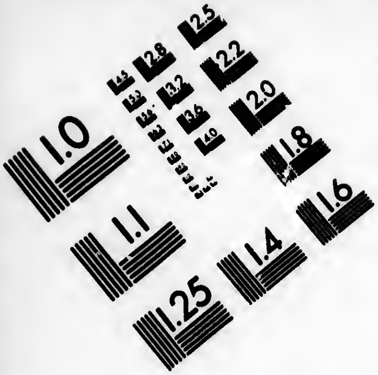


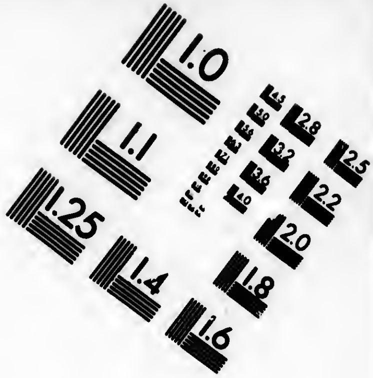
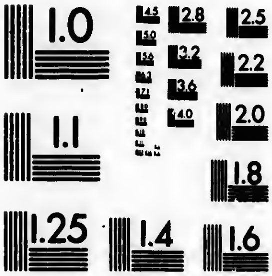


IMAGE EVALUATION TEST TARGET (MT-3)



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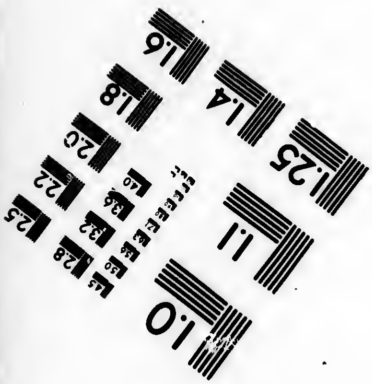

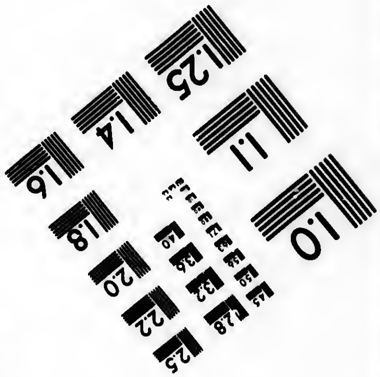

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Canadian Society of Civil Engineers.

INCORPORATED 1887.

TRANSACTIONS.

N.B.—This Society, as a body, does not hold itself responsible for the facts and opinions stated in any of its publications.

This Paper will be read on the evening of ~~Monday~~ April 5th.

THE C. P. R. BRIDGES OVER THE OTTAWA RIVER AT ST. ANNES AND VAUDREUIL.

By C. E. W. Dodwell, M. Can. Soc. C. E.

The Ontario and Quebec Railway, built some four years ago between Smith's Falls and Toronto, and forming the most important part of the Eastern system of the Canadian Pacific Railway, was extended in the years 1886 and 1887 easterly from Smith's Falls direct, thereby cutting out Ottawa, and reducing the distance between Toronto and Montreal by nearly fifty miles. The line from Smith's Falls to Vaudreuil, about 100 miles, is as nearly as possible an air line. At the latter point it comes into parallelism with the Grand Trunk Railway, running close alongside it from thence to Lachine Bank, where it slightly diverges to the north to make connection with the Atlantic and North-west Railway running from Mile End to the new bridge across the St. Lawrence at Lachine.

At Ste. Annes the line crosses a branch of the Ottawa river flowing between the Island of Montreal at Ile Perrot, by a bridge parallel to, and 61 feet distant, centre to centre, from the G. T. Ry. bridge. The bridge consists of two abutments and thirteen piers of masonry, and fourteen girder spans of steel.

Beginning at the east end, and measuring from centre to centre of piers, the first three spans are 104 ft. 9 ins. each. These are lattice "through" girders, the object being to give as much head-room as possible over the canal locks. The fourth span is 324 ft., and the girder a pin-connected through truss of the most modern American design. The corresponding span in the G. T. Ry. bridge is only 220 ft. Owing, however, to the obliquity of the current in the river at this point and the consequent danger to descending rafts, the Department of Railways and Canals required that in the new bridge there should be no pier in the stream opposite to No. 4 of the G. T. Ry. bridge; consequently pier No. 4 of the new bridge corresponds with No. 5 of the G. T. Ry., and there is one span of the former to two of the latter. The 5th span is 101 ft. 4 ins., and the 6th 100 ft. 9 ins., both being lattice "deck" girders. The remaining eight spans are 66 ft. 1½ ins. each, plate "deck" girders.

The East abutment is built directly on the solid rock, which was found at a depth below the surface of the ground of 2 or 3 feet.

The rock here is the Potsdam sandstone overlaid in the immediate vicinity by the Trenton limestone. It is of the latter stone that the whole of the masonry is built.

At pier No. 1, which comes between the public road and the new lock, the excavation was carried down about eight feet below the surface, at which depth solid rock was found sloping to the S. W., at an angle of about 15°. Convenient fissures in the rock enabled a trench to be formed a couple of feet deep and about the same in width, along the axis of the pier, in order to provide against the possibility of the pier sliding on the rock. Concrete was then deposited in this trench, and brought up level to the height of the highest point of the rock, the masonry being started on the base thus formed.

Pier No. 2 came between the old and new locks, and the excavation for the foundation encountered the puddle trench and its crib-work backing, that was formed to exclude the water from the works of the new lock constructed in 1882. This puddle trench, as well as a quantity of cribwork, had to be removed in order to reach a solid foundation. The last foot or two of the excavation being under water was finished by the aid of a diver, and at about 15 ft. below the surface of the ground the solid rock was struck, lying with but a slight fall to the S. W. After the surface of the rock had been thoroughly cleaned off by a diver, it was covered by a bed of concrete about 5 ft. thick and about a foot larger each way than the bottom course of the masonry. The first stone of the bridge was laid in this pier on the 3rd of August.

Pier No. 3 was the most troublesome and expensive of the whole thirteen. It came between the old canal lock and the river, and the South wall of the former and the cribwork bank of the latter contributed to render its construction both tedious and costly.

The excavation was carried down to water-level in the ordinary manner without much trouble. To continue the excavation below this level it became necessary to remove some forty feet in length of the cribwork in the river front; permission to do this having been obtained from the Department of Railways and Canals. A dredge was then brought up and fixed in position in the river abreast of the pier site, the excavation being by means of it carried down very nearly to the solid rock. Owing, however, to the proximity of the wall of the lock, the dredge had to work with extreme care in order to avoid disturbing its foundations. As soon as the dredge had done as much of the excavation as could be safely and conveniently done by it, three divers were sent down to complete the cleaning of the bottom; and a bottomless rectangular caisson 34 ft. long and 13 ft. wide was framed in position of whole timbers 12 inches square. The object of this caisson was to prevent the sides of the excavation from filling in and covering the site of the pier, as well as to form a mould for the bed of concrete. By means of accurate soundings, the caisson was framed as nearly as possible to conform on the upper side to the irregularities of the rock and the projections of the lock wall. On the lower or river side there was a space beneath the lowest timber of some three or four feet As soon as the caisson was finally and accurately fixed in position, this space, as well as the small cavities that still remained under the timbers on the upper side, was enclosed by driving 3 inch planks around the outside of the caisson and spiking it firmly to the timbers. Inside the caisson as now fixed and enclosed, three divers continued and completed the final cleaning of the bottom, about ten days being occupied by this work. When this was satisfactorily accomplished, a bed of concrete, varying from 5 to 9 ft. in thickness, was deposited within the caisson by means of a square box of $\frac{3}{8}$ inch boiler-plate holding a cubic yard, the bottom of which was hinged in two flaps and adapted for tripping, the scow carrying the derrick that raised and lowered it, and on the deck of which the concrete was mixed, being in the old lock immediately abreast of the pier. The top of the concrete was levelled up and finished to a height of about 6 inches above low water, and eleven days later the masonry was begun.

Pier No. 4 is the first river pier, the site being bare rock and the water about four feet deep at lowest level. The caisson for this pier was framed to half its height at a convenient spot on the river bank below the bridge, and then towed up stream by a tug, and lowered into position. On reaching the site of the pier it was rigidly held in place by anchors at bow and stern, and the remaining height of timber was added. A bed of concrete about $2\frac{1}{2}$ feet in depth was then deposited in it, and as soon as this had set sufficiently the water was pumped out and the masonry commenced. This pier, as well as No. 5, is built on a skew of 10°. 30′ i. e., the axis of the pier makes an angle of 79°. 30′ with the centre line of the bridge.

The 5th and 6th piers were built in a precisely similar manner; the water was of about the same depth, and the bottom also bare rock. At piers 7 and 8 the water being less than 2 ft. deep, caissons were not necessary, the water being excluded from the foundations by means of plain rectangular cofferdams of square timber built round the site. These were surrounded by a low wall or bank of puddle and then pumped out. All the excavation necessary consisted of the removal of about a foot of loose and shattered surface rock. At pier 7 no concrete was necessary, the masonry being laid directly on the rock. At No. 8 the rock after being stripped of the loose surface was covered or levelled up with a bed of about a foot in thickness.

Piers 9, 10 and 11 are situated on a low rocky island, the surface of which is from one to two ft. above low water level; none of them required either caisson or cofferdam. No. 9 has no concrete under the masonry, while at 10 and 11, after stripping the loose rock from the surface, the bottom was merely levelled up with it.

Piers 12 and 13 coming in a foot or two of water required cofferdams and a thin bed of concrete to level up with. At the West abutment, the rock, which was covered with some three or four feet of soil and loose material, was found to dip to the North at about the same angle as at the East abutment it did to the South. It was benched to receive the masonry and no concrete was used.

A small bridge across a creek between Ste. Annes and Vaudreuil consists of two spans of lattice deck girders 100 ft. 9 ins. each; the masonry comprising two abutments and one pier. These were built on solid rock, and present no features of special interest. The pier required a cofferdam, and the rock under it was levelled up with about a foot of concrete, none being used in the abutments.

At Vaudreuil the line crosses another branch of the Ottawa, flowing between Ile Perrot and the main land. The bridge here is parallel to, and distant 67 feet, centre to centre, from the Grand Trunk Ry. bridge. It consists of two abutments and sixteen piers of masonry with seventeen spans of steel "deck" girders. Beginning at the East End and measuring from centre to centre of piers, the first eight spans are 100 ft. 9 ins. each, lattice girders, the next seven spans are 71 ft. 2½ ins. each, plate girders, the remaining two are 65 ft. each, also plate girders. The East abutment stands just above low water mark. Its foundation was carried down to a hard bottom of stoney clay at about 5 ft. below the surface. The first seven piers, and the sixteenth, were built in water varying from 8 to 20 ft. in depth. The first operation in their construction, after having closely covered the site of each pier with accurate soundings, was the removal of the gravel, mud and boulders overlying the rock, which was accomplished by an ordinary floating steam dredge anchored over each foundation in succession. Bottomless caissons built of 12 inch square timber, and pointed at bow and stern, were then towed into place, their exact positions being determined by means of two transits, one of the centre line of the bridge on shore, and the other on the G. T. bridge in the line of the axis of the pier produced. They were then firmly held in place by suitable and sufficient anchors, and weighted until they rested on the bottom. Very accurate and careful soundings having been taken over the exact sites of the piers subsequent to the operation of dredging, the bottom (i.e., the bottom edges) of the caissons were framed to fit the irregularities of the rock. As soon as they were in position the bottom within their area was thoroughly cleaned by divers of all gravel and small boulders left by the dredge, any crevices between the bottom timbers and the rock being tightly packed with pea-straw. A depth of concrete equal to about one-third of the depth of water was then deposited with them by means of the iron box, and the surface of this bed levelled up by the divers. When the concrete had set the caissons were pumped out by a 6 inch centrifugal pump, driven by a floating engine of about 15 H. P., and the masonry commenced.

In one or two instances when the water was nearly all pumped out the bed of concrete was burst upwards by the pressure from below; when this happened, the caisson of course filled immediately, and it became necessary to send down divers to repair the leak, additional concrete also being put in for the purpose. Piers 8 to 15 inclusive, being in shallow water, required no caissons. The foundations were surrounded by cofferdams built of large flatted timbers, sheeted outside with 3 inch plank and with well rammed puddle walls all round. After the spaces enclosed by these water tight dams were baled out, the excavations were carried down to the necessary depth with pick and and shovel, and the masonry built directly on the hard bottom without the use of concrete. The West abutment, like the East one, was built just above low water mark. A solid foundation of hard-pan was reached at a depth below the surface of about 8 ft. The whole of the masonry was finished about the 1st June, 1887.

The concrete used in these bridges was composed of Portland cement, sand and limestone broken to pass through a 2 inch ring. It was mixed in the proportions of 1 volume of cement, 1 of sand, and from 4 to 5 of broken stone, which made an exceedingly rich concrete. In fact, the beds upon which the masonry was built were generally almost as hard as the stone itself. A less expensive composition in the foundations would have easily and safely carried all the weight they were called upon to bear; but one of the objects in making the concrete so rich was that it might be capable of withstanding the strain of the upward pressure of water, due to the difference in level between the outside and inside of the caisson. This was occasionally considerable, in some cases being as much as 800 lbs. per sq. ft., and consequently any economy effected by stinting the cement would probably have been sunk by the additional expense of repairing leaks, and by the loss of time in extra pumping.

The concrete was mixed on a decked scow anchored alongside the caisson. In the centre of the scow was a pile of broken stone, and at each end a number of barrels of cement and a pile of sand, leaving a clear space on each side of the pile of broken stone. A barrel of cement being broken open, the contents were spread out in a layer five or six inches thick; an equal quantity of sand was then added, and the whole intimately mixed in the dry state with shovels and hoes. A sufficient quantity of water was than poured into the centre of the mass, which was immediately worked into a moderately thin mortar. The broken stone was then thrown in from the heap, the quantity being so regulated that each fragment of stone was completely covered with and imbedded in the mortar. The whole heap, after it was thoroughly incorporated by being turned over two or three times with shovels, was then thrown into the box which it just filled. While at one end of the scow the concrete was being mixed, at the other end it was being thrown into the box and deposited in the caisson; two gangs were thus kept constantly going and no time lost. The contractors for the whole substructure of these bridges were Messrs. Wm. Davis & Sons of Ottawa.

The temporary staging for the erection of the superstructure of these bridges was of the ordinary character of trestle-work, consisting for the most part of four post bents at spans of about 14 ft.; with the exception of that for the fourth span (324 ft.) of the St. Ann's bridge, it was all erected in the winter, and calls for no special description.

Owing to unforeseen delay in the shipment of the 324 ft. span from Glasgow, where it was made, the false work for it could not be erected during the time of low water in the winter. When at length the iron did arrive, further delay was caused by having to wait till all the ice had broken up and gone down the stream. In consequence the false work for this span, commenced May 5th, 1887, had to be erected when the river was at its highest and the current at its swiftest; the depth of water at the deepest point of the channel being 37 ft., and the current from 7 to 8 miles per hour at a considerable skew. Preparatory to framing the bents, accurate soundings were taken at the position of each post by means of lengths of gas-pipe steadied by lines to bow and stern of a scow, which was held in place by wire cables to the cribs described further on.

The bents were 13 ft. apart; those under panel points, i.e., every alternate bent, had five posts each; the intermediates three each. They were framed on a large scow lying alongside the upper canal pier. Before sending any of them down to their place, two small but heavy cribs, about twelve feet square in plan and six or eight feet high, were framed, loaded with stone, and sunk in the stream some four or five hundred feet above the bridge. In addition to these anchor cribs, two tugs were employed during the greater part of the time that this span of false work was in course of erection. As each bent was framed, the scow carrying it was lowered down stream into position, escorted by a tug, and steadied by wire cables to the anchor cribs. On reaching the site the lines to the cribs were made fast and the scow firmly held. The bent was then raised with suitable tackle by two small engines, one on top of each of piers 3 and 4, wire cables having first been made fast to the feet of the posts and carried up to the anchor cribs. As the posts in the channel bents were from 65 to 70 ft. long, the current from 7 to 8 miles per hour and the water 30 ft. deep, as has been said, it will readily be seen that the difficulties to be overcome in the construction of this temporary staging were of no ordinary character. In one or two instances the posts, upon feeling the force of the current, began to swing, the bracing gave way, and the whole bent had to be dropped into the stream to save the scow from being broken to pieces by the lashing backwards and forwards of the posts as the motion increased. A tug was then despatched to pick up the posts and tow them up the canal to be re-framed.

Immediately upon each bent reaching a vertical position, it was promptly steadied from the water line to the tops of the posts, a height of about 30 ft., by braces and waling pieces of 6 ins. × 10 ins. stuff bolted and spiked to the last preceding bent. Owing to the utter impossibility of ascertaining to a few inches the exact depth of water in which each post would stand, the braces and caps were all double, and attached to the bent by bolts passing through them but not through the posts, thus leaving the latter free to move up and down to a small extent to suit the inequalities in the bottom. In addition to the wire cables attached to the feet of the posts, and as a further precaution against slipping, they were furnished with a heavy pointed spike bolt driven into the timber.

The last bent was successfully placed in position on the 27th of June the "traveller" was completed on the 20th, and the erection of the span commenced on the 30th.

Superstructure. The following table gives the more important particulars of the superstructure of the three bridges:

Number of Spans.	Length Centre to Centre of Piers.	Neat length of Girders.	Width Centre to Centre of Girders.	Weight of each Span. lbs.	Price per lb. erected.	Remarks.
	Ft. In.	Ft. In.	Ft. In.		Cts.	
1	324.0	323.3*	20.0	931,749	4.80	Pin connected "Through" Truss.
3	104.9	104.4		176,870	4.15	Riveted Lattice " Girders.
1	101.5½		10.0	108,478	4.15	" " "Deck" "
11	100.9		10.0	108,478	4.15	" " " "
7	71.2½		10.0	64,337	3.77	" Plate " "
8	66.1½		10.0	65,541	3.77	" " " "
2	65.0		10.0	55,300	3.77	" " " "

*Centre to centre of end pins.

Plates 1 to 4 give general elevations of spans 324 ft. 104 ft. 9 ft. 100 ft. 9 ins. and 66 ft. 1½ ins., and extracts from the specification are given in an appendix.

The whole of the spans are of steel, built under the direct supervision of the Company's inspector.

The contractors for the work were the Union Bridge Co. of New York. The sub-contractors who actually built the spans were as follows: —For the 324 ft. span, Arrol Bros, Glasgow (except for the eye-bars, which were made at the Union Bridge Company's own works in Buffalo). For the 104 ft. 9 ins. spans, The Horsely Co., Tipton, Staffordshire, England. For the 101 ft. 5½ ins. and the 100 ft. 9 ins. spans, The Cleveland Bridge Co., Darlington, England. For the 71 ft. 2½ ins., 66 ft. 1½ ins. and the 65 ft. spans, Arrol Bros., Glasgow.

The cost of the bridges described is given by the following statement:

ST. ANNE'S BRIDGE.

ITEM.	QUANTITIES.	RATE.	AMOUNT.	AMOUNT.
Earth excavation. Cub. yds.	1,830.4	$0.31	$567 42	
Loose rock......... " "	112.6	0.90	101 34	
Earth and loose rock excavation under water. C. yds.	573.3	2.00	1,146 60	
Concrete. Cub. yds..........	474.00	15.00	7,110 00	
1st class masonry. Cub. yds.	5,290.94	15.00	79,364 10	
Rough rip-rap. "	147	1.50	220 50	
				$88,509 96
Sundry Extras.—Removing buildings from site of E. abutment, cutting checks for girder bed-plates in pier copings, handling timber, etc., etc				1,110 97
Iron and Steel in Superstructure.—				
747,566 lbs.	@	0.04^{15}	31,023.99	
444,328 "	@	0.03^{77}	16,751.17	
931,749 "	@	0.04^{80}	44,723.95	
				92,499 11
Timber in Floor.—				
181,852 ft. B. M. @ per M.		15^{00}	2,727 78	
11,560 " " "		18^{00}	208 08	
Extra work on floor, labour, etc.			150 68	
				3,086 54
Total cost of St. Anne's Bridge.........				$185,206 58

"STOCKERS" CREEK BRIDGE.

Earth excavation.	Cub. yds.	259.2	$0.31	$ 80 35	
Loose rock do	"	31.4	0.90	28 26	
Earth and loose rock excavation under water.	C. yds.	37.3	2.00	74 60	
1st class masonry.	"	939.77	15.00	14,096 55	
Concrete	"	4.70	15.00	70 50	
					$14,350 26

Sundry Extras.—Cutting checks for bed-plates, handling timber, etc. 361 39

Iron and Steel in Superstructure.—

216,956 lbs. @ 0.04^{15} 9,003 67

Timber in Floor, etc.—

31,526 ft. B. M. @ per M.	15^{00}	472 89	
hauling timber		34 19	
			507 08

Total cost of "Stockers" Creek Bridge... .... $24,222 40

VAUDREUIL BRIDGE.

Earth excavation.	Cub. yds.	388.1	$0.31	$120 31	
Loose rock do	"	5.5	0.90	4 95	
Earth and loose rock excavation under water.	C. yds.	1,566.1	2.00	3,132 20	
Solid rock excavation under water.	Cub. yds.	71.6	3.00	214 80	
1st class masonry.	"	3,385.68	15.00	50,785 20	
Concrete	"	978.12	15.00	14,671 80	
Rough rip-rap	"	4,728.	1.50	7,092 00	
					$76,021 26

Sundry Extras.—Handling timber, cutting checks for bed-plates, etc... 870 69

Iron and Steel in Superstructure.—

867,824 lbs. @ 0.04^{15}	36,014 70	
560,264 " @ 0.03^{77}	21,121 95	
		57,136 65

Timber in Floors.—

213,422 ft. B. M. @ per M. 15^{00} 3,201 33

Total cost of Vaudreuil Bridge. $137,229 93

SUMMARY.

St. Anne's Bridge....................	$185,206 58
"Stockers" Creek Bridge....................	24,222 40
Vaudreuil Bridge............................	137,229 93
Total cost of three bridges......................	$346,658 91

During the progress of this work there occurred two fatal accidents. On Friday, Jan. 21st, 1887, Mr. Harold Waldruff Keefer, M. C. Soc. C. E., Assistant Engineer, while in the discharge of his duties, fell from the top of the girders of Vaudreuil Bridge, a height of about twenty-one feet. He struck on his head and shoulders, the blow causing concussion of the brain, from which he died at half past six the following morning. Mr. Keefer was 29 years of age, a son of Mr. T. C. Keefer, C.M.G., Past-President C. Soc. C. E., and an engineer of marked abilities and great promise. The author is glad of this opportunity of recording the highest appreciation of his excellent qualities. As an engineer he was well up in his work, active, energetic and thoroughly devoted to duty. Of sterling worth as a man, he, in every respect and with all who knew him, commanded the highest regard and esteem. Generous, open-hearted and the soul of honour, he was, in a word, his father's son.

On the 30th April, during the erection of the false work for the long span at St. Annes, a scow with five men on it, while being towed up stream by a tug, capsized in the channel just above the bridge line. Four of the men were rescued by boats from the shore, but the fifth, a young man by the name of Rodgers, from Glasgow, an employee of the Union Bridge Co., sank before help reached him. His body was recovered about a week later.

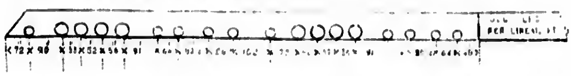
APPENDIX.

ONTARIO AND QUEBEC RAILWAY.

Extracts from General specification for the construction of the Bridges on the Ontario and Quebec Railway between Montreal and Smith's Falls.

5. Through spans, less than 100 feet in the clear, must have a clear width between the trusses of 16 feet. The 324 feet span must be 20 feet centre to centre of trusses. Deck spans less than 100 feet must be 10 feet centre to centre of trusses

Spans of 80 feet and under may be either plate or lattice girders. Those over 80 feet and under 100 feet in the clear are to be lattice girders, and spans over 100, feet in the clear may be pin connected.



10. All spans must be proportioned to carry, in addition to the dead load, two consolidation engines coupled as shewn in the above diagram, followed by a train load of 3,000 lbs. per lineal foot, and the maximum strains due to all positions of the live load must be taken in proportioning all the parts of the structure. Floor to be laid with 8" x 8" pine ties, spaced 12 inches centre to centre with two guard-rails on each side of track, one 6" x 8" and the other 10" x 10".

11. Variations in temperature to the extent of 180 degrees Fah. must be provided for.

12. All parts of the structure shall be so proportioned that maximum loads shall in no case produce a greater tensile strain upon the net section than the following:—

		Pounds per sq. inch.
On bottom chords and diagonals..	iron	10,000
" " "	steel	12,000
On counter rods, long verticals, and end lower chords....................	iron	8,000
" " " " "	steel	10,000
On lateral bracing (with 10,000 lbs. initial strain)........................	iron	15,000
" " " " "	steel	18,000
On bottom flange of riveted floor beams..	iron	8,000
" " " "	steel	10,000
On bottom flange of longitudinal plate girders (over 20 ft.)...............	iron	8,000
" " " " " "	steel	10,000
On bottom flange of longitudinal plate girders (under 20 ft.)...........	iron	7,000
" " " " "	steel	9,000
On suspension loops or other members liable to sudden loading.........	iron	6,000
" " " " " "	steel	7,000
On solid rolled beams..	iron	8,000
" "	steel	10,000

13. Compression members shall be so proportioned that the maximum load shall, in no case, cause a greater strain than that determined by the following formula:—

$$P = 8,000 \div 1 + \frac{L^2}{40,000\ R^2}$$ for square end compression members.

$$P = 8,000 \div 1 + \frac{L^2}{30,000\ R^2}$$ for compression members with one pin end and one square end.

$$P = 8,000 \div 1 + \frac{L^2}{20,000\ R^2}$$ for compression members with pin ends.

P = Allowed compression per square inch of cross section.
L = Length of compression member in inches.
R = The least Radius of gyration of the section in inches.

For steel substitute 10,000 for 8,000 in formula.

No compression member shall have a length exceeding 45 times its least width.

14. In rolled beams and girders compression shall be limited as follows:

		Pounds per sq. inch.
In rolled beams used as floor beams or stringers..............................	iron	8,000
" " " "	steel	10,000
In riveted plate girders used as floor beams, gross section.................	iron	7,000
" " " " "	steel	9,000
In riveted longitudinal plate girders (over 20 ft.) gross section.........	iron	7,000
" " " " "	steel	9,000
In riveted longitudinal plate girders (under 20 ft.) gross section......	iron	6,000
" " " " "	steel	8,000
In riveted lattice girders gross section..	iron	7,000
" " "	steel	9,000

15. Members subject to alternate strains of tension and compression shall be proportioned to resist each kind of strain. Both of the strains shall be assumed to be increased by an amount equal to 8-10 of the least of the two strains for determining the sectional areas, by the above allowed strains.

16. To provide for wind strains the top lateral bracing in deck spans and the bottom lateral bracing in through spans shall be proportioned to resist a lateral force, equal to 30 lbs. per square foot on the surface of the train averaging 12 square feet per lineal foot, and also on the vertical surface of one truss; the 360 lbs. pressure from the train surface to be treated as a moving load, and the pressure on the bridge surface as a fixed load. The bottom laterals in deck spans and the top laterals in through spans shall be proportioned to resist a lateral force equal to 50 lbs. per square foot upon the vertical surface of both trusses.

17. The strain in the chords from the assumed wind force arising from wind displacement (capsizing) and direct wind (transverse) strain will only be taken into account when they exceed one quarter of the maximum fixed strain for dead and live loads. The sections shall then be increased until the total strain per square inch will not exceed by more than one quarter the maximum fixed for dead and live loads only.

18. The rivets and bolts connecting the parts of any member must be so spaced that the shearing strain per square inch shall not exceed 7,500 pounds or ¾ of the allowed tension per square inch upon that member; nor the pressure upon the bearing surface per square inch of the projected semi-intrados (diameter x thickness of piece) of the rivet or bolt hole exceed 12,000 pounds, or one and a half times the allowed tension per square inch upon that member. In the case of field—riveting the above limits of shearing strain and pressure shall be reduced one third part. Rivets must not be used in direct tension.

19. Pins shall be so proportioned that the shearing strain shall not exceed 7,500 pounds per square inch for iron, and 9,000 per square inch for steel; nor the crushing strain upon the projected area of the semi-intrados of any member connected to the pin be greater per square inch than 12,000 pounds for iron and 14,000 pounds for steel; nor the bending strain exceed 15,000 pounds per square inch for iron and 20,000 per square inch for steel when the centres of bearings of the strained members are taken as the points of application of the strains.

20. In case any member be subject to a bending strain from its own weight, or from local loadings, such as distributed floors on deck bridges, in addition to the strain produced by its position as a member of the structure, it must be proportioned to resist the combined strains.

21. Plate girders shall be proportioned upon the supposition that the bending or chord strains are resisted entirely by the upper and lower flanges and that the shearing or web strains are resisted entirely by the web plate; no part of the web plate shall be estimated as flange area.

22. The iron in the web plate shall not be subjected to a shearing strain, greater than 4,000 pounds per square inch; and no web plate shall be less than three-eighths of an inch in thickness.

23. The web of plate girders must be stiffened at intervals of about the depth of the girders, whenever the shearing strain per square inch exceeds the strain allowed by the following formula:

$$\text{Allowed strain} = \frac{12,000}{1 + \frac{H^2}{3,000}}$$

When H = ratio of depth of web to its thickness.

24. No iron or steel plate shall be used less than ⅜ inch thick, except for lining or filling vacant spaces.

The compression flanges of beams and girders must be stayed against transverse crippling when their length is more than 30 times their width.

The unsupported width of any plate subjected to compression must not exceed thirty times its thickness.

25. The flange plates of all girders must be limited in width, so as not to extend beyond the outer lines of rivets connecting them with the angles more than five inches or more than eight times the thickness of the first plate. When two or more plates are used on the flanges, they shall decrease in thickness outward from the angles.

26. In members subject to tensile strains, full allowance shall be made for reduction of section by rivet holes, screw threads, etc.

27. All spans shall be given a camber by making the panel lengths of the top chord longer than those of the bottom chord in the proportion of ¼ of an inch to every ten feet.

28. The inner guard rails shall be let down over the ties, till the top of the 3" 3" angle iron, with which the upper inner angle is covered, shall be level with the top of rail. The angle iron must be straightened, and the holes for the ⅝" screws, with which it is to be fastened to the timber, must be slotted at the ends, so as to provide for a temperature varying between 40° Fah. below zero, and 140° Fah. above zero. Holes to be in each leg of the angle, three feet apart in centre, and eighteen inches apart at each end. The guard rails must be bolted to every fourth tie with a ¾-inch bolt, so that heads of bolts on the inner guard will not be above the top of the angle iron.

29. All eye bars, rods, bolts and pins shall be made of a tough, ductile, fibrous iron, uniform in quality, and which shall be capable of withstanding the following tests, when applied to full sized sections of the material tested.

30. Round bars up to 1½ inches in diameter must bend double, or until inner sides are in contact when cold, without showing signs of fracture.

Square bars must bend cold through 180 degrees around a cylinder having a diameter equal to two-thirds the length of side, without showing signs of fracture.

Flats must bend cold through 180 degrees around a cylinder having a diameter equal to the length of the shortest side, without sign of fracture.

The ultimate strength of the bar iron used shall not be less than $52,000 - \left(\frac{7,000 \times \text{area}}{\text{periphery}}\right)$ pounds per square inch; area and periphery being expressed in inches.

The elastic limit shall not be less than 20,000 lbs. per square inch, and the elongation of the bar before rupture shall not be less than 20 per cent. in 12 diameters.

The reduction of area of breaking point shall not be less than 25 per cent. of the original section.

31. All plate and shape iron used in tension members, or in members exposed to both compressive and tensile strains, shall fulfill all the foregoing conditions when tested in specimens of one inch area and fifteen inches length of smallest section, except that the breaking strain per square inch shall not be less than 49,000 lbs. for angles, 48,000 lbs. for beams and channel iron, and 47,000 lbs. for plate iron.

These classes of tension iron must bend cold, without fracture, as follows:

For Shape Iron, - 140 degrees	and the ductility must be	For Shape Iron, - 16 p. c.	
For Plate Iron, - 100 "		For Plate Iron, - 14 "	

32. Wrought iron for compression members must be tough, fibrous, uniform in quality, and with an elastic limit of not less than 25,000 lbs. per square inch.

Specimens of one square inch area shall bend through 90 degrees around a cylinder 1½ inch in diameter, without signs of fracture.

All cast iron used shall be good, tough, grey iron, of such quality that a bar five feet long, one inch square, and four feet six inches between knife edge supports, will sustain a weight of 475 lbs. on knife edge at middle of beam before breaking.

33. All steel used in tension shall have a minimum tenacity of 60,000 lbs. per square inch, a ductility of 18 per cent. in 12 diameters, and test pieces 15 inches long and 1 inch in sectional area, cut either or both cross-wise or length-wise, of plate steel, and length-wise of bar or shape; after being heated to a low cherry red and cooled in water of 82 degrees of Fahr., must stand bending double in a press or under the hammer to a curve of which the radius is one-and-a-half the length of the shortest side of the test piece. These test pieces may be cut in a planing machine and may have the sharp edges removed. Two samples shall be cut from each plate—one of which shall be tested for tenacity and ductility, and the other for temper and bending, as above described.

Steel failing on both sets of tests shall be rejected.

Steel up to the standard in tenacity and ductility, but deficient in bending and temper test, shall be annealed after punching.

Steel up to the standard in all but ductility may be annealed and retested.

Steel that is up to the standard in all the tests need not be annealed.

34. All steel used in compression shall be of good quality of mild steel having a minimum tenacity of 65,000 lbs. or over per square inch, an elastic limit of not less than 40,000 lbs., a ductility of 12 per cent. in 12 diameters, and not less than 15 per cent. reduction of area at breaking point.

Specimens one square inch in area of section shall bend cold through 140 degrees around a cylinder, the diameter of which is four times the length of the shortest side of the test-piece.

No steel shall be struck with a hammer or worked while at a black heat.

All steel, whether with drilled rivet-holes, or holes punched and reamed, shall be matched with the other parts of same member, and before being riveted up, all holes shall be matched and brought to a fit by reaming alone and without the use of drift-pins.

The matching of the holes shall be sufficiently close to permit the parts to be riveted up without producing an initial strain on the steel. Splice riveting in steel will be governed by the specifications for top chords and columns.

35. All tension iron shall be rolled from piles composed of piling pieces, each the full length of the pile. The use of old rails will not be allowed in the piles or this grade of iron.

All rolled iron or steel shall be thoroughly welded during the rolling, and must be straight—of full section at all points—and free from injurious or unsightly seams, blisters, buckles, slivers, cinder spots and imperfect or crooked edges.

All material as it comes from the mill must be first-class in every way; rolled pieces cut too close to the crop ends will not be accepted.

36. All specimens for testing, cut out from large pieces, whether of iron or steel, shall have a uniform least section of one square inch for a length of not less than 15 inches.

All bar and rod iron shall be tested in full sized sections whenever practicable.

No test specimen shall be hammered or forged after being cut from the original piece.

Complete facilities for inspection of material and workmanship must be given by the Contractor. Facilities and specimens for testing, and also the necessary labor, shall be furnished by him without charge when called for by the Engineer or Inspector. But when any full sized manufactured iron or steel members are tested to destruction, and proved to be up to the standard required, such material shall be paid for at cost, less scrap value to the Contractor.

Should such members fail to reach the standard they will not be paid for, and the Inspector may reject all similar members made of the same material.

The testing machine used by the Contractor shall be compared with the U. S. Government machine at the Watertown Arsenal or the Kircaldy machine in England; and if the results vary, the difference shall be equated, and added to or subtracted from the results obtained from the machine used by the Contractor.

37. All workmanship must be strictly first-class, and not what is commonly termed "merchantable work." Finished pieces shall be true to size, section and line, straight and out of wind at all points, and all machine, hydraulic, rivet or smith work done upon them shall be of the best character.

All measurements in laying out work shall be made with iron standards of the same temperature as the iron measured.

38. All eye bars shall be either upset on the solid bar, upset with piling piece, or rolled without welding. No patching at the forge fire will be allowed on bar or head. All heads shall be clean, full-sized forgings formed centrally on the bar in true line and "out of wind."

Bars of the same class and belonging to the same panel shall be drilled at the same temperature.

Pin holes in eye-bars shall be bored to exact size and distances, and to a true perpendicular to the line of strain. The pin hole shall be in the middle of the head and in the centre line of the bar. No error in length of bar or diameter of pin hole exceeding $\frac{1}{64}$ of an inch will be allowed.

The section of metal opposite the centre of the pin hole across the eye shall be proportioned according to the following table, the diameter of the bar being the unit:

PIN.	BAR.	EYE SECTION.	
		Upset Heads or Weldless Bar.	Heads Rolled on Bars.
0.67	1.0	1.50	1.33
0.75	1.0	1.50	1.33
1.00	1.0	1.50	1.50
1.25	1.0	1.60	1.50
1.33	1.0	1.70	1.60
1.50	1.0	1.85	1.67
1.75	1.0	2.00	1.67
2.00	1.0	2.20	1.75

For hammered eyes, the shape to be used shall be determined by the Engineer after the contract is awarded. No shape, which on testing shows five per cent. of breakages in the eye or neck, will be accepted.

Pins must be turned true to size and straight, no error of more than $\frac{1}{50}$ of an inch in diameter being allowed.

Pins connecting chords, posts and tie bars shall be fitted for pilot nuts, and shall not be more than $\frac{1}{40}$ of an inch less than the pin holes of the eye bars.

Pins connecting laterals with other members shall be turned down to a diameter of not more than $\frac{1}{65}$ of an inch less than the pin holes.

Pin holes in wing nuts, channel nuts or other arrangements for lateral connections shall be drilled or else punched and reamed to a size not exceeding $\frac{1}{16}$ of an inch larger than the pin.

Rods, round or square, used for ties or counters, shall be fabricated with the same precision and care as prescribed for eye bars. They may have loop-welded eyes with reamed intrados, the proportions of the loop to be approved by the Engineer. Screw ends shall be upset so as to give 10 per cent. more sectional area at the bottom of the screw thread than in the body of the bar. Sleeve nuts, clevises, or other members used for adjustment must have the pin holes, if any, drilled, and must be of sufficient strength to break the bar to which they are attached.

Rods, used for lateral or vertical bracing, may have pin holes $\frac{1}{16}$ of an inch larger than the pin, but otherwise are to be made with the same care as counter rods.

All eye bars and counter rods are to be tested to 18,000 lbs. per square inch, and bars showing structural defects, permanent set, or too great extension under strains, shall be rejected.

39. These shall be made of such iron or steel as is prescribed for members exposed to compression strain, except when otherwise specified. The splices shall be composed of edge-rolled plates in all cases. Abutting joints shall be milled off to exact lengths and square to the line of the chord. All pin holes shall be bored to an exact size, true to the line of strain, and correct as to position. No errors exceeding $\frac{1}{50}$ of an inch in length of part or in diameter or position of pin hole will be allowed. The pin holes may be bored $\frac{1}{32}$ of an inch larger than the pin, this is the utmost limit. Rivet holes in the splices shall be punched $\frac{1}{8}$ of an inch less than required, and then reamed to fit. After the splice plates are riveted on in the shop, each line of chords or columns shall be assembled—the joints matched, their abutting joints brought to a tight fit by turnbuckles, and all rivet holes in the ends of chords and splices in which the rivets are to be field-driven shall be reamed to an exact match and fit. Match marks shall then be made on each piece.

Parts composing posts or tie struts must be in one length, without splices between end bearings, unless specially permitted by the Engineer.

When necessary, pin holes in posts, chords or tie struts shall be reinforced by additional material, which must contain rivets enough to transmit the strain to the original member. The open sides of posts, chords, struts and tie struts shall be connected by lattice or trellis bars, the angles of which shall not exceed 63° 25′ for single bars, or 45° for double bars with riveted intersection.

The unsupported length of any lattice bar shall not exceed 45 times its thickness. All members of which the parts are connected by lattice or bracing bars shall have connection plates at each end, the row of rivets in which shall be equal to the width of the member in length and not more than four rivet diameters in pitch.

In all compression members the connecting rivets within two diameters of the ends shall be pitched not to exceed four times the diameter of the rivet.

The several pieces forming any built member shall fit closely together, and the member shall be free from bends, twists and open joints.

40. All joints shall be square and truly dressed. Rivet holes shall be accurately spaced, and the rivets must be of the best quality of iron for the purpose, and when driven must completely fill the holes.

All rivets with crooked heads, or heads not formed centrally on the shank, or rivets which are loose, either in the hole or under the shoulder, shall be cut out and replaced with good rivets.

Rivet holes shall not be spaced less than 2½ diameters between centres, nor more than 15 times the thickness of thinnest outside plate,—9 inches being the maximum pitch allowed in plate riveting.

No rivet hole shall be less than 1½ diameters from the end of a plate, or 1¼ diameters from the side of a plate, nor *ever* less than 1¼ inches from centre of hole to edge of plate, except in cases where the plate or side of angle is less than 2½ inches.

The diameter of hole shall not exceed the diameter of the rivet more than $\frac{1}{16}$ of an inch.

Where two or more thicknesses of plate are riveted together, the outer row of rivets shall, if practicable, not exceed three rivet diameters from the side edge of plate.

Where plates more than 12 in. wide are used in the compression flanges of girders or floor beams, an extra line of rivets, with a pitch of not over 9 inches, shall be driven along each to draw the plates together.

All joint rivet holes shall be so accurately spaced that rivets of the proper size can be passed through all the holes in the joint, after the parts are placed in position, without the use of drift pins.

All slice plates in which the holes are mismatched, either in the plates themselves or with the adjoining chord or flange, shall be matched and the holes reamed to fit before leaving the shop.

No inaccurate or otherwise defective work will be accepted under any circumstances in connection joints of riveted work.

The riveted field connections of floor beams, stringers, posts and struts, must be accurately matched before leaving the shops, and all unmatched holes reamed to fit.

All rivets in splice or tension joints must be symmetrically arranged, so that each half of a tension member or plate will have the same uncut area on each side of its centre line. Whenever practicable, rivets must be machine driven.

41. All bed plates must be of such dimensions, that the greatest pressure upon the masonry shall not exceed 200 pounds to the square inch. All spans shall have at one end nests of turned friction rollers, formed of wrought iron or steel, running between planed surfaces. The rollers shall not be less than 2 inches diameter, and shall be so proportioned that the pressure per lineal inch of iron roller shall not exceed the product of the square root of the diameter of the roller in inches multiplied by 500 pounds ($500 \sqrt{d}$). For steel rollers the pressure per lineal inch of roller shall not exceed the product of the square root of the diameter of the roller in inches multiplied by 600 pounds ($600 \sqrt{d}$). All the bed plates and bearings under fixed and roller ends must be fox-bolted to the masonry.

42. All iron work before leaving the shop shall be thoroughly cleansed from all loose scale and rust, and be given one good coating of red lead paint, mixed and applied as directed by the Engineer.

In riveted work the surfaces coming in contact shall each be painted before being riveted together. Bottoms of bed-plates, bearing plates, and any parts which are not accessible for painting after erection, shall have two coats of paint; the paint shall be a good quality of iron ore paint, subject to approval of the Engineer.

After the structure is erected, the iron work shall be thoroughly and evenly painted with two additional coats of paint, mixed with pure linseed oil, of such colour as may be directed.

All turned and faced surfaces shall be coated with white lead and tallow before being shipped from the shop.

43. The contractor shall furnish all staging and false work, shall erect and adjust all the iron work, and put in place all floor timbers, guards, &c., complete, ready for the rails.

The contractor shall so conduct all his operations as not to interfere with the work of other contractors, or close any thoroughfare by land or water.

The contractor shall assume all risks of accidents to men or material prior to the acceptance of the finished structure by the Railway Company.

The contractor must also remove all false work, pilling and other obstructions, or unsightly material produced by his operations.