REPORT

ON A

RAILWAY SUSPENSION BRIDGE,

OVER THE

RIVER ST. LAWRENCE, NEAR QUEBEC,

MADE FOR THE

CITY COUNCIL,

BY ORDER OF

N. F. BELLEAU, ESQ.,

Mayor of Quebec.

BY

WILLIAM SERRELL,

CIVIL ENGINEER.

QUEBEC:

PRINTED BY AUGUSTIN CÔTÉ & Co.

CITY PRINTERS.

1852.

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ON A

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SUSPENSION BRIDGE,

PROPOSED FOR CROSSING THE

ST. LAWRENCE RIVER AT QUEBEC,

MADE TO

HIS WORSHIP THE MAYOR

AND THE

CITY COUNCIL OF QUEBEC,

BY

EDWARD WILLIAM SERRELL,

ENGINEER.

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TO

HIS WORSHIP THE MAYOR

AND THE

CITY COUNCIL OF QUEBEC.

GENTLEMEN,

Agreeably to your resolution of 4th October last, requesting me to repair to Quebec to examine the proposed sites, for a Bridge to cross the Saint-Lawrence River, at or near your City and also desiring me, if the undertaking should be deemed practicable, to submit plans, specifications and estimates for the same, I have the honor to state, as already communicated in my letter of 4th November last, which gave an account of the progress of the field operations to that date, that I first surveyed a site near the River Chaudière, about four miles from the mouth of Cape Rouge Creek.

After which a line from the terrace of the old Palace of Saint-Louis to Point-Levy, was explored, and another from a few hundred yards above Cape Diamond to the opposite shore was inspected.

Careful reconnaissances of the whole river and harbour contiguous to the City and on the lines designated, sections of the banks, and soundings in the river, with instrumental measurements of distances, were made.

The result of these operations, is a conviction in my mind of the entire practicability of the undertaking. That is, I see no insurmountable engeneering difficulties in the case;

no reason for thinking, that a substantial Bridge, suitable for railway and other travel, cannot be built here ; and that too, within the means at your command.

I accordingly herewith respectfully submit the accompanying Maps, Plans and Report.

REPORT

OF THE DIFFERENT SITES PROPOSED.

The proposed crossing near the Chaudière River, designated as N° 1, on the general outline Map A., herewith submitted, will require a Bridge with an extreme length equal to *three thousand four hundred feet.*

The banks here are high and rocky ; on the North side, the top is one hundred and sixty-five feet, and on the South, it is one hundred and forty feet above extreme high water.

The lines of the shores are two thousand four hundred and forty feet apart.

The beaches slope gradually; they are rocky, and at low water, the river is one thousand eight hundred and fifty feet wide.

In twelve feet deep at low water, on each side, the distance is reduced to one thousand six hundred and twenty-five feet.

Beyond this the water becomes suddenly very deep, towards the middle, until it reaches upwards of one hundred and eighty feet.

The currents set in both directions accordingly as the tide is rising or falling.

There are two tides every twenty four hours and the average rise is about twenty feet.

At the site marked N°. 2, on the Map, the distance between the Terrace of the Old Palace Saint-Louis and the top of the bank at Point Levy is found to be four thousand six hundred feet, and twelve feet deep at low water on either side, would be two thousand nine hundred and eighty-seven feet apart.

Here the slopes of the beach are less gradual than at site N°. 1, and very deep water is found all across the river.

At five hundred feet from low water mark on the North Side, it is forty-five feet deep ; at a corresponding distance on the south side, it is one hundred and twenty six feet deep.

In the middle of the river, which is nearly the deepest part, it is about one hundred and seventy feet deep.

All these soundings are reduced to low water level.

The precise length of the line N°. 3, was not determined, but it is known to be several hundred feet more than N°. 2.

The soundings, etc., upon it were undertaken, at the instance of one of the City Council, who believed very shoal water would be found for many hundreds of feet out on either side.

Unfortunately, however, this was not the case and nothing was observed to warrant a comparison between its, and the other two proposed sites.

GENERAL COMPARISON BETWEEN PROPOSED SITES.

The very considerable disparate, in the cost of constructing at the proposed sites, would leave but little room for argument in favour of the one from the Palace Saint-Louis, to Point-Levy if the Bridge was the only question to be considered ; as however the province of the Bridge, when built, will be to connect the northerly with the southerly side of the River Saint-Lawrence, *at Quebec*, it would not be abeying its legitimate ends, if built at the upper site, unless a suitable mean was at hand to connect it with the City.

On Map A. a line for a proposed railway, is marked from the site N°. 1, to Saint-John's Gate, with a branch to the Lower Town.

This Railway will be six and one quarter miles in length, to Saint-John's Gate.

On this route the grades will not exceed fifty feet per mile, which is less than the maximum grade of the Quebec and Richmond Railway, while the curvatures are greater in radius than the minimum of the best constructed Railways.

By it all the business going to the Southern Shore of the River, could be, for passengers brought within less than fifteen minutes distance, in time; and for freight and heavy articles less than three quarters of an hour.

The connection with any great trunk line of Railway, to Halifax or any part of the Lower Provinces, must necessarily come to the river in such a way as to admit of an easy junction. Major Robinsons route, coming from Halifax on the line of the second concession, can be as easily if not more easily connected with the crossing of the river at this site than at any other.

Greater facilities exist at this site for connecting with the Richmond Railway, than at any other point of crossing that could be occupied by a Bridge.

At the site N°. 2, it would be necessary for the Bridge to be at least *thirty five feet higher*, than at N°. 1, as the largest class " men of war" are frequently in the Harbour, while, if I am correctly informed, they have never been up the river beyond Woolf's Cove, since the country has been in the British dominions.

In case of war, operations, in all probability, upon the waters above Quebec, would be carried on by steamers, as vessels of more than 600 tons burthen could not pass through Lake St. Peter (M. Culloughs, Geography).

Another advantage in favor of the upper site is the facility with which it can be connected with the shipping and the commercial part of the City, in the Lower-Town, by means of the branch from the proposed Railway.

This connection if made from Palace Saint-Louis terrace, would require *four miles of gradients,* to descend to the same level, at the proposed maximum grades of the Halifax and the Richmond Railways.

In view, then, of the many and very decided advantages in favor of the site N°. 1, or that near the Chaudière River, and the fact that there is nothing of a general public nature for the Bridge to perform, which it cannot do, as well at the upper as the lower site, I deem it to the interest of the City to recommend to you in the most unequivocal manner, that the bridge should be constructed at the site designated as N°. 1.

I have therefore prepared drawings in detail of the proposed work; and at the same time submit an outline of what would be necessary at the Lower Site N°. 2, with a rough estimate of the cost of the same, in order that you may complete the comparisons yourselves.

OF THE PLAN PROPOSED.

In presenting the accompanying plans for your adoption I am aware that, in all probability, opposition arising from long standing prejudices, will have to be met with and combatted, as at this moment, the opinion of the scientific world is divided on the matter at issue. I trust however that the facts here adduced will be sufficient to entitle the project to consideration, if not to settle the question.

The plan proposed is usually known as the *wire Suspension Bridge.*

It consists of two massive towers of masonry, built in the river in twelve feet deep of water at average low tide.

These towers will be in total height from their base, abou three hundred and thirty feet; they will be fifty two by one hundred and thirty-seven feet square at the base and will battar regularly upwards.

They will be *sixteen hundred and ten feet* apart at their centres.

It will be observed that the bridge will not cross quite at right angles to the river: this is done on account of the position of the shoalest water near the shores. The towers are however in the line of the currents.

The towers being so small at their base compared with the width of the river, will produce little or no effect on it.

On the banks, suitable abutments of masonry of proper proportions, will be erected as represented, forming revetments for the embankments.

The roadway at the abutments is to be one hundred and sixty-two feet above extreme high water, and will rise to the centre of the bridge eight feet.

The height at the central will therefore be one hundred and seventy feet above high water.

The roadway will consist of two carriage ways, each ten and one half feet wide in the clear, and a railway track of such width or gauge as to match the railways which may connect with it. The space for it is eleven feet in the clear.

The entire width of the roadway is to be *thirty-two feet in the clear* inside the parapets.

All the parts forming the roadway and parapets are to be of oak.

The roadway for common travel is to be on either side of the railway separated from it by a suitable railing as represented. The whole is to be supported by beams four feet apart at their centres. These beams are to be twelve by fifteen inches section; they are to be braced underneath so as to stiffen the bridge transversely by a king post and iron tension bars.

The floor plank is to be three and one half inches thick.

The railway and the space within the railways will be covered with a fire proof coating of some concreted substance, to prevent accidents that might otherwise happen from the sparks from locomotives.

The parapets are to be composed of four tiers of fifteen inches square timber, suitably tree-nailed together; each piece being jointed with ship laps, so as to form a continuous piece the entire length of the bridge.

Below the parapets and under the floor beams, three string timbers are to be fastened, the same as the parapets inverted. They are to be tree-nailed and jointed in a similar manner, and are to be secured to the other parts by bolts of iron of proper dimensions, which are to be put through the entire side including the cap, parapet, cross timbers and lower strings, in addition to which knees as represented in sheet N°. 4, are to be secured inside and outside the lower string timber and outside the parapet, making it like the sides of a heavy ship.

I am indebted to Mr. Ellet, of Philadelphia, for a part of the outline of this cross-section of the roadway and parapets.

The framing composing the parapet and string timbers is sufficiently strong to sustain its own weight for about five hundred and fifty feet, if considered as a beam supported only from either end.

Under the track strings, two additional longitudinal timbers for the purpose of stiffening this part of the bridge, and adding weight, are to be secured.

The roadway thus formed will be amply sufficient for any purpose for which it may be required.

The roadway is to be supported from suspending rods of suitable dimensions, attached to a system of cables, hung in catenarian curves from the top of one tower to the other, and from the tops of the towers to the abutments.

The cables are to be composed of iron wires laid parallel to each other. There will be one centre span and two land spans. The centre span will be sixteen hundred and ten feet, and each land span eight hundred and five feet; making the entire length of the roadway inside the abutments, three thousand two hundred and twenty-two feet.

The anchors and retaining walls are the attachments on the main land, to which the cables of support are fastened.

The mechanical arrangement consists of a system of bars to which the wire cables are attached. They pass through archways in the abutments and over segmental figures of massive masonry down through a shaft fifty-six feet into the solid rock of the banks of the river. The banks on either side are composed of the same formation as the bed of the river, a hard compact slate and lime.

In the shafts, which are slotted transversely, two inverted arches of cut masonry are to be turned; these arches will receive the keys of the anchors under suitable cast iron plates which form the key of the arch. See sheet N°. 3.

An adit level of sufficient size to get the machinery in and out, and to allow any water to escape, is to be cut, slightly sloping from the bottom of the shafts to the river bank.

These adits will cause a free circulation of air in the shafts about the retaining anchors, which will prevent any decomposition from dampness accumulating about them.

It is proposed to build the segments, retaining walls, offices, etc., of raugh masonry laid in cement, with cut caps and corners. The offices and buildings for tools, stores &c., will be in the revetments as represented: Sheet N°. 1.

Guies so arranged that they will draw evenly on the parts to which they are attached, are to be secured to the sides of the deck in such a manner that they may be fastened to blocks sunk in the river for that purpose: they are to be made of wire the same as small cables ; a mechanical contrivance has been arranged by which the guies will be kept at the same strain at all temperatures.

By the proper machinery already used, a very even strain will be produced on every wire of the main cables, so that each may carry its own proportion of the weight of the bridge and the loads which may come upon it.

It will be observed that the cables at the points of support are seventy feet apart, while at the apex of the curve they will very nearly approach the parapets of the bridge, thus forming horizontal as well as vertical curves. This arrangement will materially stiffen the entire structure ; light bracing rods are to be added to the suspending rods in such manner as to prevent heaving motions or vibrations which would otherwise arise in the very long ones from passing loads.

The main cables are to be tied together overhead by cross ones of smaller dimensions. This too will stiffen the work and tend to prevent pulsatory movement.

Most of the European suspension bridges have been built with the cables in parallel planes, and unconnected except by means of the roadway, and at the towers.

A series of cylinders on heavy plates will rest on the masonry of the towers and will carry the saddles that the cables pass over. They are more fully described at page 42 (1).

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(1) Here and elsewhere the page of reference is that of the manuscript.

COFFERDAMS.

By means of the ordinary instruments for sub-marine operations, exact measurements of the bed of the river, where it is proposed to sink the foundations and works about them, are to be made.

Crib work is then to be arranged so as to fit the rocks and surface as nearly as possible.

A general plan of the proposed dam is represented on sheet N°. 5, Fig. 1.

Fig. 2, is a longitudinal section of the same. Fig. 3. is a cross section. The other figures represent the details of construction.

It is to be built on the shore the same as cribs for piers, and hauled into place by suitable means worked by capstans on it. It is to be loaded down into place by stones thrown into compartments.

The entire system will consist of crib-work framing, forming three cellular compartments. The outside and inside ones are for the purpose of containing the ballast, and for strength to the whole. The centre compartment is to contain a puddle bank, as represented.

The clay forming the puddling is to be placed between sheet piling, which is secured to the crib work.

Braces as represented in the detached Fig. 5, will keep the two systems of crib work at proper distances from each other until such, when the braces are to be taken out as the work of filling in progresses in order that there shall be no "water lead" of any kind through the bank. The clay is to be ten feet thick and the cribs are to be twelve feet wide. A suitable framing to stiffen the whole system is to be built in it, from side to side, and to remain in place until found in the way of the masonry of the towers.

By means of trunks with valves at the lower end the puddling may be lowered to the bottom through the water and well ramened without being very much moistened.

The cofferdam being thus constructed, the water in it is to be pumped out, and the rock bed of the river, suitably prepared for receiving the masonry of the towers ; so that the towers will have the solid rock for a foundation.

When the towers are completed the crib work of the cofferdam is to be removed to the line of low water, and on either end, ice breakers are to be constructeed above and below the piers.

Heavy iron plates are to be secured to the angles of the ice breakers at the intersection of the planes ; the effect of which will be to break up the ice by its own gravity as it rises on the planes, so that it may pass away harmless, on either side.

OF THE STRENGTH OF THE BRIDGE, ETC., ETC.

It will readily be perceived by reference to the plans, that the cables have to sustain their own weight, the weight of the roadway and attachments, and any additional load which may come upon it. These loads are transmitted through the cables to the towers and anchors.

OF THE CABLES.

To those unacquainted with mechanical combinations, it no doubt, at first glance, seems almost futile to suggest, that a bridge of the enormous span of sixteen hundred and ten feet, with two shorter spans each of eight hundred and five feet, either of which is of itself, equal to most of the largest bridges in the world : over which the roaring locomotive, with its train of more than an hundred tons, is to fly, almost, as with the wings of the wind, should depend for its ultimate strength upon the cohesive force of iron wire, in strands each of which will but little exceed the one eighth of an inch in diameter.

It will however be remembered that ships of the line are held safely to their moorings amid the thunder of the storm which lays her on her broadside, by the fibres of hemp cables, each one of which is not more than the one hundredth part of an inch in thickness.

The spiders and the silkworms thread which may be woven into a fabric of prodigious tensill strength, is composed according to Biot of more than 5000 strands, (Bartlett's Mechanics) and a stick of oak, with a transverse section, capable of supporting safely fifty tons, is composed of capilliary tubes, each one of which is scarcely larger than a human hair.

If then, it can be shewn that one single strand of wire stretched across the span proposed for the bridge, will sustain its own weight and something more, which quantity is known, it needs only the most simple rules of primary arithmetic, to determine how many strands are wanted to carry any required load.

Now it is proposed that the cables of the bridge shall contain suitably disposed, *eighty thousand strands of* N°. 10, *best bridge wire,* each strand reaching the entire length of the bridge.

This wire will weigh one pound and one fiftieth of a pound for every twenty feet in length, consequently as the curve will require about twenty feet, the length of each strand from the points of support in the centre span, will be about sixteen hundred and thirty feet long, and each strand will weigh about eighty three and thirteen hundredths by pound.

By a series of the most careful experiments it has been ascertained, that a strand of the size and weight specified, will sustain before breaking, a load equal to *one thousand* *five hundred pounds net,* as an average for the best bridge wire.

Mr. Chaley who built the celebrated bridge of Fribourg which is the longest of one span in Europe, states that by experiment he found strands of this size sustained over 1760 pounds before breaking. Mr. Ellett writes that his own experiments corroborate the statement.

While building the bridge from Queenston to Lewiston, I made a series of experiments consisting of twenty-two trials. In each case wires of the size referred to were subjected to a dead load hung vertically. The wires were taken from the workshop indiscriminately, and the result of the experiment gave as an average breaking weight *seventeen hundred and twenty-two pounds :* several of the pieces had over eighteen hundred pounds upon them before breaking, and one piece which was afterwards found to be the last end of a coil and consequently a little larger than the guage sustained a trifle over nineteen hundred pounds before breaking.

The results although positively accurate for the pieces experimented upon, should not be taken as an average of bridge wire (a) of this number, because for long lengths, the probability of meeting with flaws is increased, and the stock from which the wire is made, is not always so uniform or of such tenaceous nature ; such wire however as is used for bridges should be capable of sustaining, without a question or doubt, fifteen hundred pounds breaking strain for every strand of the size and weight specified, and where due care is taken in the selection of stock and in the manufacture, the acids used in cleaning being entirely eradicated, a result

(a) This wire was made by Messrs. Cooper & Hewett, of Trenton, New-Jersey. Mr. Washburn, of Worcester, Massachussetts, recently assured me he was prepared to enter into contract to furnish No. 10 bridge wire, capable of sustaining a breaking strain of 1800 pounds per strand.

equal to that stated may be looked for with certainty. It must be borne in mind also that wire just from the blocks is not so strong as when it has been made for a few months probably from the particles having time to rearrange themselves after the process of elongation. In one experiment on a long piece, it was found to be much tougher after remaining in the air coated with linseed oil varnish for about two months, than when first made although the piece in question was subjected all the while to a load equal to about one tenth of its ultimate cohesive strength and incessant vibrations.

If then a strand of wire of sixteen hundred and thirty feet long weighing less than eighty-four pounds, were hong vertically it would sustain its own weight and the difference between its ultimate cohesive force and the weight of the strand; that is if of average strength it would not break with less than its own weight and *fourteen hundred and twenty-pounds besides.* That is for N°. 10 wire.

As then there are to be eighty thousand strands of wire in the cables they will unitedly sustain eighty thousand times as much as one strand; or the ultimate strength of the cables will be equal to 120,000,000 lbs. or 60,000 tons net.

As however in their positions as catinaries, the cables will not sustain as much, as though being vertically, owing to the direction in which the forces come which act upon them an allowance has to be accordingly made. The rules by which this is governed, are as well known as other mathematical facts, and the result can be arrived at with precision, the formulae however is some what complex and for that reason is not here introduced. Those who wish to investigate it more fully are refered to appendix A, where the condition are mathematically stated.

In the case before us and depending upon the angle given to the tangent of curvature, the strain upon the cables will be so nearly twice that which the same weight would exert if hung vertically from them, that for the sake of briefness it is assumed as such.

Therefore every pound which the cables are loaded with will strain them in their place equal to two pounds at the point of suspension, whether that weight be the cables themselves or the roadways and attachments, or any load which may be on the bridge.

If then the cables in consequence of their position are strained twice as much as if hung vertically, they will sustain only half as much, without breaking when in their place as if hung vertically.

We have seen as above that the ultimate cohesive strength of the 80,000 strands is equal to 60,000 tons net, and that the cables will sustain in their position half of this amount or 30,000 tons net. Therefore if the weight of the cables themselves and all that is attached to them, the roadways, &c., &c., is deducted from this amount, the remaining quantity will be the weight which if placed on the deck of the bridge would strain the structure so as to cause fracture.

The strength of the cables being thus determined, we shall presently see what load is likely to come upon them and how they will be affected by it.

THE CABLES OF THE LAND SPANS.

Each land span being precisely one half the length of the centre span, in order to balance the forces on the tops of the towers and being fastened in the retaining wall, on the same level as the lowest part of the curve of the principal span, the resultant of the forces, which come upon them is equal to that on the main cables and consequently they have to be of a corresponding strength. Appendice B.

OF THE TOWERS OF SUPPORT.

The towers of support in the river in average twelve feet deep at low water, are to be built hollow, see sheet N°. 2, and so proportioned that the weight which comes upon them from the cables shall be transmitted over the surface of the bare.

So far as the examinations on the ground developped the formation of the bed of the river, it appeared to be compact rock covered with a light coating of gravel and largish boulders. From the nature of the rock, which is slate interspersed with lime stone, fissures of any very considerable magnitude are not likely to be met with; on the contrary the bed of the river is most likely to be very solid and generally an even plane at the sites for the towers, sloping towards the middle of the river.

The rise of the tide is on an average twenty feet, and the foundations being set in twelve feet of water at low tide, it becomes an undertaking of no ordinary magnitude to place foundations securely which are intended to sustain the enormous weights which these are to carry.

Various methods have been employed with more or less success in similar undertakings in England, France and the United States, and perhaps that which is most highly approved of is the construction of coffer-dams.

In England this method was for many years the only plan used, recently however others have been employed.

When rock is met with near the surface of the bed in deep water, a difficulty almost insurmountable presents itself to the construction of ordinary coffer-dams, as there is little or no hold for the piling.

Owing to the very great pressure the case of the towers have to sustain, the *Caisson* plan so successfully used by the French and in the United States, is here objectionable.

It is a matter of every great consequence to have the masonry rest on the solid rock if possible.

With a view therefore to bring about these results, that is to construct by means of a coffer-dam, which shall not be subjected to the perils of a slight hold in the uncertain lands on the top of the rocks, and at the same time to avail as much as possible of the comparative cheapness of the caisson plan, I have endeavored to suggest such a structure as shall combine both, which has already been described.

It has been suggested to me to employ *blocks* made of timber in cribs with loose stones in them, sunk in the same manner as the piers near the City, and upon these to build the towers.

Independently of the objections which will arise to this method from want of permanency in the material used and the method of putting together, there would be great danger of the mass changing its position on the shelving surface of the bed of the river, and should such be the case the entire structure above must be irreparably ruined.

There being no doubt that the solid rock bed of the river will sustain a load equal to many times the weight of the bridge, it is proposed to demonstrate the strength of the towers.

It is shewn in Appendix C, that the weight which comes on the towers will under all circumstances be direct vertical pressure, and for this reason, the forces coming in this direction only have to be provided for, except for such parts of the system as sustain a lateral pressure within themselves.

That part of the tower which has the least sectional area is immediately under the saddle plates. At the four points of bearing there are 1440 square feet of surface to sustain the pressure. To these points there will be transmitted from the cables 57,960 tons net weight. See Appendix D.

The towers above the base will contain 108,687 tons net weight of material,and consequently there will be transmitted to the lower section above the base the weight of the towers and pressure from the cables.

The bases will contain 5120 square feet of section, there will therefore be about 1/5 of a ton net pressure on every square inch of that part of the tower where all the direct pressure will come.

It is proposed to build the towers of the most suitable stone selected from the quaries near Victoria Cove or farther up the river. The stone is compact lime, hard and durable, it may be seen in many of the most elegant buildings of Quebec and vicinity. Heavy iron bars and castings are to be worked into the towers for additional security, and the entire work is to be laid in hydraulic ciment of the most approved mark.

The courses are to be well bounded and the joints to be worked true.

The architectural effect is partially shewn in the accompanying drawings.

According to the most reliable published accounts stones of the formation proposed to be used, well selected, will sustain by experiments made by Rennie, Daniell, Wheatstone and others, a force equal to about three tons net per square inch section before crushing.

It will therefore be seen there is sectional surface equal to fifteen times that which would be crushed by the greatest weight which could ever come upon them. Appendix.

The towers as designed are proportioned, as to strength and the weight they have to carry, about the same as an average obtained from the dome of Saint-Peter's, at Rome, Saint-Paul's, London, and the Church Toussaint, Angers, (a) in

(a) Mahan's Civil Engineering.

all of the above some variety of lime stone is employed.

Previous to building however, very accurate experiments should be made on the particular kind of stone to be used, on which alone the ultimate proportions should be based.

If the lines of the apix of the curve of the centre span and the attachments at the retaining walls remained always on the same level, there would be no occasion to provide for any motion of the cables on the towers. But as the atmospheric changes, by contracting and expanding them, will cause the entire roadway from the revetments to the centre to rise and fall, it becomes necessary to adopt such saddle and bearing plates under the cables, between them and the masonry of the towers, as shall allow a slight movement to keep an equilibrium established between the centre and land spans.

The saddles consist of iron plates so constructed as to receive the cables where they pass through the tops of the towers. They will be made segmental in form, on the upper side, with grooves for the cables to lie in.

A system of cylendrical rollers is to be so placed between the saddle and a lower plate of cast iron, which rests on the masonry, that as the cables expand and contract an oscillatory motion will take place upon the rollers, and so continue the direction of the forces in parallel lines to the axes of the towers.

Similar rollers set in vertical planes on the inside of the saddles will transmit the horizontal strain of the cables on to the masonry arch, between one saddle plate and the other.

It will thus be seen that although the pressure of the cables will not always be quite in the axes of the towers, it will never be oblique to them, but always either directly through or parallel to them slightly on one side or the other.

EFFECTS OF ICE.

Inquiries will naturally arise respecting the effects of the enormous masses of ice which accumulate in the river and which will come with great force against the works of the bridge.

In reply it is stated that great as are the fields which are seen in motion on the river, their size and thickness being known with their velocity, their effect can be calculated with precision.

It then only remains to so proportion the parts as to be capable of sustaining any shock which will be received.

This it is believed has been done in the plans here submitted.

Ice breakers both up and down stream are provided for, as already described.

Besides the ice breakers which are separate constructions from the towers and therefore do not transmit the shocks received to them, a very considerable part of the force of floating ice will be taken off the work by the ice itsel " grounding " on the bottom of the river in front of the ice breakers, and thus receiving the pressure of the floating masses.

I am credibly informed that at the upper end of the lake Saint-Peter there are boulders of not more than twenty-five feet diameter, in the river about half out of water, which annually receive the entire force of the masses of ice which come out of this part of the river, without the slightest disturbance.

Immediately at your City also will be seen the outside blocks for loading and unloading vessels. These are usually about twenty-five by fifty feet at base, and are sunk in various depths of water from four to thirty feet at low tide. These blocks or peers, are built of crib work of timber, loaded with stone and although they frequently change their positions and lean sideways by the under-run of the river, they are not moved or injured by the fields of ice, which at this part of the river strike them more forcibly than they would above.

Some of those belonging to Mr. Gilmour, Mr. Lampson, and others, have stood upwards of twenty five years.

If then these comparatively temporary works will sustain without injury the same or more force from the floating ice, than is likely to be met with at the site for the proposed bridge, surely the heavy masonry of the towers guarded with the ice breakers and protected by the cofferdam below low water, need cause no alarm for their safety.

Besides the reasons given above may be mentioned the fact that the ice will attach itself to the ice breakers, the shores &c., or will " take " as locally known, and thus leave the channel comparatively clear, that which has " taken " guiding the running ice into the middle of the river, where there are no works proposed, except such as are so far above as to be entirely out of reach.

Should it be thought necessary diagonal piers of rough material may be built as represented in dotted lines on sheet Nº. 1, this would throw the whole of the ice through the centre opening.

It is however believed there will be no occasion for these additional guards and consequently they are not recommended and are not estimated for.

OF THE STRENGTH OF THE ANCHORS.

It is intended that the anchors shall be made of the very best refined iron, which is capable of sustaining eighty thousand pounds per sectional inch. The greatest weight which can come upon them cannot exceed the ultimate tensile force of the main cables.

I have estimated them to be of such section that at the ultimate strength of the cables they will be strained with only two thirds their breaking load. This considerable excess of strength, proportionally to the other parts of the work, is necessary from the form of the material.

Large bars and forgings are never proportionally so strong as small ones of the same kind of iron.

The direction of the stratification and the position of masonry arches which are put in, to obtain a hold upon a greater quantity of rock, will be such that within the lifting lines of the tangents of the arches there will be 30,000 tons net of rock, or more than seven times as much as the strain which will come on it. Besides the weight of the rock itself which has alone been considered the tensile force of its particles is very considerable, probably equal to twice its weight.

The position of the masonry in the segment, is such that the forces which come upon them will be directly transmitted to the rock and foundations of the retaining walls in right lines across the natural beds of the stones employed.

OF THE LOADS WHICH WILL COME ON THE BRIDGE AND THEIR EFFECTS.

It is estimated that a train of the first class locomo tives and tenders, filling the track on the bridge from end to end will be the greatest load which can be brought on the railway in motion. An extraordinary train of freight in this country or Europe will not exceed one hundred and sixty tons engine and all.

The gradients upon the lines of railway in progress or projected, that will connect with this bridge, will not allow of trains heavier than this upon them, economically.

Thus the load estimated for is equal to one thousand six hundred tons, between the towers, or on the centre span, and eight hundred tons on each of the land spans.

Besides this very great load, I have estimated that by some unforeseen circumstance the entire roadway may be filled with people.

This is the greatest load unless put on purposely, that is at all likely to come upon the bridge, that is, a line of locomotives and tenders reaching from one end of the bridge to the other, and the roadways filled with as many people as can stand upon them (a).

At the usual standard this is equal to thirty pounds per square foot. The weight will then be:

	Net, tons.
Locomotives and tenders. - - - - - -	3,200
People. - - - - - - - - - - - - -	966
	4,166
One half of this will be on the centre span. -	2,083

In appendix B, it is shewn that the strain on the cables of the land spans, is equal to that of the cables of the centre span, consequently as the cables are the same strength in each, the calculations for the centre span will demonstrate also the strain on the land spans.

It has been shewn at page 18, that the strain on the cables in place arising from their catenarian position would leave one half of their ultimate tensile strength to support the weight of the bridge and the loads upon it.

Estimating the roadway as oak at sixty pounds per cubic foot, and taking the weight of the cables, the suspending bars, brans, and every kind of suspendended weight, there is in the centre span, tons net. - - - - - - - - - - 7,019

(a) The number of people here estimated is equal to upwards of one third of all the inhabitants of Quebec and the neighbouring districts.

Add to this the moveable weight of trains, people, &c., as above. - - - - - - - - - - - 2,083

9,102

As it is necessary, in order to be safe, that the strain should never exceed *one third* of the strength of the material strained, we multiply the weight of the bridge, and its greatest load by three, and we have 27,306 tons; therefore as the 80,000, strands are capable of supporting in their catenarian position 30,000 tons, net, we have 2,694 tons of surplus strength.

It must be borne in mind that the load upon the bridge is estimated at such a quantity as can never be exceeded, while the usual load which the bridge will carry, will not exceed one hundred and eighty tons, including a train of cars and such transient loads as may be expected, cattle, &c.

Now the effect of this great or maximum load if uniformly distributed over the bridge, will be no more than though the bridge itself weighed such an additional quantity, provided the load is at rest. See Appendix E. I shall therefore estimate the effect of a load more than ordinary,say, the passage of a train of four hundred tons distributed over four hundred feet only. This is, however, much more than can possibly occur in so short a space during the ordinary working of a railway.

Any load whatever either the weight of the bridge itself or any passing load at rest, upon it, must be transmitted through the intervening mechanisms, directly to the points of support, that is, to the cables at the tops of the towers, where (appendix A.) all the accumulated loads will exert themselves.

Now if the bridge was perfectly rigid, and remained a true horizontal line without flexure, and the rails were a perfect plane, the wheels of the cars and locomotives, being circles, without irregularities, no more effect would be due to the *passage* of a train than to the *same weight at rest* on the bridge.

But as all mechanical work is more or less irregular, there would be disturbing causes to operate, the tendency of which (such as the eccentricity or irregularity of the wheels of the machinery, or one part of the track being slightly above or below the rest) would be to cause the passing weight to deflect into other than right horizontal lines, and thereby to exert a portion of its accumulated forces, as a falling body consequently striking the bridge with a weight in proportion, to the squares of the distance, through which the part so operating passed vertically. This in practice will amount to more or less in proportion to the perfectness of the machinery and the velocity of the body moving.

Another condition has to be considered. The bridge is not and cannot be from the nature of its construction perfectly rigid nor is it desirable it should be. Therefore every load which passes over it will bend it, more or less; consequently, there will be a force operating, which is due to the amount of the deflection of the roadway, or in other words, if the bridge is deflected any given quantity, by the passage of a load over it, the load so passing will exert on the bridge a force equal to its static weight and an additional amount, due to the accumulation of momentum, through the vertical space it has passed in according to the time it is so passing. Therefore the greater the speed the greater the effect on the bridge unless it is perfectly rigid.

The effect af the horizontally moving load on the trajectory caused by the flexure of the bridge *in front of the load* has not to be considered in proportioning the strength of a suspension bridge, although it is an essential item in the calculation for determining the operation of a moving load on a metal girder, cast iron arch or tubular bridge, as any force in the horizontal direction would not be transmitted through the suspending bars to the main cables, which are the ultimate strength of the bridge, but would only operate on the roadway without affecting any other part.

The greatest load which is likely to be on the bridge at one time in rapid motion as before stated will not exceed four hundred tons. It has been shewn at page 26, that the bridge will bear safely 2,083 tons net weight uniformly distributed over the centre span. Although it scarcely needs demonstration, to make it appear that a weight so inconsiderable a portion of that which the bridge will bear safely at rest, will not affect it in any manner, injuriously while passing over it. Still, to make the matter more clear it may be done as follows.

The greatest static deflection that this weight will produce considering the bridge as a perfectly flexible catenary in equilibrium, will be equal to nine inches. That is, if the bridge is considered a series of chains with perfectly flexible joints, irrespective of any stiffness, in itself, except what arises from *its own weight merely*, as any load placed in the middle before it can depress it must draw up the ends of the platform and the haunches of the cables. (See appendix F.)

The augmentation of the vertical force of the load during its passage from the horizontal through the amount of this deflection, will carry it beyond the static quantity, corresponding to the increase of force.

The deflection produced by a train of four hundred tons moving at the rate of sixty miles per hour will be equal to about eleven inches considering the bridge as above, as perfectly flexible, and the force which it will exert equal to about 427 tons, vertical pressure in which if added to the weight of the bridge, will be 7,446 tons, or less than one fourth of what the cables are capable of sustaining in their catenarian position.

But the bridge is not perfectly flexible, but is so far rigid by means of the parapets and lower string timbers, and the deck planks and strings for the track, that if the parapets were detached from the suspending rods, they would support their own weight held from either end a distance of 550 feet.

It must therefore be evident, that where so powerful a combination exists, forming a truss over which the passing load is to travel, that any deflection which would otherwise occur will be distributed over at least one half the distance that the parapets will support themselves, and therefore the deck will deflect only one half what it would without this combination, or there abouts.

With any very considerable deflection, there might be danger of fracturing the side timbers, but it is well known that combinations of timber will spring much more than this amount without injury. The steamboats on the western rivers, frequently spring from two to four feet when grounding, without causing a leak.

In the above calculations the effect of a train of four hundred tons burthen, at speed of sixty miles per hour, has been estimated. This is a much greater weight and higher speed than necessary. The loss of time in slacking up to a speed of nine miles per hour while crossing the bridge will be *three minutes* only, should it be thought advisable to do so, but the effects of the maximum load as above, at the high speed cannot possibly injure the work.

DURABILITY.

The masonry of the towers, revetments, retaining walls, &c., being built with the best material and in the most substantial manner, may be considered almost indistructible.

The iron work of the anchors and attachments is all so arranged that a free circulation of air will be about these parts ; they can also all be inspected and painted, and although underground, will not be subject to any dampness or corroding influences, that cannot be guarded against.

The wires of the cables being each separately varnished and collectively coated with suitable annealed wire, wound round them and covered with prepared (a) Franklinite and linseed oil and afterwards painted, if kept so will never rust ; and the wood work being so arranged that it is well drained and kept from standing water the joints being pitched and caulked will last for years.

The atmosphere, too of Quebec, is particularly well adapted to iron structures, as may be evinced in the manner that the plated tin roofs resist the attacks of the weather, where they are left unprotected, as is the case on most of the buildings. On the whole if well taken care of, and painted at intervals, there is no reason why the entire work will not last for centuries, with the exception of the deck which will require renewing, when worn out by travel (b).

LIGHTNING.

It may be supposed by some that the lightening will injuriously affect a work where there is so much iron exposed as there will be here.

No danger however need be apprehended from this cause as similar works testify.

There appear to be distinct electric currents, constantly passing and repassing through the different parts of the

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(a) A native mineral composed of oxide of iron, zinc and manganese.

(b) See that part of this report which refers to the Chineese Bridges.

work, and the number of points, such as the heads of bolts, angles &c., of the small pieces, which will be presented, will be so many conductors of the electric fluid, that no very severe shock will be experienced anywhere, even while the bridge is a medium between differently charged electric bodies.

I am not aware that any iron ship has ever met with severe accident from the effects of lightening while many wooden ones are known to have been entirely destroyed. This fact may perhaps be explained satisfactorily by the same reasoning as will apply to the bridge, namely the number of points which act as conductors of the fluid.

Time alone can determine the effect produced upon the ultimate particles of the material, by the constantly recurring changes in the electric and magnetic currents; but evidence is not wanting to prove that centuries may elapse before any very decided change takes place by these agencies, while operating under, and circulating by slightly exciting causes, even where the material is under continuous heavy strains. (See for example the chain bridges of China, discribed hereafter.)

OF THE ESTIMATES, ETC.

In making the estimates of cost I have borne in mind the request of his honor the mayor, that every thing should be "thoroughly considered as to cost" and for this reason have more fully developed the details of the work than is usual in similar cases; in consequence of which I am able to assure you that the prices here named are such as will actually build the work in the manner proposed.

I am also authorized in stating that there are some of the most reliable contractors *ready to contract for the work above water at these prices.*

I have sought from them very definite information respecting the prices of materials, labor, &c., and the means of getting supplies and workmen, and you may I confidently believe, depend on the results.

The work below water, that is the cofferdams and foundations to the towers, including the ice breakers, is usually the subject of special contract. The estimate, I believe, will fully cover any expenditure necessary for this part of the undertaking.

The plans here proposed contemplate a structure capable of carrying safely a train of cars of maximum load, at great velocity, and two lines of public road each ten and one half feet wide, filled from end to end with people, the most severe load which it can ever be called upon by accidental circumstances to carry.

Should it however be thought advisable to incur a less considerable outlay than is required for the proposed work, a bridge of smaller dimensions and less strength designed for lighter travel may be constructed.

It may be thought best, financially, to dispense with the line of rails across the bridge and to have it lighter and less costly, and to use waggons from the railways, on the south side connecting again with a railway into the City, or to have a bridge intended only for light trains to be drawn by stationary steam or by horse power.

Or, again, it may be well to build such a bridge as can be enlarged and strengthened and at first use it for light travel if it is thought that facilities will exist in future for obtaining means which are not now available.

As however all these questions are subject to many contingencies, I have not entered into the merits of any of them, more particularly as I am of opinion that the bridge here proposed is the best suited to the wants of the city and as there appears to be but little difficulty in the way financially.

It will however be borne in mind that any change in Provincial Tariff affecting the price of materials, will make the work more or less costly.

SUMMARY OF ESTIMATE OF COST.

	£	S	D	$	c.
All the timber including the Races in the deck of the Bridge................	11,693	10	7	46,774.	12
Suspending rods, refined iron.	4,180	0	0	16,720.	00
Cable rings and cross cables with attachments to main cables	1,000	0	0	4,000.	00
Small iron castings........	600	0	0	2,400.	00
Small forgings, bolts, nuts &c.	5,820	0	0	23,280.	00
Annealed wire best quality..	30,000	0	0	120,000.	00
Cable wire, (average strength) 1500 lbs strand..........	188,100	0	0	752,400.	00
Masonry in the two towers and foundations, including hydraulic ciment, and pumping cofferdams......	195,134	10	0	780,538.	00
Large cast iron work, including the saddles, anchor plates and fitting same....	5,255	0	0	21,020.	00
The large forgings, consisting of anchor bars, saddle bars and attachments........	46,300	0	0	185,200.	00
The masonry in the revetments, including the offices &c., the foundations to be laid in ciment...........	5,842	0	0	23,368.	00
Machinery, Engineering, &c.	15,000	0	0	60,000.	00
Building and sinking cofferdams and ice breakers....	45,413	2	0	181,652.	40
Amount carried forward....	£554,338	2	7	$2,217,352.	52

Amount brought forward...	£554,338	2	7	$2,217,352.	52
Building cables and putting same up................	6,300	0	0	25,200.	00
Carpenter's work on roadway	4,525	0	0	18,100.	00
Putting on deck and parapets.	2,425	0	0	9,700.	00
Guies and machinery for same	2,000	0	0	8,000.	00
The adits, anchor shafts and chambers..............	4,400	0	0	17,600.	00
	£573,988	2	7	$2,295,952.	52
Add for contingencies 10 per cent, and for negotiations of bonds, interest during construction and profits to contractors 23⅓ per cent	191,329	7	6½	765,317.	51
Total amount for Bridge complete.................	£765,317	10	1½	$3,061,270.	03

NOTE.—The £ signifies pound Halifax currency.

OF SUSPENSION BRIDGES GENERALLY.

Having now discribed the nature of the sites proposed to be built upon, the bridge itself proposed to be built, with its strength, the loads which will come on it and its capacity to bear these loads, and having submitted with the same the estimated cost of the completed structure ; it is now proposed to offer a few general remarks on the subject of this class of bridges, and to compare the one proposed with other works for similar purpose, in existence, and to reply to the objections which are usually urged against suspension bridges for railway traffic.

I deem it due to your honorable body, to lay before you all the supposed difficulties, resting assured there is no good to be gained by shrinking from the most scrupulous enquiries. If the premises are correct and the deductions rightly made the results must be certain even though we have no precedent.

Suspension bridges are no *new* method of construction. The general principle upon which their strength depends, was known and in use before the historic period.

It is supposed the ancient Peruvians were amongst the first who used this kind of structure in any thing like the form now employed; but if we may believe the traditions of the Chineese and the channels through which the information comes, suspension bridges built of iron wire were in use at the formation of the present dynasty of the empire, and how much before we are not told; in Kirchers' China illustrated is as follows, translated by Mr. Fordham, (Drewry).

" In the province of Junnan over a valley of great depth and through which a torrent of water runs with great force and rapidity, a bridge is to be seen said to have been built by the Emperor Mingus of the family of the Hamae, in the year of *Christ sixty-five;* it is of chains of iron put together with hooks so secured to rings on both sides of the Chasm, that it forms a bridge by planks placed upon them. There are twenty chains each of which is twenty perches or three hundred palms in length (330 feet).

Iron suspension bridges are probably of Asiatic Origin.

The bridge of Chouka, is so ancient that the inhabitants are ignorant of the date of its erection and attribute to it a fabulous origin. (Drewry on suspension bridges).

The suspension bridges of Peru were built of ropes made from the bark of the trees of the country and the fibres of the *Agara Americana.*

Rope suspension bridges were used in France as early as the reign of Charles the ninth. In Davilas, Historia del] Guiore, civil de Francia, (Vol. 1. p. 264), may be found an account of a rope bridge which was used at the siege of Poictiers, to cross the river chain.

Douglas, in his work on military bridges, says that rope suspension bridges were used in Italy in 1742.

It is difficult to determine when the first European permanent suspension bridges were built; some years ago, Mr. Stephenson published an account of a suspension bridge built across the Tees near Middleton, which is supposed to be the first one built in Europe.

The date is set at 1741, but it is uncertain. It is only a foot bridge and is intended for the use of the miners.

Mr. Navier speaks of a chain stretched between two rocks near the town of Moustiers in the department des basses Alpes. It is six hundred and fifty-six feet long. It is made of rods, about ¾ inch diameter linked together. It is supposed to have been erected in the thirteenth century. For what purpose is not known. The traditions of some assign it as an offering to the Virgin Mary, others suppose it to have been constructed by the knights of Rhodes. The most important fact however connected with it in a scientific point of view, is that it has hung so long, uninjured by rust, which is distinctly stated by Drewry.

It is to be regretted that exact dimensions are not given by which the strain on the points of suspension, could be determined, as such would materially assist to demonstrate the effect of loads on matter subject to vibration under strain, during great lengths of time, evidence which is much wanted in the scientific world.

In the United States, Mr. Finley, in 1796, built a suspension bridge of chain cables, near Greenbush, on the road to Uniontown, (See Pope's bridge architecture); and between then and 1810, several suspension bridges of considerable span were built on his plan.

In the year 1814, in England, the attention of engineers, was directed to this subject. Mr. Dumbell, of Warrington, suggested plans for a road from Kuncorn in Chester to Liverpool. It was proposed to cross the valley of the Kuncorn, by a web of metalic rings, one opening of one thousand, and two of five hundred each were thought necessary to accommodate the navigation.

Mr. Telford suggested for this place a bridge of iron bars made in links, and made many experiments relative to it, which are given in the appendix of Prof. Barlow's work on the strength and stress of timber. (Third edition 1826).

Up to 1819, several small suspension bridges were made in England, some of bars, some of rods and some of wire cables.

The first large bridge in England, on the suspension principle, was built across the Tweed, near Berwick. It was designed and erected by capt. Samuel Brown, R. N. It was begun in 1819, and finished the next year.

The span is four hundred and forty-nine feet.

The same year that the bridge above referred to was began, Mr. Telford commenced operations at the Menai Straits, and in seven years completed the work now standing as a monument to his exalted talents.

Since then to the present time,suspension bridges, more or less modified in form, have been constructed throughout the civilized world, some of them of very great magnitude.

On the following pages will be found a table of some of the largest suspension and fixed bridges, now completed and in course of erection.

Some of the largest Suspension Bridges.

NAME AND SITUATION.	CLEAR SPAN.		COMPLETED.	ENGINEER.	AUTHORITY.
Union Bridge, over Tweed.....	449	feet.	1820	Capt. Sir Sam. Brown,	Drewry.
Chain Pier, Brighton...........	255	"	1823	Idem.	Do.
Bridge in Isle of Bourbon.......	220 3/10	"	1823	Sir J. Brunel,	Henry Law.
Hammersmith over Thames....	422 25/100	"	1824	Tierney Clarke,	Do.
Conway over an arm of the sea..	327	"	1826	Thomas Telford,	Do.
Menai Straits Bridge..........	580	"	1826	Idem.	Do.
Over the danube, Vienna.......	334	"	1828	Her Von Mitis,	Do.
Montrose, over the Este........	432	"	1829	Capt. Sir S. Brown,	Do.
Pont des Invalides, Seine.......	236	"	1829	M. Navier,	Weale.
Fribourg acros Valley Sarine....	870	"	1834	M. Chaley,	Do.
Charring Cross, Thames........	676½	"	1845	J. K. Brunel,	Do.
Fairwount bridge over the Schuylkill at Philadelphia..	357	"	1842	C. Ellet, Jr.	Ellet.
Wheeling over Ohio...........	1010	"	1848	Idem.	Do.
Belvieu bride : Niagara........	759	"	1848	Idem.	Do.
Lewiston and Queenston, Niagara, 7 miles from the Falls..	1040	"	1850	Edward W. Serrell,	Serrell.
St. John's bridge N. Brunswick.	630	"	In progress.	Idem.	Do.
Clifton, overt he Avon.........	703	"	do	J. K. Brunel,	Heale.
Nashville, over Cumberland....	538	"	1851	Idem.	Annual scientific discovery.

Some of the largest Stone Bridges.

NAME AND SITUATION.	CLEAR SPAN.	COMPLETED.	ENGINEER.	AUTHORITY.
Vielle Brionde over the Allier..	178 feet	1454	Grenier & Estone,	Prof. Mahan.
Rialto " "	98 6/10 "	1578	Michel Angelo,	....
Claix " " Drack	150 "	1611	....	....
Neuilly " " Seine......	127 9/10 "	1774	Perrouet,	Prof. Mahan.
Lavour " " Agout	160 5/10 "	1775	Saget,	Do.
Gignac " " Erault.....	160 "	1793	Garipuy,	Do.
Rouen " " Seine......	101 7/10 "	1813	Lamande,	Do.
Waterloo " " Thames....	120 "	1816	Sir J. Rennie,	....
Gloucester " " Severn	150 "	1827	Telford,	Weale.
London over the Thames....	152 "	1831	Sir J. Rennie,	Prof. Mahan.
Turin " " Dora riparia	147 6/10 "	....	Masca,	Do.
Grosvenor " " Dee.	200 "	1833	Hartley,	Do.

Large Cast Iron Bridges.

NAME AND SITUATION.	CLEAR SPAN.	COMPLETED.	ENGINEER.	AUTHORITY.
Wearmouth, over the Wear....	240 feet	1796	Burdon,	Prof. Mahan.
Staines	181 "	1802	....	Do.
Austerlitz,Seine..............	106 "	1805	Lamande,	Do.
Southwalk, Thames..........	240 "	1818	Rennie,	H. Law.
Tewkesbury, Severn..........	170 "	1826	Telford,	Do.
Pont du Carrousel............	187 "	1836	Polonceau,	Do.

NOTE.—The Britannia and Conway Tubular Bridges are described in the text.

The Britannia and Conway Tubular Bridges were built by Mr. Robert Stephenson. The Britannia cross the Menai Straits at the Britannia Rock.

As for the Chester and Holyhead Railway bridge, it consists of four spans; two of 230 feet each and one of 458 feet, nine inches, and one of 459 feet, three inches.

The roadways of either bridges are sustained in rectangular tubes of wrought iron plates riveted together.

The Britannia bridge is 103 feet above high water. The entire length is from out to out of the abutments 1832 feet eight inches.

The estimated cost of this work before completed was £602,000 sterling, with the experiments to proportion it by, it cost many thousand of pounds more; it was finished in 1850.

The Conway bridge is one span of 400 feet; it cost complete £146,000 sterling.

The ultimate strength of one of the large tubes of the Britannia bridge is equal to 78 tons per foot run (E. Clark, Brit. and Con. Tub. Bridges, Vol. II, p. 760), while that proposed at Quebec is 1427 tons per foot run, the difference being necessary to ensure safety to travel on the side roads of the bridge.

Tho cost per foot run for the Britannia and Conway bridges within the abutments is equal to about £397 sterling; while the bridge at Quebec will cost only £195 sterling per foot run within the abutments, or if estimated per foot run at the same price as the tubular bridges, the plan here proposed affects a saving of £791,061 currency, while it is an admitted fact that the greater the span, the greater proportionally should be the cost, for a similar construction. A tubular bridge, if it could be built at all, at this site, would not cost less than £4,600,000 currency.

From the foregoing remarks and tables, it be may observed that the longest suspension bridge now finished, is five and one fifth times as large as any stone arch in existence.

It is also four and one third times as large as the largest cast iron arch, and twice and one third times as large nearly as the span of the Great Britannia Tubular Bridge.

Mr. Robert Stephenson, when before a parliamentary committee, gave it as his deliberate opinion that cast iron arches could not be carried beyond spans of three hundred and sixty feet with safety.

Sir John Rennie, thought they might be made somewhat larger, but was not prepared then to discuss the question. (See Edwin Clark, History, Brit. Tub. Bridge).

I am of opinion that cast iron arches may be made much larger than to span 360 feet, notwithstanding the difficulties arising from the expansion and contraction of the metal, not however any thing like the span required at Quebec.

Although the Britannia and Conway Tubular Bridges are very large works, yet they are but little over one quarter of the span required. These are the largest railway bridges yet built. The largest cast iron arches are about one 0.149, the span required, and the largest stone arch is less than one eighth what is wanted.

We are then forced to something different, something yet to be tried, new for the object, but after all older in application and much longer known scientifically but for purposes slightly different.

The Britannia bridge and the great cast iron arches and in fact every great work in existence were experiments until tried; we must then suit the application of principles to the work required, nothing more is necessary.

THE SUPPOSED OBJECTIONS TO SUSPENSION BRIDGES FOR RAILWAY PURPOSES.

It might appear almost presumptuous to suggest a plan for a work of such great magnitude as is required at Quebec, in principle the same as that which has been condemned in such unqualified terms by those standing high in the profession, if it had not within itself such evidences of its appropriateness, as may be easely discussed in general terms without the din of abstruce technicalities, and if the question had not its warm advocates in the highest ranks of science.

In the calculations and description of the proposed bridges it has been demonstrated mathematically, that the weight of the bridge will be a certain quantity, that this quantity is in equilibrium, and that there is a certain inertia due to this amount of matter so disposed. That a train of cars and the other loads which will be on the bridge, at any time constituting a maximum, will bear a given proportion to the bridge, the effect of which, in motion or at rest will be a given quantity. This amount, it is shewn, is not likely under the most unfavorable circumstances to injure the structure or to produce any unlooked for results.

Similarly favorable results have not been met with, when trials have been made with railways on bridges of this kind for the following reasons.

Mr. E. Clark, in the work before referred to, states that the experiments on the Stockton and Darlington railway, upon which it appears the only trials were made with locomotives on a suspension bridge in England, and upon which the sweeping conclusions are formed against this class of structure, (Vol. 1. p. 41.) " Mr. Stephenson had practically
" seen the difficulty of employing the ordinary suspension
" bridge for railway purposes, on the Stockton and Darling-
" ton railway, where he was called in to erect a new bridge

" across the river Tees, in consequence of the failure of a " bridge of this discription which had been constructed " there. This was a case in which an attempt was made " to render the roadway rigid by ordinary trussing.

" It is remarkable in this case that after the roadway was " strengthened and rendered rigid by piles driven into the " bed of the river the chains only affording partial support, " their vibration literally destroying the framework under " the platform, and *drew the piles out of the ground.* These " considerations led Mr. Stephenson to abandon the at- " tempt to render an ordinary suspension bridge, rigid " and to resort to an independent beam."

From what is here remarked it is evident that Mr. Stephenson made up his mind and came to the conclusions which he has since persisted in with regard to suspension bridges for railway travel, from his experiments on the bridge built on the Stockton and Darlington line, near Middleton.

As I am unable to learn the precise dimensions of the bridge in question, it is not in my power to make an analytical comparison of its capacity and the conclusion arrived at. I have sought in allmost all the scientific periodicals of the time when the experiments were made for the necessary data, and although frequent mention is made of it in general terms, but few dimensions are given, probably because the result was a failure and was expected to be so by many.

According to the statements made before the parliamentary committee, where the Britannia Tubular Bridge was under consideration, the Middleton bridge must have been very disproportionately built (E. Clark's, work, page 63).

" The platform of the bridge, says Mr. Stephenson, rose " up three feet before a locomotive at ordinary speed."

After the trial which it appears nearly proved destructive to the work, piles were driven into the bed of the river, and the bridge secured to them.

This must necessarily have made a bad business worse. Independently of the effects of passing loads on such a structure, which must have been to depress one end of the bridge and by so doing to raise the other, alternately drawing the piles out and pressing them into their places again ; the expansion and contraction of the cables would be such that as they shortened by a decrease of temperature the platform would rise and with it the piles would be drawn out correspondingly.

When the cables again become elongated by an increase of heat they would have nothing to support, as the piles would remain as the cold had left them, the weight of the platform being insufficient to drive them to their places again ; (such changes might easily occur from midnight to noon) and when any load in addition, sufficiently heavy to press the piles down again, was brought on to the platform, the heaving and throwing so destructive to the bridge was necessarily produced.

Yet upon these insufficient premises the important question of the applicability of suspension bridges for railways, mainly depended.—An experiment differently terminating, would probably have entirely changed this very important branch of railway construction.

The inertia of the bridge or the weight in equilibrium compared to the weight of the load to pass over it, appears to have been entirely foregotten or neglected.

This is however the principal data upon which the entire calculation should rest.

If the load to be moved upon any body in equilibrium bears such a proportion to the body upon which it is to move, that its momentum will readily overcome the inertia of the quiescent body, a disturbance will ensue, and in a proportion of one body to the other, but when the momentum of the moving body is small compared to the inertia of the body in equilibrium, the effect will be little to such a degree that it may in many cases be imperceptible.

Theoretically a pound weight placed on the bridge proposed will actually depress the part under the weight, but the quantity will be imperceptible.

The Fribourg bridge, with a span of eight hundred and seventy feet weighing only 190 tons, had upon it a body of troops marching numbering 500 men these would weigh $31\frac{1}{4}$ tons, the load was therefore nearly one sixth, the suspended weight of the bridge, and yet the deflections or heavings were very inconsiderable.

At the Fairmount bridge, Mr. Ellet, the engineer, writes, that the suspended weight of the bridge is 115 tons. "I had, says he, upwards of 70 tons on it in motion at one time, the deflections were about four inches. This was before any trusses were put on."

At Queenston, when the platform of the bridge was so far finished that loaded waggons might pass over it, but before any truss of any kind, (not even a hand railing) was put on it, a very considerable load was allowed to go over.

The bridge in this unfinished condition might be considered as flexible as the cables, which supported it, no condition rendering it rigid but its *own weight*, and the slight stiffness of the floor planks, which were three and one half inches pine laid lengthwise. The two chords one $3\frac{1}{2}$ x 9 inches laid flat and the other 5 x 8 inches of pine, were in place, but they are not *screwed up* and consequently formed no part of the truss which they afterwards carried.

In this condition the suspended weight of the bridge was about 160.

It was desired to demonstrate to the judges appointed by the respective legislatures of New-York and Canada, (the

Honorable Judge Millet, of Buffalo and Gilbert McMichen esquire, of Niagara Co., who were then present), that the bridge was in all respects competent to carry more than was likely at any time to come upon it, under ordinary circumstances, and accordingly a number of waggons were loaded with gravel and stones which with their horses were estimated at from seventy to seventy-five tons weight. This load evenly divided on either side of the river, at a signal, accompanied by between two and three hundred persons, several light waggons and some persons on horseback, moved simultaneously on to the bridge and passed over, the two lines crossing in the centre. The deflections although observable were not considerable, certainly not enough to have prevented a locomotive from over coming them. They were not determined while the load was passing but by comparing the load with the weight of the bridge, and that with the weight of the proposed bridge at Quebec, we shall find that it will require the enormous sum of 3,509 tons to deflect the Quebec bridge as much as the Queenston bridge was deflected.

So far as opinions are concerned, it may be remarked that Mr. Robert Stephenson of England when before a parliamentary committee, (See E. Clark's works, on Britannia Tubular bridge, Vol. 1. p. 63), distinctly stated that it is feasable to carry a railway across the old Menai Suspension bridge, and that it was not used for the railway because the government objected.

This bridge is merely a common suspension bridge intended for the travel of ordinary roads merely, and was built before railways were in use.

General Sir Charles Paisley, Inspector General of railways in England, also stated before the same committee, that he believed suspension bridges entirely practicable for railways if rightly constructed : Sir John Rennie, also coincided with these opinions. See the same work, page 71.

This it must be remembered was after the failure of the bridge, which for the time being decided the question ; and which it can only be presumed both these eminent engineers were acquainted with.

As to the expansion and contraction of the cables, I need only remark, that the wires being in such near proximity to each other any change of temperature experienced will act on them all, and so produce a uniform strain.

The saddles before described will allow these changes to operate without disturbing the equilibrium of the bridge, and the alteration in the line of the roadway will be so slight as not to impede the passage of a train, while to ordinary road travel it will be inappreciable.

I have estimated the effects due to a change of temperature equal to one hundred and eighty degrees Farenheit.

I am indebted to the principal of the City Academy for tables of mean temperature, at your city, prepared by himself for many years past, upon which these calculations have been based.

THE OPERATIONS OF THE WIND.

Independently of the fact that a suspension bridge has less wind surface than any other kind of structure for the same purpose, in order to assure you that no apprehension for the safety of the work from this cause need be fear, I desire to state that in proportion to the main span this will be the heaviest suspension bridge ever constructed.

The Menai Strait, the Wheeling and the Queenston bridges are all of them in situations quite as much exposed as the Quebec bridge will be, yet while the wind surface is only twelve times that of an average obtained from these works the weight of the bridge or the body to be moved by the wind is thirty-nine times as much as a corresponding average.

Besides this the guies, as specified in the description, are to be added capable of sustaining a lateral strain equal to fifty pounds per square foot of the wind surface.

OF THE EFFECTS OF VIBRATION.

In the previous pages will be found descriptions of some bridges in principle the same as that here proposed, which have withstood the operations of vibrations for several centuries.

It is however a question of very great interest to ascertain precisely what changes take place in the ultimate particles of metal affecting their cohesive force during long continued vibrations and pulsations, and for this reason the Royal Commissioners appointed by Her Majesty to enquire into the application of iron to railway structures, instituted a very elaborate and carefully made set of experiments, and in their report to the Queen, which was presented to the Houses of Parliament, they state (page X), that by ingenious contrivances, worked by steam power they bent cast iron bars upwards of one hundred thousand times successively, at the rate of four depressions per minute, and that each of these depressions was one third of what would have caused the bar to break, but that the bars were not at all injured by this process, which they afterwards proved by breaking them in the ordinary way, with stationary loads placed in the centre.

In a second experiment with the bars laid horizontally one half of the breaking weight was drawn slowly backwards and forwards over the bars bending them each time ninety-six thousand times, without apparently affecting it in any manner.

Wrought iron bars were subjected to ten thousand periodic deflections, through half the space which would produce a large permanent flexure, which did not in any manner injure them.

At Quebec, any flexure that the cables may receive due to the passage of the greatest loads or to the wind, will not be more than the two hundredth part of what would produce a permanent bend in good wire.

The commissioners though have taken but little notice of the subject of suspension bridges for railways, stating that they have generally been condemned for such uses.

The objections which they urge, in reference to loads moving on beams, only apply to the suspension bridge as far as stated in the article on the " *effects of loads*."

The experiments they made bore more particularly on the subject of cast iron as applied to girders, and to beams and tubular bridges.

As before shewn the effect of the horizontally moving body on the trajectory in front of the load is not transmitted to the main cables, but is confined to the roadway itself at least so far as any direct vertical pressure is concerned.

I am unable to reconcile the conclusions arrived at by the commissioners, with regard to the operations of loads, moving at ordinary or very high speeds, with the usually received theories or with experiments made by myself to determine this question.

They state they have determined (see page XII) that a body in *motion*, actually presses heavier on that which supports it than when at *rest*.

The apparatus they used for this purpose is discribed in the report and consisted of two bars supported at either end over which from an inclined plane which terminated at them, a car loaded at pleasure was projected.

It is not stated that any horizontal plane intervened between the inclined plane and the flexible bars, and consequently if the load descended directly unto the bars, it must have operated impart as a falling body,and would produce a greater effect in so doing than if at rest.

In order to determine this question more satisfactorily to myself, I requested Mr. Grant,of Fredericton N.B., in January last, who was then in charge of the bridge being built under my directions over the Saint-John river, at the city of Saint-John, to have the necessary machinery prepared and the experiments made.

They resulted in furnishing very different data to what had been obtained by the commissioners.

In this case the apparatus used was similar to that used by them, except that instead of the inclined plane terminating at the flexible bars it ended with a curve having a tangent in a horizontal rigid platform, made stationary and instead of flexible bars an almost rigid platform, was used upon which the rails for the cars to run upon were laid.

This plane was supported by four levers, in the manner of a *platform scale*, so that the plane would descend the same distance, with any weight on it whether placed at either end or in the middle.

The levers being connected at the middle a helical spring ballance was used to determine the depressions, and the quantities were measured by sliding verniers.

By these means it was shown that there was no more vertical force due to the *passage* of a load than to thesame load at *rest*, except that which resulted from the accumulation of momentum in the space the weight passed through vertically.

This the machinery was made to determine by lifting the platform to the same position with the weight upon it as when it received the car from the incline, in motion, and then suddenly releasing it.

Hence the deduction that had the plane been perfectly rigid and without vertical motion, there would have been no more pressure exerted by the load in motion than at rest, but without the vertical motion, the amount of the pressure could not have been determined.

There was no more deflection, when the car passed at the rate of twenty-five miles per hour, which was nearly the greatest speed attained, than when the same load passed at miles per hour.

At the highest speed a slight vibration was perceptible that did not occur at the lower speeds. This constituted the only apparent difference, and probably arose from inequalities in the machinery.

On the other hand, I cannot agree with those engineers who have maintained, that a degree of velocity might practically be attained, which should diminish the pressure on the plane or bridge that the load was passing over.

Those holding the views frequently cite examples of persons having skated safely over ice upon which if they remained stationary for an instant would have broken with them.

In this instance the deductions have been erroneously made.

It is not that the person skating over the ice actually pressed with less force on it when moving swiftly than when standing still, but that it takes a certain time to communicate motion to the particles of the ice and for them to transmit the motion to those contiguous to them, before which the mass cannot break, which time in the example before us is not allowed on account of the velocity of the skater.

Illustrations, modifications of this principle have occured in several instances, where small cast iron bridges have been broken by the passage of trains but had not time to fall until the cars had passed over in safety.

At the Fairmount bridge, experiments were made with loaded carts to determine this question and the results were recorded.

It is stated (a) that the depressions were less while the load was in motion than when the same weight was at rest on the bridge.

I am of opinion that some of the conditions were overlooked.

I know of no law which will lead to the conclusion that a body weights more or less, while in motion than when at rest; velocity cannot augment or diminish the force of gravity on a body moving in a right horizontal line in free space.

If the surrounding medium was composed of strata of variable density with the lower part most dense, a body at very high speed would rise in it and consequently press less heavely on what supported it than when at rest.

This law of projectiles is well understood in connection with gunnery.

In the atmosphere with the moving body a train of cars the differences are too small to be appreciable.

Hence I am distinctly of opinion that the same effect is due to a load in motion over a bridge as while at rest on it, if the machinery could be perfect and the bridge perfectly rigid.

The other conditions applying as before stated.

Several estimates and offers have been made at various times in the United States, for constructing *suspension bridges for railway purposes.*

(a) See a report made by Mr. Ellet, to a committee of the citizens of Hartord on the crossing of the Connecticut river, at Middleton.

Mr. Ellet, who has built some of the largest and best suspension bridges in the world, recently proposed to the citizens of Hartford, a railway bridge for the crossing of the Connecticut river, near Middletown, and offered to construct the work for a given sum, furnishing security for the performance of the contract.

The bridge proposed was to have one span of eight hundred feet, to be built in conformity to the principles of the work proposed at Quebec.

It has not yet been built owing probably to the policy of the company being somewhat at variance with the wishes of the people of Hartford, and because the line of railway connecting with it is not so far completed as to require it.

Several engineers of eminence have proposed a railway suspension bridge to cross the Niagara River,near the Falls, among them Mr. Robeling, who has built the largest suspension aqueducts, has offered for this work.

I trust that your honorable body will consider that what I have remarked, relative to the views and opinions of others has not been said with any desire to disparage the efforts of those who are entitled to the plaudits of the civilized world, particularly of those who have launched out on new and untried paths, where unusual difficulties have had to be encountered, which they have successfully surmounted, my only regret is, in reference to this matter, that so many have labored to *prove the insufficiency*, instead of endeavoring *to overcome the difficulties* of a combination, which it is believed will ultimately be the only system suited to the very great spans which are frequently to be met with in railway constructions, particularly on the American Continent.

Should any objection arise as to the height of the bridge above the river, it may be increased at least twenty-five feet without materially affecting any thing but the cost of the masonry in the towers below the roadway and in the revetments and embankments.

The gradients of the railways, and every other condition remaining the same.

A good example in practice of the strength of wire is found at Fort Washington on the Hudson river, where the wire for the telegraph makes a span of upwards of 4000 feet. This wire has stood for a great length of time and is, I understand, only renewed, when rusted away.

At Quebec, the provisions made against rust will effectually prevent any action from it, and the greatest span is only two fifths of what practically is here shewn wire is capable of attaining.

DREDGE'S PLAN.

A plan of suspension bridges known on account of a patent for the same having been issued to Mr. Dredge, the designer as *Dredge's suspension bridge* has of late been much commented upon.

It may not therefore be out of place here to refer to this design as if proved useful it should be adopted.

It is claimed for the plan in general terms, that by placing the suspending rods diagonally the main supporting cables may be made much lighter than when the suspending rods hung vertically.

Some of the advocates of this plan have gone so far as to assert that if the chains were sundered at the middle, the bridge would sustain itself as well as if they were connected.

Admetting these premises *for the sake of illustration,* it will be seen that the resultants of the forces will so act that the semi-bridge may be considered a *bracket,* projecting from one side of the tower, the apex of the tower being the point of suspension and the line of the roadway being the point of compression ; the neutrial axis, will be on the face of the tower, now the forces which will operate here do not need any formular to make them perfectly plain.

If the chains were parted at the middle the crushing force upon the ends of the roadway would at once be in proportion to the angle of direction of the chains, and the load, either of the bridge itself or any weight upon it.

In any of these bridges which I have yet seen the designs for, the end of the roadway is not so proportioned as to receive this strain without flexure and crushing, and if this takes place by the mechanical distribution of the suspending rods it must prove an injury. Besides if the combinations in the flooring &c., were so made as to resist permanently these strains,there would be greater weight suspended and more material employed than in the ordinary suspension bridge of the same effective strength.

I am therefore constrained to the same opinion as the editor of the *Mechanic's Magazine*, (Vol. 3, page 407), "that the obliquity of the suspending rods is positively injurious."

SOCIAL INTERESTS, ETC.

A very large portion of the mechanical work of the bridge can be done within the city by its own inhabitants.

I have taken particular pains to ascertain the condition of the foundaries, machine shops, quarries, &c., &c.

All the castings both heavy and light can be made at Quebec.

It may cost a trifle more to do so, but the tax payers (if the bridge is built as here suggested), will have the advantage of reimbursements, in their own line of business. The masonry and woodwork, and in fact every thing used in the construction of the bridge, may be either the direct product or the legitimate merchandize of the city.

A very considerable part of the cost of the work will be labor from which an immediate return will be made to the city through the supplies required, and although the cost of the work will be very considerable, it is by no means large when compared with other undertakings.

Some idea of the comparative magnitude of the undertaking may be formed from Inspector Generals Hincks' work on Trade and Navigation,in which it is stated that the custom entry value of the exports and imports of the City of Quebec for 1850, were £1,491,863, or nearly twice as much as the entire cost of the work, or about 56 times as much as will be required to pay principal and interest on the proposed work if built as here suggested.

That the port of Quebec must grow in importance commercially, socially, and in every other manner, cannot be doubted, if once connected with the Atlantic coast by means of such lines of communication as will not be closed by the revolving seasons.

Major Robinson has reported that from Quebec to Halifax a railway may be built, on which the business of a very large country may be carried on at all times of the year; my own examinations verify these assertions.

If then this railway is constructed, and there is no doubt it will be, sooner or later, suitable and adequate means must be provided for connecting with it.

The entire trade of the great upper country for nearly one half the year, must go over it.

From the nature of the country and the width of the river, the railway cannot cross the St.-Lawrence below Quebec.

If then it does not cross here what is the alternative?

where is Quebec ? The entire trade with all its concomitant advantages gives your city the " go by."

For half the year the river is almost impassible, masses of ice deny the stoutest boat a passage, and frequently the passenger who is compelled to cross is many hours and sometimes a whole day doing so.

At the best of times it will be difficult and expensive to transport goods and merchandize across the river in boats and lighters, and to load and unload from cars to carts and carts to boats and to carts again before reaching the warehouses, while in the winter time, no marchandize at all can cross in sufficient quantities to be worthy of remark.

While by means of the bridge and the railway as here proposed, the cars may be loaded in Halifax, Boston or New-York, and not unloaded until they are under the roofs of warehouses in your city.

It appears to me there is no alternative, Quebec must be connected to the southern shore of the river by some permanent means, by something upon which communication can be kept up at all times without reference to time or season, something that the wind, the waves, the cold or heat will not impair.

Gentlemen of Quebec, you must either *build a bridge or a New City*.

Without suitable means of crossing, rival communities to Quebec will spring up on the south shore, and the trade of the ancient capital will leave it.

It is no parallel case at New-York. There although to a great extent the business of the city on railways is carried on by ferries crossing to the island from the main land, they run uninteruptedly or nearly so at all seasons, for it is near fifty years since the harbor of New-York has been closed and almost as long since the rivers at the lower part of the island have been so frozen as to impede steam navigation except for a few hours together.

Three great lines of railway however cross directly on to the island from the north by means of bridges, and come immediately into the heart of the city and the Erie railway Co., which in summer runs boats from Piermont twenty-seven miles up the river, find it to their advantage to send the passengers in winter over the Patterson Railway, in order that they may cross the river at the city to avoid the inconvenience and delay attendant at the upper terminus where there is usually more ice.

As regards the distance of the bridge from the present city proper, it may be remarked, that should the city increase as rapidly as there is every reason to suppose, it will when the railways and other great contemplated improvements are completed, not be a generation hence when the bridge will be within its limits. New-York has grown over as much distance in thirty-five years as from Victoria Cove to Saint-John Gate.

OF THE PLAN AT SITE N°. 2.

Owing to the considerable length of time, which would necessarily be occupied and the additional cost I have not prepared plans in detail for any proposed bridge at the Palais Saint-Louis, but estimates have been made by which it has been determined that a bridge suitable for railways of proportionate strength with the one proposed, cannot be constructed for less than *nine millions of dollars* while it would most likely cost from eleven to twelve millions.

The very great height of the towers required here and the considerable addition to the main span makes this great difference in cost.

The towers should be 444 feet high and 210 by 46 feet square at the base, to be in proportion with those proposed at site N°. 1, and of sufficient strength for the work. The other parts would be in nearly the same ratio.

With considerations of respect,

I am your, &c., &c.

EDW. W. SERRELL,

Engineer.

Dated at New-York, March 1852.

In relation to the means of obtaining the necessary funds to construct a bridge for railways and common road travel to cross the Saint-Lawrence at Quebec, with the probable revenue from the same predicated on the accompanying estimates of cost.

The bridge as proposed will cost £765,317 currency or $3,061,270.

It is for the purpose of connecting the city of Quebec with the Halifax and Quebec railway, the Quebec and Richmond railway, or any other great trunkline of railway through this part of the Province, and with any overland means of transit on the south side of the Saint-Lawrence, and will be if there should ever be a railway on the north shore from Quebec to Montreal, a part of the main trunk line from the Atlantic coast to the interior of the country.

Presuming then that it is necessary to connect the railways with the city to make them the *Halifax and Quebec* and the *Quebec and Richmond*, etc., railways or to resort to a change of name and change of purpose corresponding to any change of terminus, it is thought that at least one half the cost of the bridge should be appropriated from the three and one half per cent, Imperial loan to be employed in the construction of the great trunk line of railways.

The remaining half to be paid by the city of Quebec in order to insure the terminus within itself with its concomitant advantages.

The city of Quebec will then have to pay £382,658 currency, or $1,530,634.

By obtaining a loan at four per cent on the credit of the city, which can no doubt be easely done, which loan shall be paid off in annual sums divided over a period of twenty years, the equated amount to be paid per year including the interest on the part unpaid will be equal to $108,280 or £27,070 currency.

The value of the real property of the city of Quebec, according to the official statement of the treasurer, supposing that the assessments made on the rental are in proportion, uniformly as twenty-five is to forty of their value (which is about what he supposes them to be) is equal to £5,992,089 currency or $23,968,356.

Therefore if every citizen and the corporation were to pay for this purpose, upon the value of their respective real property within the city a sum equal to $0.45 per year on each $100 value, equal to 1 2[25 pence per pound,the bridge may be built and the city enjoy its advantages, and thus pay for the work in twenty years.

These calculations have been based on the supposition that the bridge would not contribute any revenue towards paying for itself, while the result will be very much more favorable.

Among the many sources of direct revenue from the bridge, may be estimated the following, the indirect advantages to the city it is impossible to calculate.

It has been calculated by those who thoroughly understand the subject, that about forty thousand persons annually visit Quebec on pleasure for the purpose of sight seeing.

Each of these persons would no doubt pay twenty-five cents to see the bridge and cross over; this is equal to $10,000.

The districts on the southerly side of the river which would keep up a constant communication with the city by means of the bridge, contain 139,077 inhabitants.

While the towns lying beyond the Saint-Charles river, from which the inhabitants cross the Saint-Charles river bridge to reach the city, contain 22,180 inhabitants only.

The very large number of ferry boats and small steamers which cross the river from the city to the south side, running a short distance up or down, is evidence that there is a very considerable business done in this way, from which a large revenue must be derived.

Most of those who now cross in boats will when the bridge is finished, cross on it and if any estimate was obtained of the revenue from the boats it must fall far short of what would be realized at the bridge for the same purpose, for many reasons, among which may be mentioned that the bridge will be open at all times of the year and day and night, while the boats can run but little more than half the year.

Waggons and heavy articles will also be taken over on the bridge, which never are taken over in small boats or in the winter time, in any manner except when the river is frozen over.

From these sources of revenue, and that which the work will create, independently of the railways, and many others that cannot be enumerated, it may be safely calculated that the bridge will earn enough to pay the cost of repairs, attendants, and a very considerable sum besides which when the bridge is paid for as here proposed, will be direct revenue or profit to the city.

MAPS AND PLANS.

MAP A.—A general outline map, shewing the vicinity of Quebec and so much of the river Saint-Lawrence as to determine the narrowest parts near the city, compiled from Major Hollands and other surveys.

SHEET 1.—The general side elevations and plan of the proposed bridge, shewing the embankments, revetments, &c.

SHEET 2.—The towers for the same in side and front elevation and section.

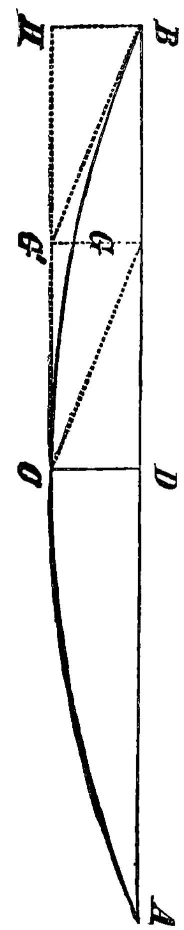
SHEET 3.—The revetments shewing the adits. The segmental masonry, and the elevation of the office, &c.

SHEET 4.—Represents the details of the woodwork. The cross section of the bridge at the roadway, with the side elevation of the trusses, &c., &c.

SHEET 5.—The plan and details of the cofferdams.

APPENDICE A.

The strain on the cables, resulting from their position.



A. C. B., is a catenary. The curve is in equilibrium; therefore the part B. C., will not be disturbed by supposing the point C. fixed regarding it and the point B. as the point of suspension. (The curve A C B represents the centre span, and B C either of the land spans).

G denotes the centre of gravity of the part B C.

The tangents B I and C I will intersect at I on a vertical line drawn through the point G.

Denote by T the tension at B; by K the tension at C; and by p the weight of the portion B C.

Because the three forces p, T and K are in equilibrium about the point I, we have

$$p : K :: BH : HI$$
$$p : T :: BH : BI$$

Whence

$$K = p.\ \frac{HI}{BH},$$

$$T = p.\ \frac{BI}{BH},$$

Denote the versed sine by f, and where this does not exceed 0.07 of the span A B, the space H I may be without sensible error regarded as half the semi-span B D, which denote by l, and we have:

$$BI = \sqrt{\overline{BH}^2 + \overline{IH}^2} = \sqrt{f^2 + \frac{l^2}{4}}$$

Substituting these quantities in the above equations, we have

$$K = \frac{p\,l}{2\,f}$$ or the horizontal tension or thrust.

$$T = \frac{p.}{f}\sqrt{f^2 + \frac{l^2}{4}} = p\sqrt{1 + \frac{l^2}{4\,f^2}}$$ or the tension at the points of suspension, which being determined, proportion the cables accordingly.

B.

By reference to the first part of Appendix A, it will be seen that the strains remain the same, whether the catenary is complete or divided in the centre, with the apex as one of the fixed points.

Therefore the semi or land spans may in every respect be considered the same as the entire catenary, so far as applied to the direction of forces and their quantity.

C.

THE STRAIN ON THE TOPS OF THE TOWERS.

The angle of direction of the cables of the land spans being the same as that of the centre spans, the resultant of the forces becomes vertical pressure only.

Where the backstays of a single span, or the cables of a Bridge of more than one span, leave the towers at different angles, the pressure becomes more or less horizontal or sideways, tending to press the towers inwards or outwards, but when the angles are the same the horizontal forces neutralize each other, and the pressure becomes only vertical.

D.

The vertical pressure of the cables is $= T \times$ Nat. Cos. of the angle of direction of the cables $\times 2$, because the land spans and centre spans will counterbalance each other.

The pressures calculated in the text are the breaking forces of the Bridge.

E.

Any two catenaries are similar when their points of suspension are on the horizontal plane, whether the elements and other dimensions constituting them are proportionately increased or decreased indefinitely.

Hence the tension in similar catenaries are directly as their weights.

Therefore when any weight is uniformly distributed on any catenary, an increase or decrease will only produce different tensions on the parts, without altering the figure of the curve.

When a platform or deck is hung (as in the case of a Bridge) to the catenaries by means of the vertical suspending rods, their conditions remain very nearly the same, as if the weight was uniformly distributed on the catenary.

F.

As an excess of weight upon any part of a catenary will tend to depress that part, it follows necessarily that unless the catenary changes its length, one part cannot sink without raising some other part a corresponding quantity.

Therefore when the centre is depressed the haunches are raised, and when the haunches are depressed that portion opposite to it will be raised, and will grivitatc on the centre.

ERRATA.

Page	6	*line*	18	between its,	*read*	between it
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"	20	"	6	lands	"	sands
"	21	"	18	bounded	"	bonded
"	22	"	5	apix	"	apex
"	34	"	6	races	"	knees
"	34	"	19 et 30	ciment	"	cement
"	38	"	5 et 6	Kuncorn	"	Runcorn
"	39	"	14	Fairwount	"	Fairmount
"	39	"	17	Belvien bride	"	Belvieu bridge
"	39	"	21	Heale	"	Weale
"	40	"	6	Perrouet	"	Perronet
"	41	"	19	78	"	7.8
"	41	"	24	Tho	"	The
"	45	"	12	become	"	became
"	46	"	32	160	"	160 tons
"	48	"	26	fear	"	felt
"	52	"	9	miles	"	ten miles
"	52	"	18	the	"	these
"	53	"	19	heavely	"	heavily
"	56	"	2	neutrial	"	neutral
"	61	"	27 et 28	proporty	"	property