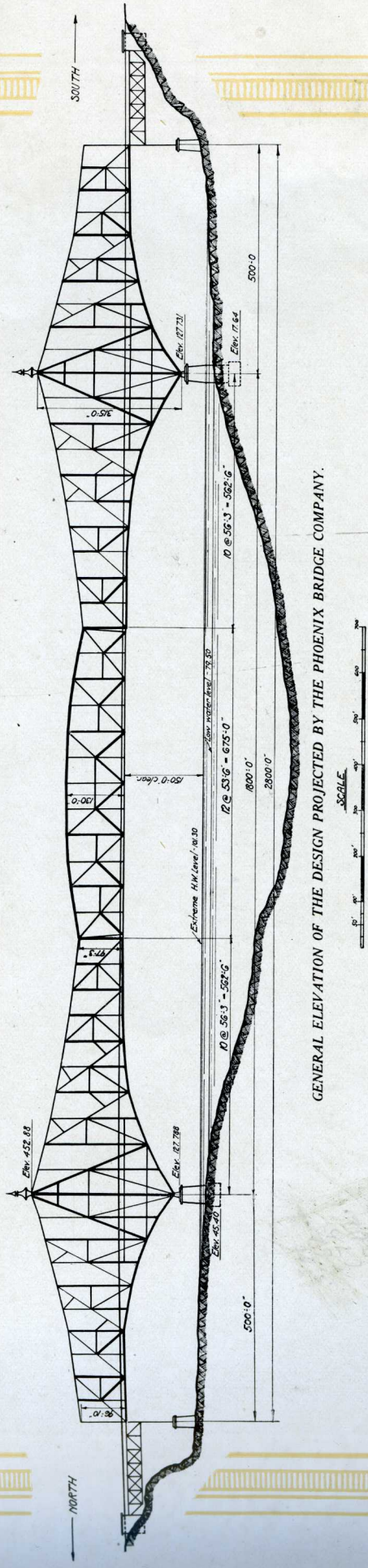


THE MONONGAHELA BRIDGE
(PITTSBURGH, PA.)



THE BEAVER BRIDGE
(BEAVER, PA.)

4—Elevations, to the same scale, of the Quebec and other great cantilever bridges



GENERAL ELEVATION OF THE DESIGN PROJECTED BY THE PHOENIX BRIDGE COMPANY.

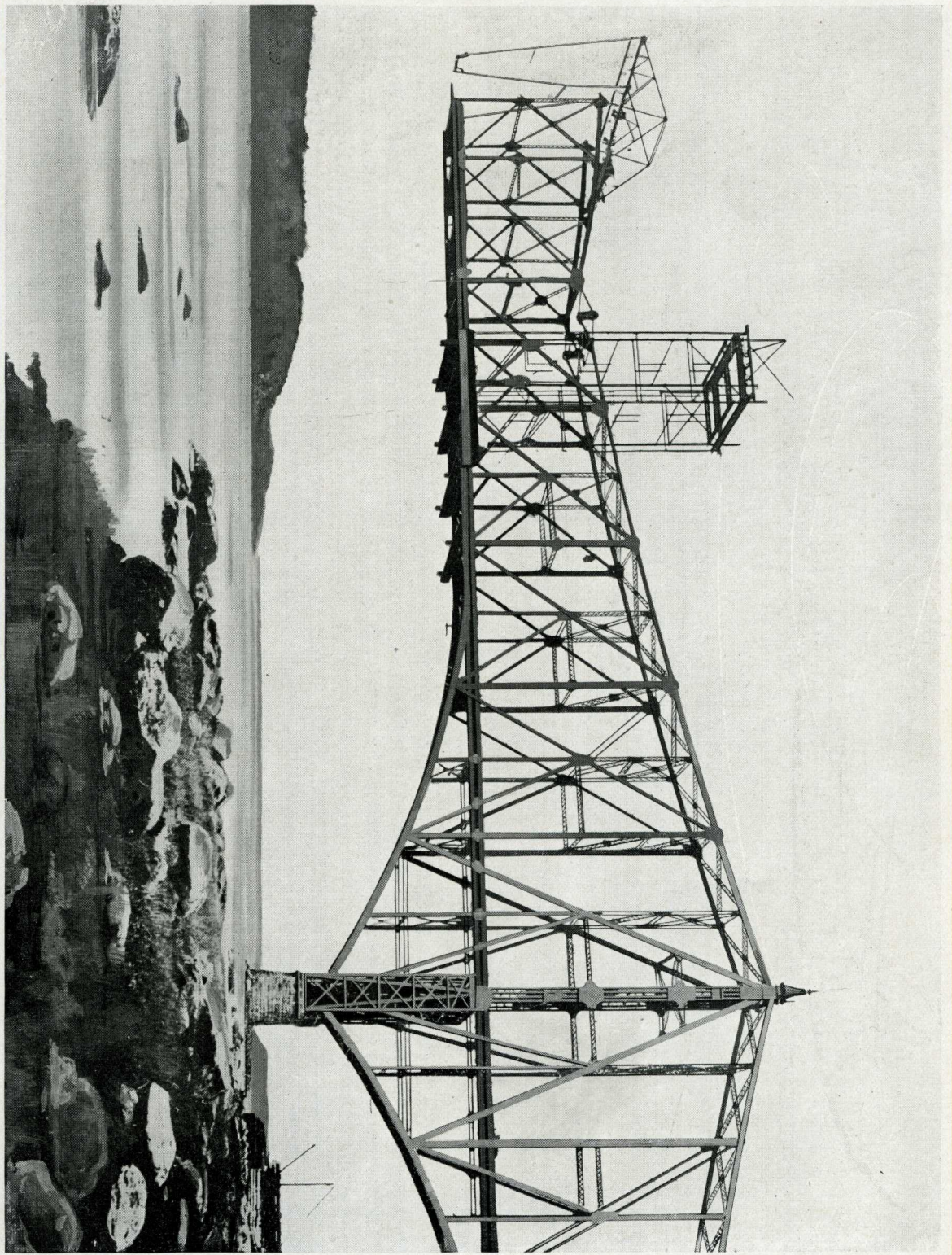
The cut above is an elevation of the Quebec Bridge as projected by the Phoenix Bridge Co.

Plate 5 is a photograph taken of the bridge on the 27th August, 1907, two days before it collapsed. Plates 6 and 7 show views of the wreck after the accident. The disaster was accompanied with heavy loss of life. The accident made a profound impression upon the Engineering World and, indeed, upon the general public both in Canada and in other countries. The Government at once appointed a Royal Commission consisting of Professor John Galbraith, J. G. Kerry and Henry Holgate, Chairman, to investigate and report upon the accident. An independent report was also asked from Mr. C. C. Schneider which was incorporated in the Blue Book on the inquiry. The Blue Book was very complete, the Commission having assembled most of the available data on other long span bridges, illustrated their important features, recorded the tests on large size compression members that had previously been

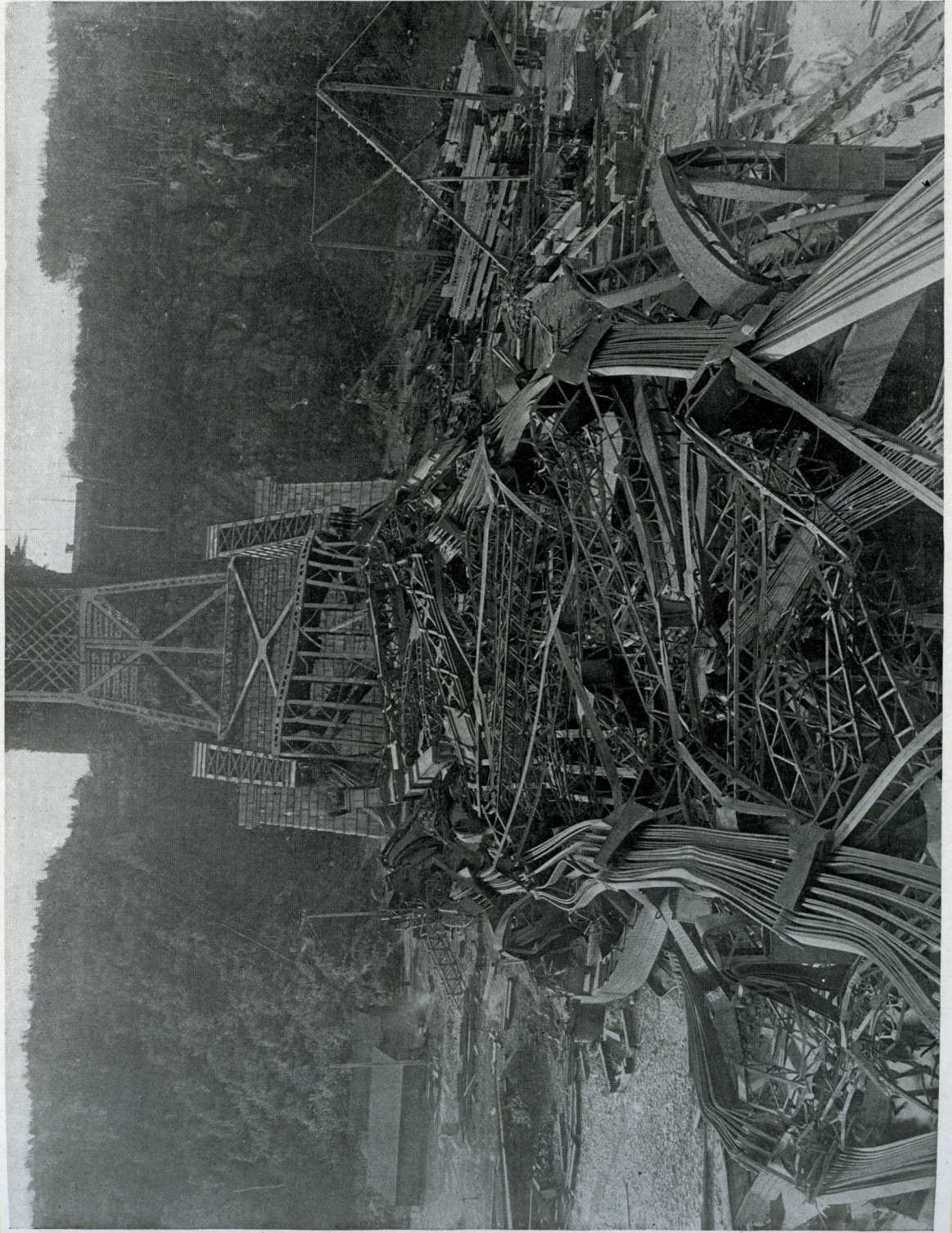
made together with a number of tests made by the Commission on the behavior of such members under stress.

After receiving the report of the Royal Commission the Minister of Railways & Canals appointed a Board of Engineers to prepare plans and specifications for a new bridge. The Board, which was appointed on the 17th August, 1908, consisted of Messrs. Maurice FitzMaurice, M.I.C.E., of London, England; Ralph Modjeski, M.A.S.C.E., Chicago, and H. E. Vautelet, M.C.S.C.E., of Montreal, Chairman and Chief Engineer.

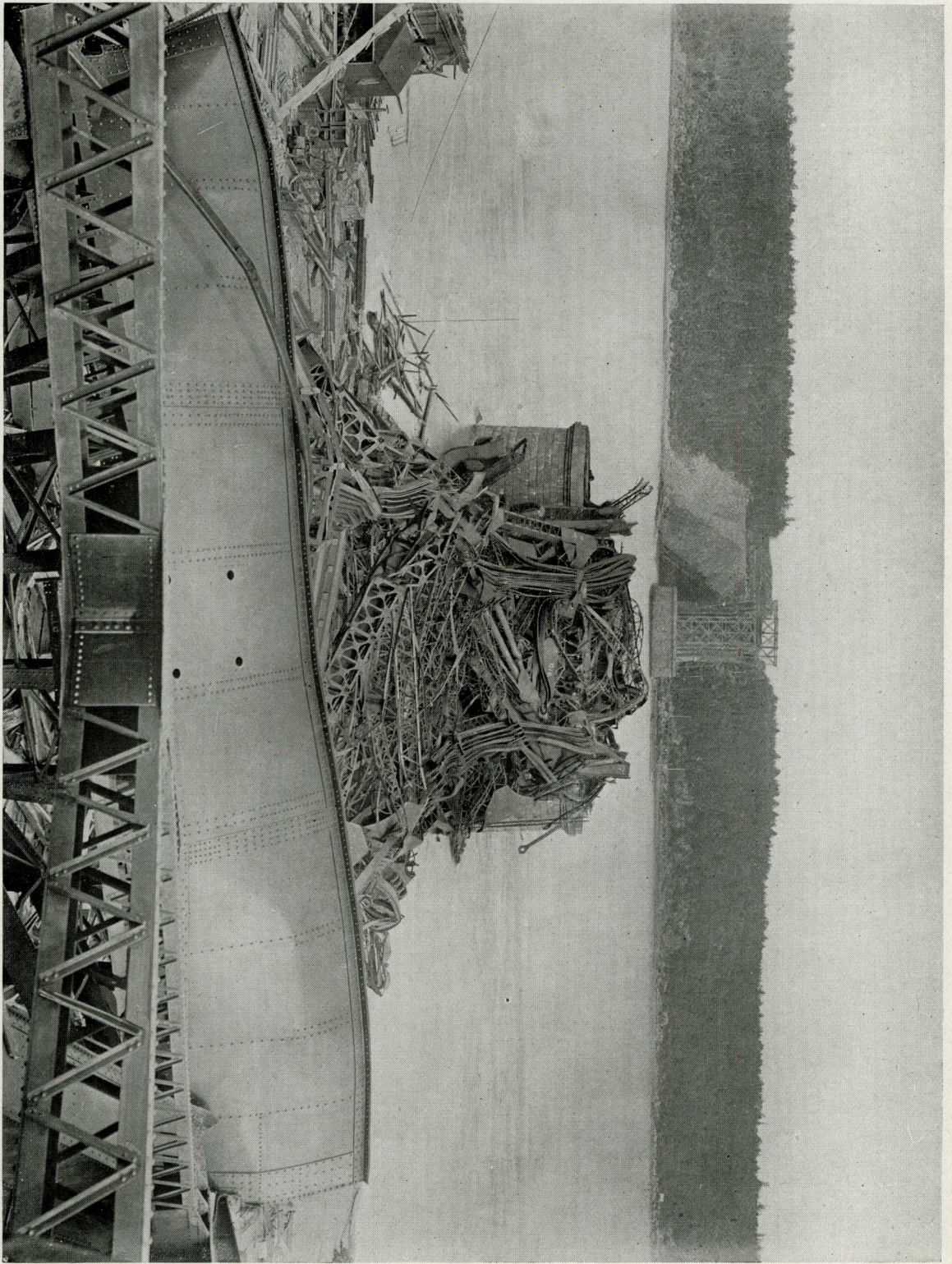
Mr. Vautelet prepared plans and specifications which were exhibited to intending bidders about the first of January, 1910, but the other Members of the Board did not fully approve of the plans, believing that a more practicable design could be produced and consented to tenders being called upon the design only on condition that bidders might submit tenders on their own plans if they so desired.



5—Photograph of the Phoenix Company's bridge taken August 28, 1907, showing condition of the structure just previous to its failure



6—General view after the collapse from the Main pier Southwards



7—General view after the collapse from the anchor pier Northwards

Plate 8 shows the other designs on which tenders were submitted.

During the discussion of the plans Mr. FitzMaurice resigned and Mr. Chas. MacDonald, then retired from active practice, was persuaded to join the Board until a design should be selected. After tenders were received Mr. Vautelet still strongly contended for his design, while his colleagues favored the design of the St. Lawrence Bridge Company, and Messrs. M. J. Butler, C.M.G., M.C.S.C.E., and Henry W. Hodge, M.A.S.C.E. of New York, were called in to assist the Board in coming to a decision. Four Engineers of the Advisory Board so constituted recommended the design of the St. Lawrence Bridge Company, Mr. Vautelet alone dissenting and, when his colleagues' recommendation was adopted, he resigned from the Board.

The duties of Messrs. MacDonald, Butler and Hodge were discharged when a design was selected and after the contract was let, in April 1911, Mr. Modjeski was the only member remaining of the original Board. The Minister appointed a new Board about a month later to supervise the construction of the Bridge. This Board consisted of Messrs. Ralph Modjeski, C. C. Schneider and C. N. Mon-sarrat, Chairman.

The magnitude of the disaster to the bridge being erected by the Phoenix Bridge Company with its lamentable loss of life and serious financial loss, coupled with the fact that the proposed bridge was larger and much heavier than anything that had heretofore been attempted, had caused serious misgivings in the minds of the Government and the public as to the practicability of the construction, and from the outset the Government safeguarded itself in every possible way, a prominent clause of the Contract reading as follows:

"The Contractor must satisfy himself as to the sufficiency and suitability of the design, plans and specifications upon which the bridge is to be built as the Contractor will be required to guarantee the satisfactory erection and completion of the bridge, and it is to be expressly understood that he undertakes 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 therein specified. And the enforcement of any part or all parts of the specifications shall not in any way relieve the Contractor from such responsibility."

To implement the above guarantee, the St. Lawrence Bridge Company was required to make a cash deposit of \$1,297,500, and, in addition, both the Canadian and Dominion Bridge Companies became joint and several guarantors for the completion of the bridge, putting their entire assets at stake.

The design of a cantilever structure of this magnitude does not differ sensibly in the calculations of the stresses from similar structures of much shorter span, but owing to the unusual size of the members it was necessary to keep constantly in view the manufacture and transportation of such large members and even more important to consider the erection of these members in the bridge. It was also necessary to consider the elastic deformation of the bridge as the erection proceeded.

There were no shops in Canada equipped to manufacture the large members required by the design and as soon as the contract was signed the Company proceeded to provide the necessary facilities for manufacturing the rolled material into finished bridge members. About half the manufactured material was destined for rail level at each side of the River and as there was no crossing below Montreal the shops were built at Rockfield, near Montreal, where short sidings connected the shop tracks to both the Grand Trunk and Canadian Pacific Railways. The Government Railway on

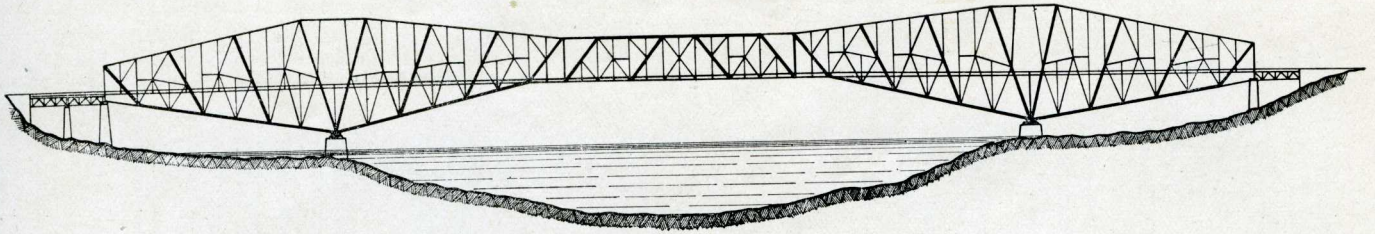


Fig-1

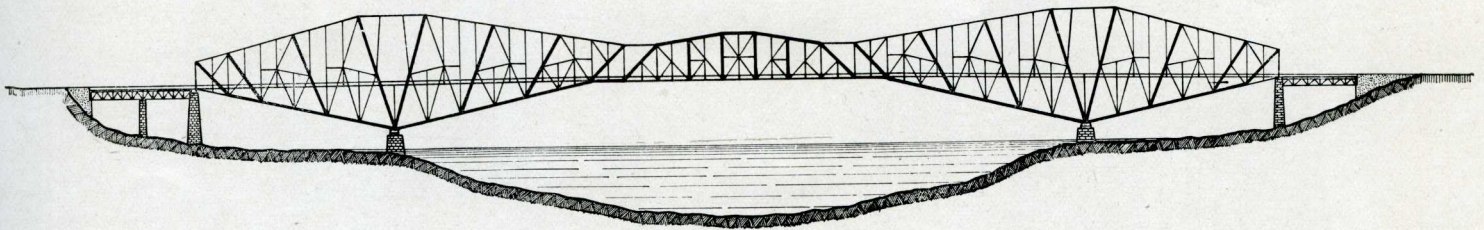


Fig-2

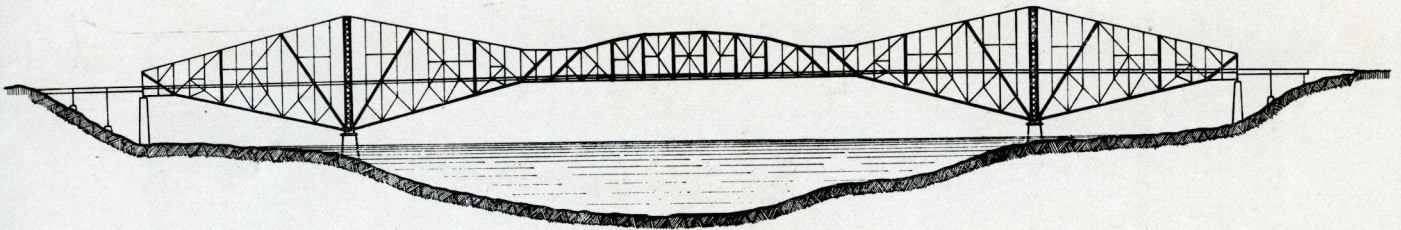


Fig-3

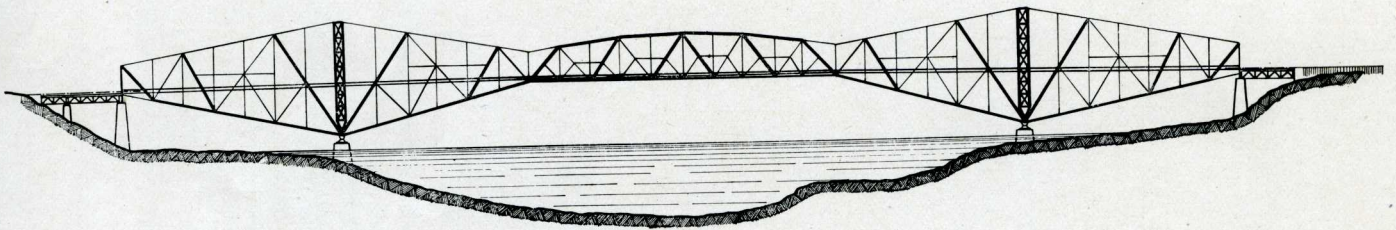


Fig-4

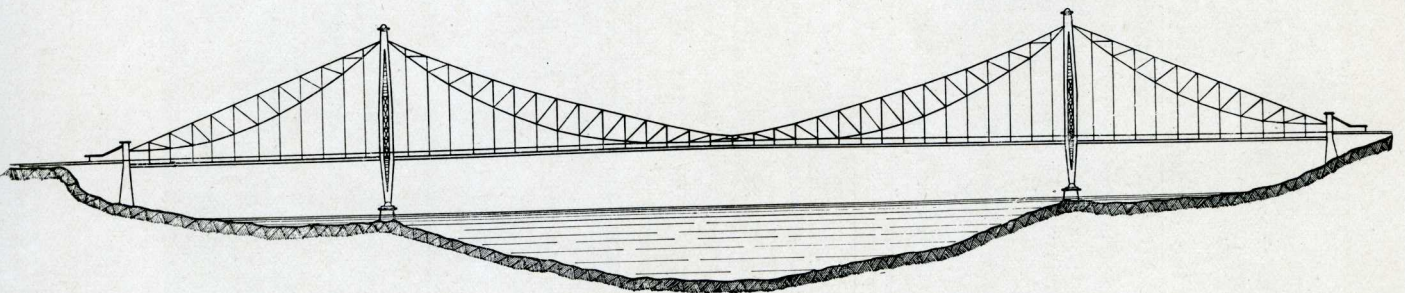


Fig-5

8—Other Designs on which tenders were submitted:

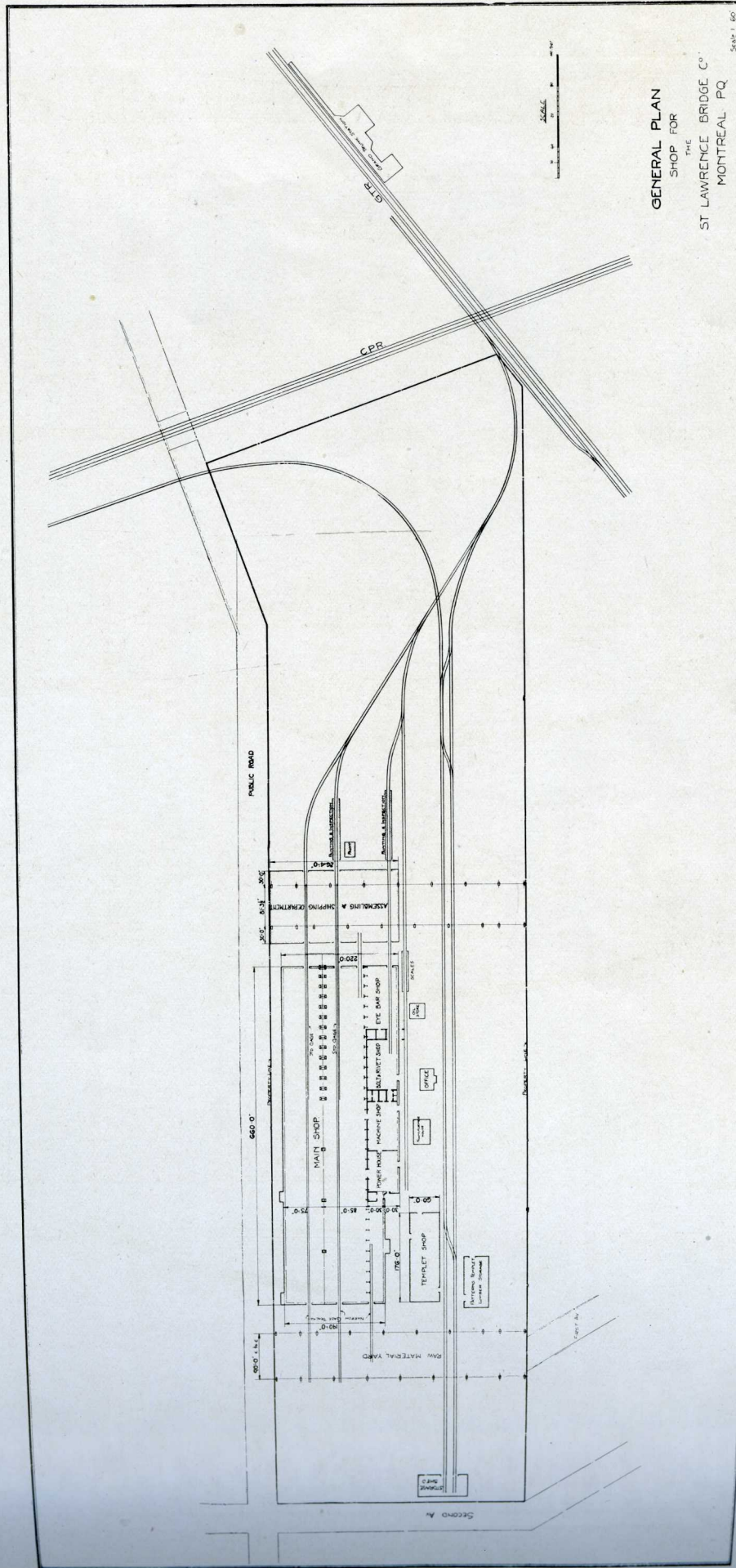
Fig. 1 is the Official Design exhibited when the call for tenders was advertised

Fig. 2 is a modification of the Official Design

Fig. 3 is one of the alternative designs submitted by the St. Lawrence Bridge Company

Fig. 4 is a German design submitted by Maschinen-Fabrik, Augsburg, Nuremberg

Fig. 5 is a suspension bridge submitted by the Pennsylvania Steel Company



9—Plan of shops showing rail connections to the principal railways

the South shore had running rights over the Grand Trunk Railway and the Canadian-Pacific Railway served the North shore. Direct rail connection was thus established with the bridge on both sides of the River by the shortest routes. A good supply of efficient labor at Montreal also had its influence on the choice of a manufacturing site.

Plate 9 shows a general plan of the shops. The shops were constructed of steel and masonry and made fireproof throughout. Although they were established for the manufacture of this bridge only, it was considered prudent to incur the extra expense of fireproof buildings for the sake of minimizing the risk of delay through fire.

The cost of the shops and their equipment was about \$1,300,000.

The specifications adopted were exacting as regards quality of material and manufacture. The Contractors realized that the structure could be properly erected and without difficulty only if the utmost precision in lengths, fitting and connections should be attained. Special machinery was provided; all important holes were drilled; great care was taken in assembling and rivetting the material and to finish the ends and bore the pin holes of the members perfectly square as well as to the exact lengths.

Plates 10, 11, 12, 13 and 14 show interior views of the shops with some of the large members being manufactured.

The normal season at Quebec during which field work can be successfully carried on is so short—some seven months each year—that it was necessary to provide plant that would allow the erection to proceed at the maximum safe speed. Convenient storage yards were established both on the North and South shores of the River equipped with crane runways, 500 feet long, overhead travelling cranes,

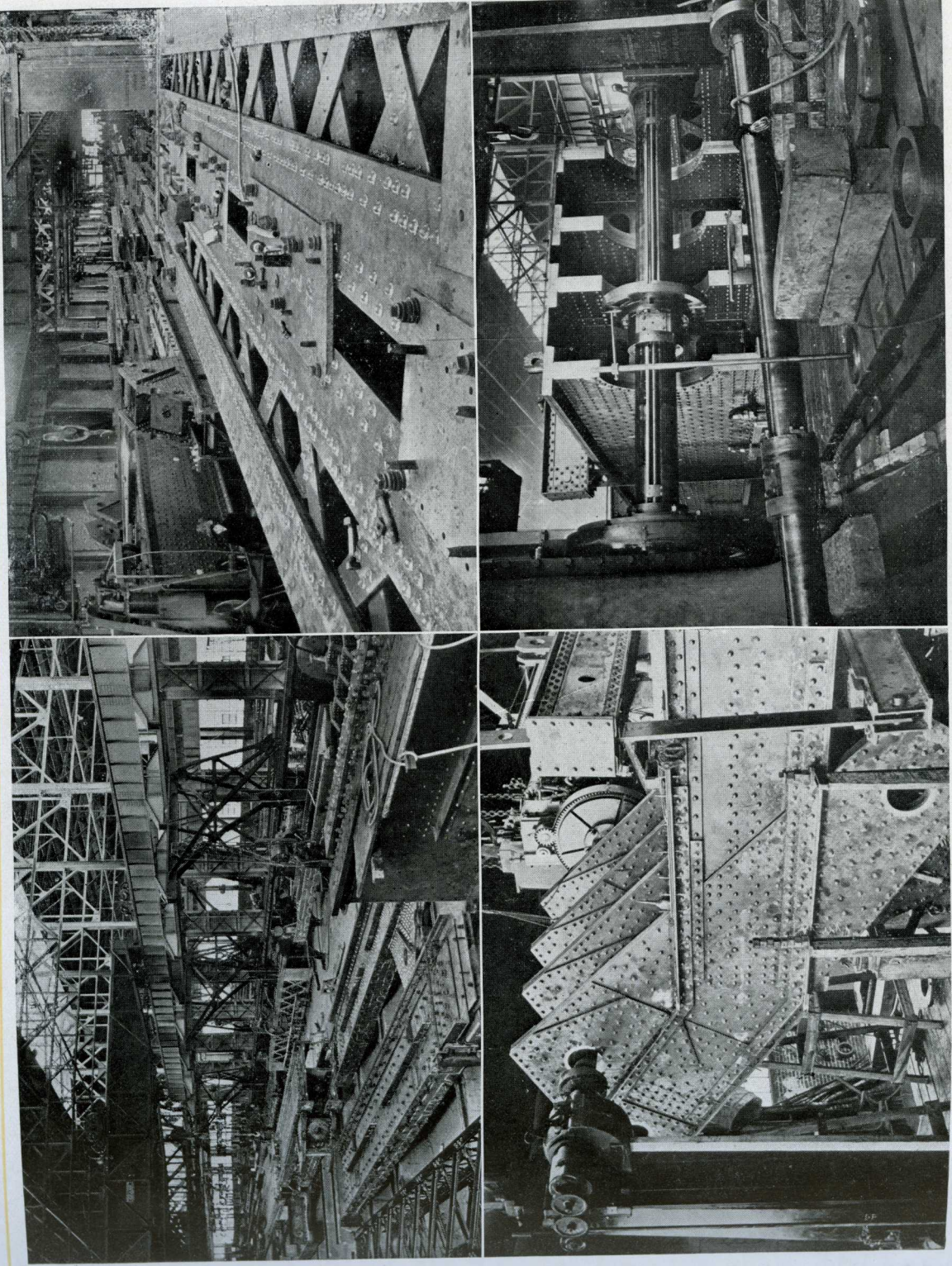
83 feet span and of 70 tons capacity. Ample storage tracks were also laid for the lighter material to be operated by thirty-ton locomotive cranes. Offices and a completely equipped boarding-camp were erected in which the engineers and most of the erection force could be accommodated.

Plate 1 shows the locations of the main camp and the North and South storage yards.

The design of the main erection travellers received much consideration—indeed the designs of the bridge and the travellers were to some extent interdependent.

These travellers are illustrated on Plates 15, 16 and 17, and will be seen in many of the progress photographs. The travellers were about 210 feet high from the rails on which they ran to the top of the hoists. The travelling cranes on top carried two 60-ton hoists which had a transverse travel of about 14 feet, the maximum spread at which they worked being 96 feet. The width of the tower was 54 feet centres, its length 37 feet, and the length of the upper trusses carrying the crane runway 151 feet. There were four booms each 90 feet long capable of handling 15 tons and there were small 7-ton auxiliary gantry hoists at the end of the cranes for handling cages, pins and light work. The weight of the traveller was 940 tons about equally distributed on the two tracks when the cranes were at the rear end for moving. When the traveller was lifting its maximum loads the total reaction at the front end was about 1,300 tons. The traveller was carried by two rails on each side, the inner rail being carried by the track girder of the permanent floor and the outer rail by a girder placed temporarily for the purpose, shown on Plates 17 and 37.

Steel falsework was provided for carrying the erection travellers and the floor system of the anchor arm during its erection. The permanent floor beams and stringers were



10—Views showing the interior of the shops with bridge members in the process of manufacture