APPENDIX.

No. 1.

Appointment of the Commissioners by the Board of Trade.

Whereas by the Regulation of Railways Act, 1871, it is provided that the Board of Trade may direct an inquiry to be made by an inspector into the cause of any accident, of which notice is for the time being required by or in pursuance of the said Act to be sent to the Board of Trade; and where it appears to the Board of Trade, either before or after the commencement of any such inquiry, that a more formal investigation of the accident, and of the causes thereof, and of the circumstances attending the same, is expedient, the Board of Trade may, by order, direct such investigation to be held: And whereas it is by the same Act further provided that the Board of Trade may, by the same or any subsequent order, direct the county court judge, stipendiary magistrate, metropolitan police magistrate, or other person or persons named in the same or any subsequent order, to hold the same: Now, therefore, the Board of Trade, in pursuance of the powers conferred upon them by the said recited Act, do hereby direct a formal investigation to be held into the causes of, and circumstances attending, an accident which took place on the railway bridge crossing the Firth of Tay, on the North British Railway, on the twenty-eighth instant; and do further, in pursuance of the powers conferred by the said recited Act, hereby appoint and direct Henry Cadogan Rothery, Esquire, Wreck Commissioner, Colonel William Yolland, Chief Inspector of Railways, and William Henry Barlow, Esquire, President of the Institute of Civil Engineers, to hold the said formal investigation.

Given under my hand this thirty-first day of December 1879.

(Signed) T. H. Farrer,
Secretary to the Board of Trade.

(L.S.)

No. 2.

Letter, with Instructions, sent by the Court of Inquiry to Mr. Law.

Tay Bridge Casualty.

Wreck Commissioner's Office, Somerset House,
January 22nd, 1880.

Sir,

We have been requested by Her Majesty's Government to select an engineer, in whose knowledge and character we have full confidence, to obtain for us on the spot information on certain matters connected with the recent accident to the Tay Bridge, which is essential to enable us to form an opinion as to the causes of the casualty. We have accordingly selected you, and are very glad to hear that you are willing to accept the appointment, and are prepared to leave for Dundee on Friday next, the 23rd instant, for the purpose of at once entering upon the duties.

Annexed are instructions showing the objects to which we wish you especially to direct your attention; any other matter, however, which may seem to have a bearing upon the subject of our inquiry, even though not specially referred to in your instructions, should be noted, and a report thereof made to us.

2. We shall be glad to receive from time to time reports of your proceedings; and should any matter come under your notice to which you think that our attention should be at once called, or on which you require instructions, we should be obliged by your immediately communicating with us on the subject.

We enclose two letters, one to the Provost of Dundee, and the other to the Chairman of the North British Railway Company, requesting them to afford you every assistance in their power in carrying out your instructions.

We propose to recommend that you be paid for your services at the rate of five guineas a day during the time you are employed, such sum to include your hotel charges, but exclusive of your travelling expenses, and any other costs that may be necessarily and properly incurred in carrying out the operations at the scene of the casualty. Your accounts should be sent to the Assistant Secretary to the Board of Trade, Railway Department, for payment.

Trusting that these arrangements will be satisfactory to you, and that you will be able to leave, as you propose, for Dundee on Friday next.

We are, &c.

(Signed) H. C. Rothery, W. Yolland, W. H. Barlow, } Commissioners for the Tay Bridge Casualty.

Henry Law, Esq., M.I.C.E.,
5, Queen Anne's Gate, Westminster.

General Instructions for Mr. Henry Law's Guidance.

1. Whether any, and if so, what settlements have taken place in any of the piers between piers No. 27 and No. 42.

2. Whether any, and if so, what amount of scour has arisen in the river bed in consequence of the erection of the piers. For this purpose a cross section of the river will be required along the centre line of the viaduct, and two others at a short distance east and west of the piers, and not exceeding 30 feet from the centre line. Such sections to be plotted so as to compare them with the original sections of the river bed as sent to the Board of Trade.

3. The exact dimensions of the diagonal ties and the mode in which they are fastened to the cast iron columns. The amount of play, if any, resulting from the relative dimensions of the bolts and bolt holes to be especially noted.

4. The nature of the fractures which have occurred in the cast iron lugs of the columns to which the diagonals (running east and west) have been fastened.

5. The dimensions of the bolts which fasten the bases of the columns to the cast iron bed plates.

6. The dimensions in length and sectional area of the holding down bolts by which the bed plates have been fastened to the masonry or brickwork, and the mode of fastening; also how the masonry is dowelled and joggled.

7. The fractures, if any, which have occurred in these holding down bolts.

8. The dimensions of the bolts which fasten the top of one column to the base of the one above it.

9. Description of the state and condition of each of the piers from Nos. 28 to 41 inclusive, showing accurately by drawings the movements which have taken place in the masonry and brickwork, and the manner in which the stonework has lifted where such has been the case.

10. The fractured ends of the cast iron columns to ascertain whether the core has been cast central, and, if not, the degree of eccentricity.

11. The condition of the concrete or other material with which the columns have been filled.

12. The manner in which the base of one column has been let into the top of the column below it, and the degree of accuracy in the fitting.

13. To report generally on the apparent quality of the iron, as shown by its fracture, with a view to selecting samples for testing.

14. To note as far as possible the positions of the fallen girders with reference to the piers.

15. Carefully to examine the condition of the cast iron columns of the standing piers to ascertain if there is any appearance of cracks in them, arising from frost or other causes.

16. To report generally on any matters bearing on the subject of the inquiry which may come to his notice.

Dated 22nd day of January 1880.

(Signed) H. C. Rothery, W. Yolland, W. H. Barlow, } Commissioners for the Tay Bridge Casualty.

No. 3.

First Report to the Commissioners for the Tay Bridge Casualty, by Henry Law, Memb. Inst. C.E.—Dated 9th April 1880.

To the Commissioners for the Tay Bridge Casualty.

5 & 46, Queen Anne's Gate,
Westminster, 9th April 1880.

Gentlemen,

In obedience to the instructions contained in your communication of the 22nd of January 1880, I have now the honour to lay before you the following report, embodying the information which I have been able to obtain upon those matters which have a bearing upon the casualty which occurred to the Tay Bridge on the night of the 28th of December 1879.

In accordance with your subsequent instructions, in the present report I have confined my attention exclusively to that portion of the bridge which has fallen, and for the sake of brevity and distinctness I have omitted all reference to those details and particulars of the structure, which, although they may have an important bearing upon the question of reconstruction, have no connexion with the cause of the catastrophe.

The bridge, as constructed, consisted of 85 spans, namely, 28 still standing upon the southern side of the river, varying in span from 67 feet to 145 feet, 13 spans which have fallen, and 44 still standing on the northern side of the river, and varying in span from 162 feet 10 inches to 28 feet 11 inches.

It will not be necessary to refer to the construction of any other portion of the standing parts of the bridge beyond the two spans immediately contiguous to those which have fallen.

These consist of wrought iron lattice girders resting upon piers, each of which are composed of six cast iron columns, braced with wrought iron struts and ties, resting upon foundation piers of masonry, brickwork, and concrete. The southern span is 145 feet, and the northern span is 162 feet 10 inches. Each girder is 16 feet 6 inches in height, and their distance apart from centre to centre varies from 9 feet at their in-shore ends to 14 feet 10 inches at the ends adjacent to the fallen spans.

These girders rest upon seven cast iron rollers, bearing upon raised surfaces on thick cast iron bearing plates, the rollers having bevelled flanges to serve as girders, but there being no attachment between the girders and the piers. The ends of these girders are strengthened to enable them to carry the ends of the larger girders which have fallen, forming a table or shelf upon which the latter girders rested, three cast iron rollers being interposed to allow the girders to expand or contract. These rollers were provided with flanges similar to those below, but there was no attachment between the upper and lower girders. The upright ends of the lower girders were steadied by two transverse wrought iron girders, one at the top and the other at the bottom, with diagonal tee-iron stays.

In the portion of the bridge yet standing, the rails are carried upon transverse timber beams laid upon the upper surface of the girders, but in the portion which has fallen, the rails were carried upon transverse wrought iron beams, resting upon and secured to the lower booms of the girders.

The length of the portion of the bridge which has fallen is 3,149 feet, consisting of three separate girders, the southernmost one being 1,225 feet in length, divided into five equal spans, each of 245 feet, the middle girder being 944 feet in length, divided into four spans, of which the two outer ones are each 227 feet, and the two inner ones each 245 feet, and the northernmost girder which is divided into four equal spans, each of 245 feet. It will thus be seen that the fallen portion of the bridge consisted of eleven spans, each of 245 feet, and two spans each of 227 feet

The gradient of the railway over the southern standing portion of the bridge is a rising one of 1 in 353·68, and this gradient was continued over the first span. Over the second span the gradient changed to 1 in 490, still rising; the line then continued level for six spans, this being the most elevated portion of the bridge; the next span had a falling gradient of 1 in 130, and the remaining four spans had a falling gradient of 1 in 73·56, which continues over nearly the whole of the northern portion of the bridge.

The course of the railway over the fallen portion of the bridge, and for a considerable distance upon each side of it, was a continuous straight line.

The fallen portion of the bridge consisted of wrought iron lattice girders 27 feet in height placed at a distance of 14 feet 10 inches apart from centre to centre. The upper and lower booms were trough-shaped, being each 2 feet in width, and between 15 and 16 inches in depth. The girder over each span was complete within itself, the vertical ends being of similar section to the booms, only 18 inches in width upon the face; the lattice bars, which had only a tensile strain to resist, consisted of flat bars in pairs, one being riveted to each side of the booms; those which were in compression consisted of Σ shaped struts, placed between the sides of the booms, and secured to them and to the tensile bars at their intersections.

The upper booms were braced by transverse wrought iron beams with diagonal stays. The railway was carried upon transverse wrought iron fish-bellied girders about 5 feet 5 inches apart, which rested upon the upper side of the lower booms, and being riveted thereto served as struts to the girders, the bracing being rendered complete by diagonal angle iron stays, crossing through the centre of each alternate transverse girder. In order to lessen the transverse strain upon the bottom boom, suspension bars of wrought iron were attached to the lattice bars at their intersections, and riveted at their lower extremities to the sides of the boom.

The various parts of these girders have been carefully proportioned to the several strains to which they had to be exposed, and as the catastrophe did not result from the failure of these girders, it is not necessary more particularly to describe them. It is, however, desirable to make an observation with reference to how far each division should be regarded as having formed a continuous girder. As already mentioned, each girder was complete in itself, and the booms of these separate girders were connected by cover plates with the intention of making them continuous; but in the face of the evidence given at Dundee, of the manner in which these connexions between the girders were made, I do not think that these divisions can be considered to have been continuous in such a manner as to produce an increased pressure upon any of the piers. It was stated by William Oram (Question 6,494) that the connecting cover plates were temporarily secured by service bolts, which were afterwards removed and replaced by rivets; the bridge in the meantime being used for the passage of heavy ballast trains (Questions 6,821 to 6,825). It is true that the ends of the girders had been originally raised before the cover plates were bolted on; but it must be evident that no strain such as would produce continuity in the girders in the sense now under consideration could have existed, for if it had it would have been quite impossible to have removed any of the bolts.

Judging from the portion of the bridge which is standing, the permanent way appears to have been very carefully constructed. The rails are laid upon longitudinal timbers or way-beams, 18 inches wide by 15 inches in depth, the rails themselves are of steel, 75 lbs. to the yard, with guard rails of the same weight and material, both rails being secured in the same chairs, which are placed 3 feet apart; a flat wrought iron tie bar is also introduced at distances of about 19 feet apart to preserve the line in gauge.

The platform of the bridge was formed of planks 4 inches in thickness, covered with asphalte and with a few inches of ballast as a preservative against fire.

I now proceed to describe the most important part of the structure in connexion with the subject under consideration, namely, the piers upon which the fallen portion of the bridge was supported.

These piers each consisted of an assemblage of six cast iron columns, braced by means of wrought iron struts and ties. Their foundations consisted of hexagonal-shaped piers of concrete, faced with brickwork, measuring 27 feet 6 inches in length from point to point of the cutwaters, and 15 feet 6 inches in width. These piers were carried to a height of 5 feet above the level of high water of spring tides, the upper four courses being faced with stone, and no movement or settlement appears to have taken place in them.

The height from the top of the upper course of the masonry to the under side of the lattice girders varies from 83 feet to 91 feet 3 inches, in the following description and in all the calculations the highest pier is referred to; as,

however, the height of the pier affected the strength, it may be desirable to give in a tabular form the heights of the several piers above the masonry and the spans of the girders which they supported; the numbers in the first column are the numbers of the piers in the structure, counting from the southern side, and to avoid confusion will be adhered to throughout this Report.

No. of Pier.	Height of Pier.	No. of Span.	Width of Span.	Description of bearing on Pier.
	ft. in.		ft.	
28	87 6	29	245	3 rollers on lower girders.
29	89 6	30	245	8 rollers on pier.
30	89 0	31	245	8 rollers on pier.
31	89 0	32	245	Bolted to top of pier.
32	89 0	33	245	8 rollers on pier.
33	89 0	34	227	6 rollers and an expansion joint.
34	88 0	35	245	8 rollers on pier.
35	88 0	36	245	Bolted to top of pier.
36	88 0	37	227	8 rollers on pier.
37	82 8	38	245	6 rollers and an expansion joint.
38	82 4	39	245	8 rollers on pier.
39	88 0	40	245	Bolted to pier.
40	81 8	41	245	8 rollers on pier.
41	66 10			8 rollers on lower girders.

Cast iron base-pieces, 2 feet in height, for the reception of the columns, were secured to the piers, each piece having four holding-down bolts passing through the upper two courses of masonry, each of which was 15 inches in thickness,

The six columns were arranged in the form shown upon the plan, Drawing No. 1, so as to form two clusters, each triangular on plan, and having no other connexion at their upper extremities beyond the struts and ties. The two extreme columns marked 1 and 4 on the plan were each 18 inches in diameter, and inclined inwards at the top 12 inches in their whole height; the other four columns 2, 6, and 3, 5, were each 15 inches in diameter. They stood in vertical planes parallel to the direction of the bridge, but in those planes 2 and 6, and 3 and 5, were each inclined 12 inches towards each other in their whole height.

Each column was composed of six flanged pipes, connected at their joints with eight screwed bolts, each 1½ inches in diameter. Each triangular cluster was surmounted by a wrought iron box girder ⊥ shaped on plan, taking its bearing upon the three columns; and upon this box girder another wrought iron cellular girder was placed, running in the direction of the axis of the bridge, and vertically under the longitudinal lattice girder of the bridge itself. Upon the upper side of this cellular girder was bolted a massive cast iron plate, a similar plate being also bolted to the underside of the longitudinal lattice girders of the bridge, and between these two plates were placed the cast iron rollers, each 5 inches in diameter and 2 feet in length, upon which the weight of the bridge was carried. This description applies to all the piers, excepting Nos. 31, 35, and 39, in the case of which piers the rollers were omitted, and the longitudinal lattice girders were united to the cellular girders by screwed bolts.

Measuring across the bridge, the cellular girders were equally distant from the centres of the tops of columns 1, 2, and 6, and 3, 4, and 5, and consequently the pressure of the girders of the bridge was borne half by each outer 18-inch column, and one-fourth by each inner 15-inch column.

The three columns forming each triangular group were braced to each other at every joint by wrought iron struts and ties; the struts were horizontal, and consisted of two channel irons placed back to back and bolted at each end by two 1½ inch bolts to lugs cast upon the columns. Each of the rectangular openings formed by the columns and struts was stayed diagonally by flat wrought iron bars 4½ inches broad and half an inch in thickness, the upper ends being connected with the columns by 1½ inch bolts passing through lugs cast upon them, and the lower ends being secured to two sling plates, each 4½ inches by ⅞ths of an inch thick by gibs and cotters, and the sling plates being connected with the columns by 1½ inch bolts passing through lugs cast on to them.

The two triangular clusters of columns were braced to each other in a similar manner by struts and ties between the lowest openings, that is to say, between columns 2 and 3, and columns 5 and 6. Furthermore, at each end a wrought iron rod 1½ inches in diameter was introduced horizontally to tie together columns 2 and 5, and column 3 and 6.

Having thus given a general description of the portion of the bridge which fell, I proceed to consider the strains to which the several parts were exposed under varying circumstances, and how far the structure was capable of resisting those strains. In order, however, to render this report as brief as possible, and to avoid as far as can be done the introduction of technicalities, I shall here confine myself to a statement of results, but for your information the mode of arriving at those results is annexed in the form of an Appendix.

The four forces to which the structure was liable to be exposed were those resulting from changes of temperature, from the weight of the structure itself, from the weight of a passing train, and from the lateral pressure of the wind.

For our present inquiry the strains produced by changes of temperature may be disregarded, and those resulting from the weight of the structure itself, or when loaded with a train, are very easily ascertained. Assuming, for the reasons already stated, that no additional strain is produced upon any of the piers in consequence of the continuity of the girders, and assuming a train with the weight and conditions of that which fell with the bridge, namely having a weight, including the passengers, of 120 tons, and supposing it to be placed over one of the piers in the position which would produce the heaviest pressure, I find that the structure alone would produce, a compressive strain upon the 18-inch columns of 1·47 tons, and upon the 15-inch columns of 1·06 tons to the square inch; and that with the train over the pier these strains would be increased to 1·84 tons on the 18-inch columns, and to 1·30 tons on the 15-inch columns.

There are so many doubtful elements, the values of which have to be *assumed* in attempting to determine the amount of the strains to which the several parts of the piers would be exposed by the action of a powerful wind pressure, that it is impossible to arrive at any positively definite result.

As regards the actual pressure of the wind upon the structure, I have adopted the same views as those taken by Dr. Pole and Mr. Stewart, namely, as regards the lattice girders, for the windward girder I have taken the entire area of the outer face, including the way-beams and rails; for the leeward girder I have taken only the surface above the level of the rails, and I have supposed that the wind would only exercise half of its force against this surface, in consequence of the shelter afforded by the windward girder. As regards the train, I have wholly deducted the surface of the leeward girder which it would shelter, and for the train itself I have only taken half the round surfaces, and have reduced the pressure of the winds by a sixth, that being the extent to which the train would be sheltered by the windward girder.

In the case of the pier I have again adopted the views of Dr. Pole and Mr. Stewart, namely, in supposing that there would be one 18-inch column and three 15-inch columns exposed to the wind, and that the tie-bars and struts would be equivalent to one fourth of the space (when seen in end elevation) between the columns.

Now, it is a matter of the first importance to determine what wind pressure would suffice to overturn any portion of the train; it is at once evident that the second-class carriage, being the last but one in the train, was the one which had the least stability; and Dr. Pole and Mr. Stewart state that a wind pressure equal to 28½ lbs. upon the square foot would suffice to overturn this carriage. They have, however, assumed that the carriage was empty, whereas the evidence of those who collected the tickets shows that there were eight second-class passengers.

In my own calculation I have assumed the average weight of the passengers at 140 lbs. each, and I have taken into account the vertical pressure resulting from the action of the wind upon the curved surface of the roof, and the conclusion at which I arrive is, that the second-class carriage could not have been overturned with a less wind pressure than 35·68 lbs. upon each square foot; and as there is no position in which this carriage could have been placed where it would have been sheltered to a greater extent than between one-seventh and one-eighth of its entire surface, it results that the actual pressure of the wind must have exceeded 40 lbs. on the square foot to have overturned this particular carriage, in the condition in which it was upon the night of the catastrophe, and without regarding any assistance which the couplings might afford in retaining the carriage upon the rails.

The next subject that I have investigated is the effect which the wind would have in lessening the weight of the superstructure upon the windward rollers, and in increasing

the same upon the leeward ones, and the results are shown in the following table:—

	Without any Wind.	With Pressure of Wind equal to			
		10 lbs.	20 lbs.	30 lbs.	40 lbs.
Without any Train:—	lbs.	lbs.	lbs.	lbs	lbs.
Pressure on west rollers	322,450	300,190	277,930	256,670	233,410
" east rollers	322,450	344,710	366,970	389,230	411,490
	644,900	644,900	644,900	644 900	644,900
With a Train:—					
Pressure on west rollers	427,615	399,205	370,795	342,385	313,975
" east rollers	427,615	456,695	485,775	514,855	543,935
	965,230	855,900	856,570	857,240	857,910

The slight increase which will be observed in the total pressure upon both rollers with an increased wind is owing to the vertical pressure resulting from the action of the wind on the curved roofs of the carriages.

These pressures upon each set of rollers are, as I have already explained, equally divided between one 18-inch and two 15-inch columns; these pressures are, however, still further modified by the horizontal pressure of the wind acting against the exposed surfaces of the superstructure, pier and train, but to what extent it is very difficult to determine.

If for a moment it is assumed that the pier may, by virtue of the system of bracing, be considered as a rigid structure, and the effect of the bolts in holding down the columns be disregarded, then the wind pressure required to overturn the structure, about the east 18-inch column as a centre, would be 36·38 lbs. without any train, and 32·69 lbs. on the square foot, with a train over the pier.

But, unfortunately, the piers must have been very far from being rigid structures, in consequence of the imperfect manner in which the struts and ties were connected with the columns. The struts consisted of channel irons, placed back to back, with the lug of the column between, and connected therewith by two 1⅛-inch bolts at each end; the holes for the bolts were cast 1¼ inches in diameter, and being rough and larger than the bolts, and the ends of the struts having no bearing surface to abut against, the struts themselves were only retained in their positions by the pinching action of the bolts. But the security thus afforded must have been very slight, because owing to inequalities in the surfaces of the lugs themselves, and to the fact that in some cases the holes in the struts had been roughly enlarged with a blunt tool so as to leave a burr, the actual bearing surface of many of the struts against the lugs was very small.

As regards the flat ties, when the structure was first erected they were tightened up by means of gibs and cotters, but owing to the slots in the bars against which the gibs and cotters bore being rough, and the gibs and cotters also roughly forged, and, further, owing to the holes cast in the lugs not being cylindrical, and to a screwed bolt being used to secure the ends of the ties instead of a pin, the real bearing surface was exceedingly small, and a comparatively slight strain would suffice to crush the edge of the hole in the lug into the thread of the screw.

In reference to the tie-bars it should also be observed that the bearing surface of the gib against the slot in the bar was quite inadequate, for while the area of the section of the bar exposed to a tensile strain was 1·625 square inches, the bearing surface of the gib being in compression should have had an area of 1·86 square inches, whereas it had only a surface of 0·375 square inches, or about one-fifth of the strength of the bar.

From these circumstances it would result that a lateral pressure against the columns would produce movement in the struts and ties, resulting in the latter becoming slack. And this movement actually did take place, in some of the tie-bars still standing I found packing pieces of iron a quarter of an inch in thickness had been introduced between the gibs and cotters, and on inquiry I learned that these had been introduced from time to time since the opening of the bridge.

From the accounts which have been furnished to me it appears that about 150 of these packing pieces were inserted in the ties between the middle of October of 1878 and the time of the bridge falling, and that the necessity for them arose before the bridge had been opened five months. This circumstance clearly shows that there must have been a considerable racking movement in the piers under the united action of passing trains and wind, and I cannot but consider points to the primary cause of the disaster.

For the slackening of these ties and struts means the removal of that condition upon which alone the power of the structure to resist being overthrown by a lateral pressure depends. And it is easy to conceive that a storm of the violent character of that of the 28th of last December would produce such movements, in the connections of these struts and ties with the columns, as would render the columns unable to sustain the additional weight of the train and the lateral pressure of the wind.

An examination of the ruins of pier No. 32, being that over which the train was situated when the structure fell, indicates that the columns doubled up about their joints as the lower lengths of the westward 15-inch columns were pushed over to the west, or in the reverse direction to that in which the rest of the structure fell. A similar action in pushing back the westward columns is seen in piers Nos. 36, 39 and 40.

The present state of piers Nos. 29 and 31 affords conclusive proof of a weak point existing in the structure at the time of the overthrow in each of those piers, namely, in pier No. 29 at the level of the top of the second tier of columns, and in pier No. 31 at the top of the lower tier; for the strain at the point of fracture was in the former case only ⅘ths, and in the latter case only ⅔ths of the strain at the base of the pier, while theoretically the strengths of the pier at the base and the points of fracture were the same. It is clear, therefore, that the power of resistance of these two piers had been reduced at the points of fracture in the case of pier No. 29 to the extent of ⅕th, and in the case of pier No. 31 to the extent of ⅓rd, of their normal power of resistance.

Considering that the columns are 76 feet in height, that with a wind pressure of only 20 lbs. on the square foot, a pressure of 337 tons will be thrown upon the eastward 18-inch column at the time of the passage of the train, and that a horizontal pressure of 37½ tons is acting against the top of the column, it is easy to conceive what must have been the inevitable consequence of any slackness on the part of the ties.

It is also necessary to point out that owing to the double angle which the ties by which the 18-inch columns are braced make, with the direction of the force tending to overthrow the structure, the efficiency of these ties is reduced in the proportion of 1 to 2·73, or to little more than one-third of their full strength, and that any elongation or movement of the ties would allow of nearly three times that movement in a horizontal direction in the point of the column to which they were attached.

There are also other circumstances in connexion with the construction and workmanship of the bridge which undoubtedly contributed to the catastrophe.

The mode of securing the holding-down bolts was not satisfactory, as they had no anchor-plate or bearing at their lower extremities, but were merely inserted in a hole drilled through the two 15-inch courses of stone, and were then run round with cement, and as the angle of taper of the conical head was only 6½ degrees it is evident that a very slight compression of the cement would allow of a considerable movement in the bolt; some of these bolts have evidently yielded as much as 8 inches in screwing down the base piece at the erection of the bridge, and in one or two cases the stones have been burst by the wedge action of the conical head. It would have been better also if they had been carried to a greater depth, so as to have had a greater weight of masonry to be lifted, instead of trusting to the adhesion of the cement which appears to have been very slight, partly in consequence of the smoothness of the sawn face of the stone, and partly, I imagine, from the stone having been dry when set. In many cases the cement has parted from both stones, forming a thin detached sheet of large dimensions. In many cases also the nuts at the upper ends of the bolts have a very imperfect bearing upon the base-piece.

Passing on to the columns, it is apparent that many of them have blow holes of considerable size, which have been filled in with a composition of resin and filings; sufficient care does not appear to have been taken to keep the cores from shifting, or in properly adjusting the upper flask, and as a consequence there are many instances of a considerable difference in the thickness of metal on opposite sides of the column; in some cases the metal on one side being only ⅛ths of an inch, and on the opposite side 1⅛ths, or a difference of ¼ of an inch; and as is usually the case when the upper side of a casting is thin, the metal becomes chilled, and has accumulations of scum and air which very much deteriorate from the strength of the metal.

The mode of attaching the ties to the columns by means of lugs was evidently insufficient, as in almost every instance the lugs have been torn away, it is difficult to believe that the burning on of defective lugs in the manner described by the witnesses examined at Dundee could have been sanctioned by any person who had the intelligence to

understand that the whole security of the structure depended upon the strength of these lugs.

I consider that the mode of connecting the columns at the flange joints was also in some respects defective, the bolts being an eighth of an inch less in diameter than the hole, and the flanges being separated in some cases as much as ¾ of an inch, the bolts could not act as steady pins, and as in several cases there was no spigot on either of the pipes, there was nothing but the pinching of the bolts to prevent the columns from shifting, and there are evidences that some of them did so shift at the time of the catastrophe.

I have not regarded the concrete as having added in any way to the security of the structure, otherwise than in its increasing the weight of the columns and so increasing the moment of stability of the pier; and my reason for taking this view is that the concrete was so unequal in its quality that no dependence could be placed upon its being of proper strength in the place where strength was required.

Before leaving the columns, I should observe that some of the flanges were so imperfectly faced that the only portions of the metal in contact was a strip of about five-eighths of an inch round the margin of the flange.

In conclusion, I would sum up by the statement that, in my opinion, the base of the pier was too narrow, occasioning a very great strain upon the struts and ties, that the angles at which the latter were disposed, and the mode of connecting them to the columns, were such as to render them of little or no use, and that the other imperfections which have been pointed out lessened the power of the columns to resist a crushing strain; I consider that the yielding of the struts and ties was the immediate cause of the disaster, but that the other circumstances stated contributed to it.

It is only due to Sir Thomas Bouch, to his assistant Mr. Thomas Peddie, to Mr. Noble, and the officials of the North British Railway, to say that they have afforded me every facility for making the most thorough and searching investigation.

I have, &c.
(Signed) HENRY LAW.

APPENDIX.

CALCULATIONS of the Powers of Resistance of the several parts of that portion of the Tay Bridge which has fallen, and of the strains to which they were exposed.

SECTION A.—RESISTANCES.

1. RESISTANCE OF BOLTS.

The base-pieces are held down by four bolts, each 1¼ inches in diameter; then the effective diameter through the screwed portion is 1·44 inches, and the sectional area 1·63 square inches.

Then assuming the strength to have been 21 tons, or 47,040 lbs. to the square inch, we have 47,040 × 1·63 × 4 = 306,700 lbs. for the ultimate tensile strength of the holding down bolts.

The columns were secured to the base-pieces by eight bolts, each 1¼ inches in diameter; then their effective diameter through the screwed portion is 0·92 inches, and their sectional area 0·66 square inches.

Their collective ultimate tensile strength equals 47,040 × 0·66 × 8 = 248,371 lbs.

It is therefore evident that the security of the columns depended upon the flange bolts.

2. THE RESISTANCE OF THE FLANGE BOLTS TO THE OVERTURNING OF THE COLUMNS SEPARATELY.

The relative positions of the bolts in the flanges of the 15-inch and 18-inch columns are shown in Drawing No. 2.

Supposing a horizontal force to be applied to the top of the column tending to overturn it, and assuming that the flange would crack across upon the line AA passing through the centres of the outer bolts on one side of the column, putting t = the ultimate tensile strength of one bolt, b = the distance of the furthest bolt from the line AA, b_1 = the distance of any other bolt from the line AA, and t_1 = the resistance which any other bolt would offer when the furthest bolt was at the point of fracture, and adopting the law "*sic tensio ut vis*," then we have—

$$t_1 = t\frac{b_1}{b}$$

and for the moment of resistance

$$t_1 b_1 = t\frac{b_1^2}{b}$$

Substituting the actual values, the following are the calculated results:—

Position of Bolts.	Distance of Bolts from line AA.	Moment of resistance of Bolt about line AA.	Number of Bolts.	Total moment of resistance.
In case of 15-inch columns:—				
Bolts BB - - -	0·427	3,882	2	7,764
Bolts CC - - -	1·031	22,634	2	45,268
Bolts DD - - -	1·458	45,265	2	90,530
			6	143,562
In case of 18-inch columns:—				
Bolts BB - - -	0·487	4,375	2	8,750
Bolts CC - - -	1·196	26,386	2	52,772
Bolts DD - - -	1·683	52,250	2	104,500
			6	166,022

Showing that the total amount of resistance offered by the bolts to the overthrow of a 15-inch column would be 143,562 foot-lbs.; and to the overthrow of an 18-inch column would be 166,022 foot-lbs.

And for the distance of the centre of resistance of all bolts from the line AA we have, in the case of the 15-inch columns—

$$\frac{0{\cdot}427^2 + 1{\cdot}031^2 + 1{\cdot}458^2}{0{\cdot}427 + 1{\cdot}031 + 1{\cdot}458} = 1{\cdot}156$$

and in the case of an 18-inch column

$$\frac{0{\cdot}487^2 + 1{\cdot}196^2 + 1{\cdot}683^2}{0{\cdot}487 + 1{\cdot}196 \times 1{\cdot}683} = 1{\cdot}337$$

3. THE RESISTANCE OF THE FLANGE BOLTS TO THE OVERTURNING OF THE PIERS CONSIDERED AS RIGID STRUCTURES.

In this case it is assumed that the pier would be overturned upon the centre of the leeward 18-inch column marked 4 in Drawing No. 1.

Then pursuing the same mode of calculation as in the case of the separate columns, the following results are obtained:—

Positions of Bolts.	Number of Bolts.	Distance of Bolt from centre of Column 4.	Moment of effective Resistance of Bolts.
Nearest bolts of column 4 -	2	0·35	$t \times$ 0·01
Furthest " " -	2	0·84	0·06
Nearest bolts of columns 3 and 5	4	5·27	4·90
Next " " " -	4	5·70	5·73
" " " " -	4	6·30	7·00
Furthest " " " -	4	6·73	8·00
Nearest bolts of columns 2 and 6	4	15·11	40·28
Next " " " -	4	15·54	42·60
" " " " -	4	16·14	45·96
Furthest " " " -	4	16·57	48·44
Nearest bolts of column 1 -	2	21·00	38·88
Next " " -	2	21·49	40·72
" " " -	2	22·19	43·42
Furthest " " -	2	22·68	45·36
			$t \times$ 371·36

The total amount of effective resistance of the whole of the bolts to the pier as a rigid structure being thrown over upon one of the 18-inch columns as a centre is 47,040 × 0·66 × 371·36 = 11,529,390 foot-lbs. And for the distance of the centre of resistance of all the bolts from the centre of the 18-inch column we have 15·914 feet.

4. RESISTANCE OF THE TIE BARS.

The tie bars are 4½ inches by half-an-inch, but their section is reduced by the bolt holes, which averages 1¼ inches in diameter, but in some instances are somewhat more. Their sectional area to resist a tensile strain is (4·5—1·25) × ½ = 1·625 square inches, but the whole pull upon these ties was sustained by a gib ¾ of an inch in thickness, offering a surface for compression equal only to ¾ × ½ or 0·375 square inches. Furthermore, the strength of wrought to resist compression cannot be taken at more than the ⅛ths of its tensile strength, or 40,320 lbs. to the square inch, therefore the greatest strain which these ties

could be calculated to sustain would be 15,120 lbs., or 6¾ tons.

The diagram, Drawing No. 3, shows the manner in which these tie bars acted to prevent horizontal movement at the points of their attachment to the tops of the columns. If s = the strain which the tie bar is capable of sustaining in the direction of its length, e = the effective resistance of the tie bar to prevent the top of the column moving in a horizontal direction, and h, d, and d_1 represent the distances of the upper and lower points of attachment measured vertically and horizontally, then in the case of the ties between the 15-inch columns we have—

$$e = t\frac{d_1}{\sqrt{h^2+d_1^2}} = 15{,}120 \times \frac{8{\cdot}13}{\sqrt{9{\cdot}35^2+8{\cdot}13^2}} = 9921 \text{ lbs.}$$

and in the case of the ties between the 15-inch and 18-inch columns, we have—

$$s = t\frac{d}{\sqrt{h^2+2d^2}}$$

In consequence of the columns not being vertical d varies from 3·92 to 4·62 feet, the value of h being as before; consequently the value of e varies from 5,453 lbs. in the case of the upper ties to 6,124 lbs. in that of the lowest ties.

To calculate the extent of the horizontal movement in the top of the columns which an elongation or yielding in the ties would allow, if we put n for the measure of the elongation of the tie, and m = the movement of the column, we have very nearly—

$$m = \frac{nt}{e}$$

or in the case of the ties between the 15-inch columns—

$$m = n\frac{15{,}120}{9{,}921} = 1{\cdot}524 \times n$$

and in the case of the ties between the 15-inch and the 18-inch columns, we have for the upper ties—

$$m = n\frac{15{,}120}{5{,}453} = 2{\cdot}772 \times n$$

and for the lower ties—

$$m = n\frac{15{,}120}{6{,}124} = 2{\cdot}469 \times n$$

6. Resistance of Columns to a Tensile Strain.

Taking the thickness of metal in the 15-inch columns at 1¼ inches, and that in the 18-inch columns at 1 7/16 inches, the sectional area of the former would be 49 square inches, and of the latter 63 square inches; and if the tensile strength of the cast iron be taken at as low as 6 tons or 13,440 lbs. to the square inch, the strain required to tear asunder the 15-inch columns would be 658,560 lbs., and to tear asunder the 18-inch columns would be 846,720 lbs., the least of which is more than 2½ times greater than the collective strength of the eight flange bolts; so that where the column is broken it proves that it must have been exposed to a transverse strain.

8. Resistance to the Overturning of the Pier as a Rigid Structure.

If w_1 = the weight upon the nearer set of rollers.
w_2 = the weight of the pier above the base-pieces.
w_3 = the weight upon the further set of rollers.
d_2 = the horizontal distance from the centre of the 18-inch column, about which the moment is taken, to the centre of the nearer set of rollers.
d_3 = the horizontal distance from the same point to the centre of the pier.
d_4 = the horizontal distance from the same point to the centre of the further set of rollers.
r = the moment of resistance of the flange bolts.
R_1 = the total moment of resistance of the pier to being overturned without any flange bolts at the bottom joint.
R_2 = the same moment taking the effect of the bolts into account.

Then we have

$$R_1 = w_1d_2 + w_2d_3 + w_3d_4$$

and

$$R_2 = w_1d_2 + w_2d_3 + w_3d_4 + r$$

Then substituting those quantities which are known, namely, d_2=3·5, d_3=10·92, d_4=18·34, and r=11,529,390, we have

$$R_1 = 3{\cdot}5 \times w_1 + 10{\cdot}92 \times w_2 + 18{\cdot}34 \times w_3$$

and

$$R_2 = R_1 + 11{,}529{,}390.$$

9. Resistance to the Overturning of the Pier on the Separate Columns.

Drawing No. 4 is a side elevation of one of the piers with only those tie bars shown which would tend to prevent its being overturned upon the separate columns, by a horizontal force applied at the point indicated by the arrow F.

Let p_1 = vertical pressure on column 1.
p_2 = " " columns 2 and 6.
p_3 = " " " 3 and 5.
p_4 = " " column 4.
b_2 = horizontal distance from centre of 18-inch columns to the line AA, about which the moments are taken.
b_3 = similar distance in 15-inch columns.
r_1 = the moment of resistance of the bolts in each 18-inch columns.
r_2 = the moment of resistance of the bolts in each 15-inch column.
s_1 = the effective horizontal strain resulting from the tie bar at its point of attachment in the ties between the 15-inch and 18-inch columns.
s_2 = the similar strain resulting from the tie bars between the 15-inch columns.
h_1 = the height of the point of attachment of the lowest tie bar above the top of the base piece.
h_2 = the mean height of the points of attachment of all the tie bars above the top of the base piece.
M = moment of stability.
F = the horizontal force required to be applied at the height H above the top of the base piece to overthrow the pier.

Then we have—

$$M = 2b_2(p_1+p_4) + 2b_3(p_2+p_3) + 4r_1 + 8r_2\frac{b_3}{b_2} + h_2(28s_1+14s_2)$$

And

$$F = \frac{M}{H}$$

To calculate the values of s_1 and s_2, let b=the horizontal distance of the furthest bolt from the line AA, in the 18-inch columns, and let x = the amount of extension of the bolt at the instant of its fracture, l_1 = the length of the bolt, and l = the length of the tie bar; then, according to the law, "*sic tensio ut vis*," we have—

$$\text{As } \frac{x}{l} : \frac{n}{l} :: e : s.$$

$$\therefore\ x = \frac{nel_1}{sl}$$

Furthermore we have—

$$\text{As } x : m :: b : h_1$$

$$\therefore\ m = \frac{xh_1}{b}$$

But we have also—

$$m = \frac{nt}{e}$$

$$\therefore\ \frac{xh_1}{b} = \frac{nt}{e}$$

$$\text{And } x = \frac{ntb}{h_1e}$$

$$\therefore\ \frac{ntb}{h_1e} = \frac{nel}{sl}$$

$$\text{And } s = \frac{l_1h_1e^2}{ltb}$$

In the case of the ties between the 15-inch columns, we have—

$$s_2 = \frac{0{\cdot}3 \times 9{\cdot}7 \times 9921^2}{12{\cdot}39 \times 15{,}120 \times 1{\cdot}683} = 908 \text{ lbs.}$$

And in the case of the ties between the 15-inch and 18-inch columns, if we take 5,790 as the mean of e, and 11 as the mean value of l, we have—

$$s_1 = \frac{0{\cdot}3 \times 9{\cdot}7 \times 5790^2}{11 \times 15{,}120 \times 1{\cdot}683} = 350 \text{ lbs.}$$

Then substituting the values of those quantities which are known, and putting h_2 = 42, we have—

$$M = 1{\cdot}683\ (p_1+p_4) + 1{\cdot}458(p_2+p_3) + 8{,}131{,}740$$

It should be observed that the values of r_1, r_2, s_1, and s_2 are very small at first, and as they increase, so the moments of the pressures p_1, p_2, p_3, and p_4 decrease.

SECTION B.—WEIGHTS.

1. Weight of the Superstructure.

In calculating the weights of the girders I have taken those of the intermediate girders which are somewhat heavier than the end spans. The results are as follows—

Weight of one 245 feet intermediate span.

	lbs.
Two main lattice girders	317,500
Lower transverse girders and bracing	70,260
Upper cross bracing	39,490
Cast-iron roller plates	2,820
Timber planking and way-beams	89,040
Permanent way, including guard rails	40,570
Ballast	52,800
Hand railing	7,670
Water pipe (filled) and casing	19,850
Telegraph wires and tube	4,900
288 tons, nearly =	644,900

In the subsequent calculations the above is the weight which I have taken as being that which would be produced by one of the 245 feet intermediate spans upon the rollers on the top of one of the piers, and I have omitted to add any increased pressure on account of the continuity of the girders for the reason stated in the body of the Report.

2. Weight of the Pier.

The results of my calculations are as under:—

	On one 15-in. column.	On one 18-in. column.
Weight of ironwork	25,950	31,570
„ of concrete filling	9,800	14,000
	35,750	45,570

Then the total weight of the pier is as follows:—

Four 15-inch columns at	35,750	=143,000
Two 18-inch „	45,570	= 91,140
105 tons nearly		=234,140 lbs.

3. Weight of the Train.

The information as to the composition of the train and the weight of the several carriages was furnished by Mr. Drummond, the locomotive superintendent of the North British Railway, and I have added the weights of the passengers and other persons in the train, distributing them, to the best of my judgment, in accordance with the return put in by Mr. Robert Morris, the station agent at St. Fort (Question 129). I have allowed 140 lbs. for the weight of each person, and have assumed that there was 900 lbs. of luggage in the luggage van.

The engine weighed 34 tons 12 cwt. =	78,848	
Fireman and stoker	280	
		79,128
The tender weighed 24 tons 17 cwt. =		55,664
First third-class carriage weighed 8 tons 8 cwt. =	18,816	
20 passengers	2,800	
		21,616
Second third-class carriage, the same as last =		21,616
First-class carriage, weighed 14 tons 5 cwt.		31,920
After third-class carriage weighed 9 tons 16 cwt. =	21,952	
21 passengers	2,940	
		24,892
Second-class carriage weighed 5 tons 19 cwt. =	13,328	
8 passengers	1,260	
		14,448
Luggage van weighed 8 tons 9 cwt. =	18,928	
3 guards	420	
Luggage	900	
		20,248
120 tons =		269,532

4. Weight of Train borne by the Pier.

I have taken that position of the train which brings the greatest load upon the pier, namely, when the front of the buffers of the engine were 43 feet in advance of the centre of the pier, in this position the portion of the weight of the train borne by the pier would be 210,330 lbs., the remainder being borne by the piers on either side.

SECTION C.—ACTION OF THE WIND.

1. Action on Superstructure without Train.

In the following calculations the direction of the wind is assumed to be horizontal and at right angles to the side of the bridge. Where the surface opposed to the wind is hemispherical, as in the case of the columns, its area has been reduced by half; where the surface is inclined to the direction of the wind at an angle of c degrees, a being the area of the surface, and f the force of the wind in lbs. per square foot, I have taken—

The pressure of the wind in its own direction = $f \sin.^2 c.a.$

„ „ „ perpendicular to same = $f\,a.\,\sin^2 c \cos c.$

I have calculated the surface presented by the superstructure of one 245 feet intermediate span, taking the whole surface presented by the face of the windward lattice girder, and adding the ends of the lower cross girders, the longitudinal timbers and rails, and the railing, and the result gives an area of 2,036 square feet, having its centre of pressure 11·14 feet above the top of the rollers upon which the lattice girders rested.

For the inner or leeward girder I have calculated the area of that portion of it which is above the level of the rails, and I have reduced this by half to allow for the shelter which would be afforded by the windward girder, the result gives an area of 593 square feet, having its centre of pressure 17·47 feet above the top of the rollers.

To calculate the effect which the wind would have in lessening the weight of the superstructure upon the windward or west rollers and in increasing it upon the leeward or east rollers, let f=the force of the wind, a=the area of the surface exposed, h=the height of the centre of pressure above the top of the rollers, d=the distance from centre to centre of the lattice girders, and p=the pressure taken off the windward rollers and added to the leeward rollers; then we have—

$$p=\frac{ah}{d}f=\frac{2036\times 11{\cdot}14+593\times 17{\cdot}47}{14{\cdot}84}\times f$$
$$=2226\times f.$$

And if F_1 be put for the horizontal force of the wind acting at the level of the top of the rollers tending to overturn the pier, we have—

$$F_1=f(2036+593)=2629\times f.$$

2. Action of Wind on the Train.

The action of the wind upon the several carriages composing the train have been calculated upon the data furnished by Mr. Drummond, and the results have been collected in a tabular form.

Description of carriage.	Weight of carriage including passengers = w	Half-width between rails = $\frac{s}{2}$	Moment of stability of carriage = $w\times\frac{s}{2}$	Actual side surface of carriage.	Reduced side surface of carriage = a	Height of centre of wind pressure above rails = h	$a\times h$	Reduced roof surface exposed to wind = a_1	Horizontal distance from east rail of centre of wind pressure on roof = d_1	Moment of a unit of wind pressure acting vertically to retain carriage on rails = $a_1\times d_1$	Moment of a unit of wind pressure tending to overturn the carriage = $ah-a_1d_1$	Value of f, when $\frac{wr}{s}=f(ah-a_1d_1)$ or force of wind in lbs. per square foot required to overturn carriage.
Engine	78,128	2·5	197,820	194	162·8	4·69	763·0	—	—	—	763·0	259·27
Tender	55,664	2·5	139,160	113	111·4	4·81	535·8	—	—	—	535·8	259·78
Third-class carriage	21,616	2·5	54,040	225	206·9	6·21	1285·3	3·14	5·62	17·7	1267·6	42·63
Third-class carriage	21,616	2·5	54,040	225	206·9	6·21	1285·3	3·14	5·62	17·7	1267·6	42·63
First-class carriage	31,920	2·5	79,800	345	306·5	6·36	1948·2	30·16	5·62	169·5	1778·7	44·87
Third-class carriage	24,892	2·5	62,230	267	240·3	6·67	1656·0	24·26	5·62	136·3	1419·7	43·86
Second-class carriage	14,448	2·5	36,120	191	174·1	5·90	1027·9	2·77	5·62	15·6	1012·3	35·68
Luggage van	20,248	2·5	50,620	216	194·5	6·23	1210·9	16·16	5·66	91·1	1119·8	45·20
The whole Train	269,532				1603·3	5·90	9611·4					

In the foregoing table no deduction is made for the partial screening of the train by the windward lattice girder. I have, however, made a calculation which shows that the surface of the train exposed to the wind would be reduced by about one-sixth.

Adopting the same notation as in the table, and putting k for the pressure taken off the windward rail and added to the leeward one, we have—

$$k=\frac{5}{6}\times f\frac{ah}{d}=\frac{5}{6}\times f\frac{1603\cdot3\times6}{5}=1603\times f$$

But this being partly borne by three piers has to be reduced to

$$k=1251\times f$$

Then taking into account the action of the wind upon the roofs of the carriages, we have for total weight of the train borne by the pier—

$$210{,}330+67\times f$$

Again if k_1 = the pressure taken off the windward rollers, and 9·92 and 4·92 be the respective horizontal distances of the two lines of rails from the centre of the rollers, we have—

$$k_1=1251\times\frac{9\cdot92-4\cdot92}{14\cdot84}\times f=421\times f$$

And the proportion of the roof pressure thrown on the west rollers being $48\times f$, we have for the pressure on the west rollers resulting from the train—

$$105{,}165+48\times f-421\times f=105{,}165-373\times f$$

and for the pressure on the east rollers

$$210{,}330+67\times f-105{,}165+373\times f=105{,}165+440\times f$$

3. Action of Wind on Superstructure with a Train.

The train would reduce the exposed surface of the east girder from 1,186 square feet to 757 square feet, and as before, deducting one-half as being sheltered by the windward girder, we have 378 square feet for the area of the exposed surface of the east girder, and the centre of pressure is 22·54 feet above the top of the rollers.

Then for the pressure taken off the west rollers and added to the east rollers, we have—

$$p=\frac{ah}{d}f=\frac{2036\times11\cdot14+378\times22\cdot54+\frac{4}{5}\times1603\times4\cdot12}{14\cdot84}\times f$$
$$=2468\times f$$

And for the horizontal force of the wind acting at the level of the top of the rollers we have

$$F_1=(2036+378+\tfrac{4}{5}\times1603)\times f=3750\times f$$

I have shown upon Drawing No. 5, which is a transverse section of the superstructure of the bridge with a train upon it, the amount and direction of the various pressures which are produced by the joint action of the weight of the structure, the weight of the train and the wind, the force of the latter being equal to f lbs. on the square foot.

4. Action of Wind on Pier.

I have adopted the views of Dr. Pole and Mr. Stewart, as to the mode of estimating the effective surface exposed to the wind by one of the piers, namely, to take one 18-inch column and three 15-inch columns as being exposed, deducting half their diametric section to allow for their being cylindrical, and allowing for the tie bars one-fourth of the space (when seen in end elevation) between the columns. The result gives a surface of 393 square feet, the centre of pressure being 41·8 feet above the top of the base pieces of the columns.

5. Action of the Wind on the Complete Structure.

For the moment of the horizontal force of the wind taken about the top of the base pieces of the columns as a centre, we have—

Without any train on the bridge:—

Surface of west girder	2036	
„ east „	593	
	2629 × 80·7	= 212,160
Surface of pier -	393 × 41·8	= 16,427
	3022 × 75·64	= 228,587

$\therefore M_1=FH=228{,}587\times f$

And with the train upon the bridge:—

Surface of west girder	2036	
„ east „	378	
„ train „	1336	
	3750 × 80·7	= 302,625
Surface of pier -	393 × 41·8	= 16,427
	4143 × 77	= 319,052

$\therefore M_1=FH=319{,}052\times f$

SECTION D.—STRAINS.

1. Vertical Pressures on Columns.

a. *Without any Train or Wind.*

Weight on each 18-inch column:—

Weight of column - - -		45,570
„ superstructure -	$\frac{644{,}900}{4}$	= 161,225
	92·32 tons	= 206,795 lbs.

Weight on each 15-inch column:—

Weight of column - - -		35,750
„ superstructure -	$\frac{664{,}900}{8}$	= 80,612
	51·95 tons	= 116,362 lbs.

The sectional area of the 18-inch column being 63 square inches, 92·32 tons is equal to a strain of 1·465 tons per square inch; and the sectional area of the 15-inch column being 49 square inches, 51·95 tons will produce a strain of 1·06 tons per square inch.

b. *With a Train, but without any Wind.*

Weight on each 18-inch column:—

Superstructure and column as above -		206,795
Weight of train $\frac{210{,}330}{4}$ - -		= 52,582
115·80 tons - -		= 259,377 lbs.

Giving a strain of 1·838 tons per square inch.

Weight on each 15-inch column:—

Superstructure and column as above -		116,362
Weight of train $\frac{210{,}330}{8}$ - -		= 26,291
63·68 tons - -		= 142,653 lbs.

Giving a strain of 1·30 tons per square inch.

c. *With a Wind Pressure, but without any Train.*

Weight of superstructure on west rollers - -	$=322{,}450-2226\times f$
Weight of superstructure on east rollers - - -	$=322{,}450+2226\times f$

Weight on column 1:—

Weight of column - -	45,570
One-half of weight on west rollers - - -	$161{,}225-1113\times f$
	$206{,}795-1113\times f$

Weight on each of columns 2 and 6:—

Weight of column - -	35,750
One-fourth of weight on west rollers - - -	$80{,}613-556{\cdot}5\times f$
	$116{,}363-556{\cdot}5\times 5f$

Weight on each of columns 3 and 5:—

Weight of column - -	35,750
One-fourth of weight on east rollers - - -	$80{,}613+556{\cdot}5\times f$
	$116{,}363+556{\cdot}5\times f$

Weight on column 4:—

Weight of column - -	45,570
One-half of weight on east rollers - - -	$161{,}225+1113\times f$
	$206{,}795+1113\times f$

d. *With a Wind Pressure and with the Train on Bridge.*

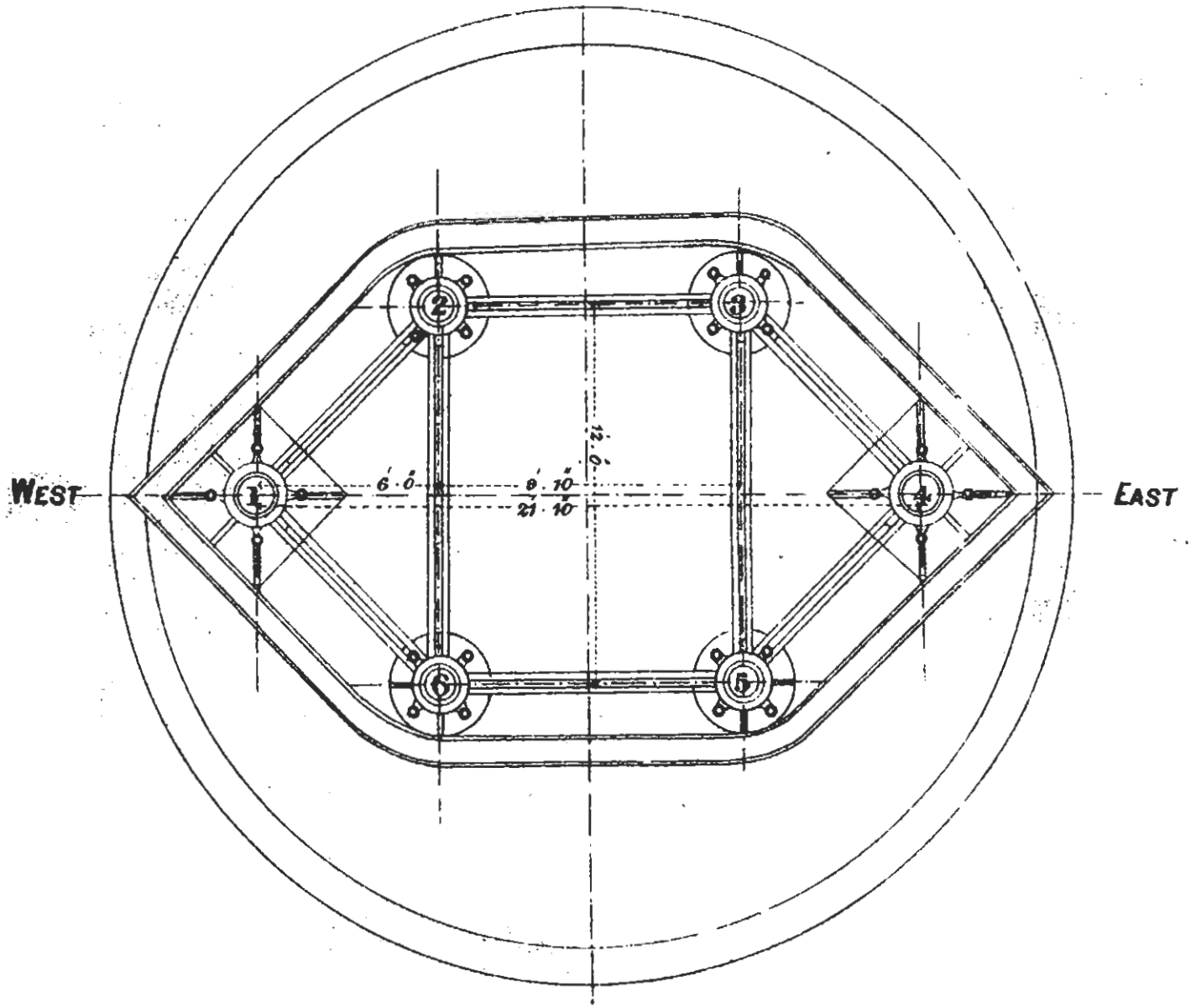
Weight on west rollers:—

Weight of superstructure -	$322{,}450-2468\times f$
Weight of train - -	$105{,}165-373\times f$
	$427{,}615-2841\times f$

Drawing No. 1.

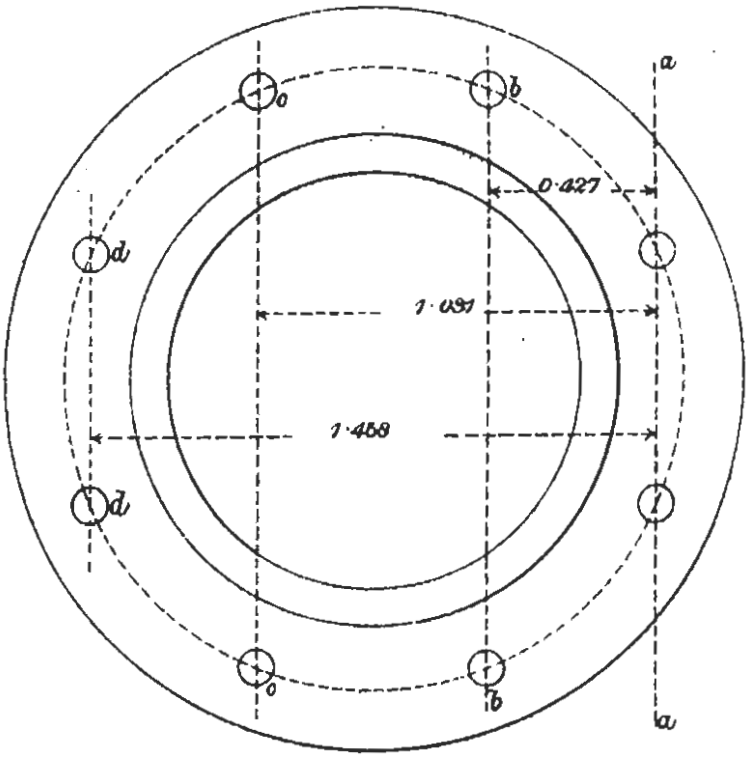
TAY BRIDGE.

SECTIONAL PLAN OF THE BASE OF ONE OF THE FALLEN PIERS.

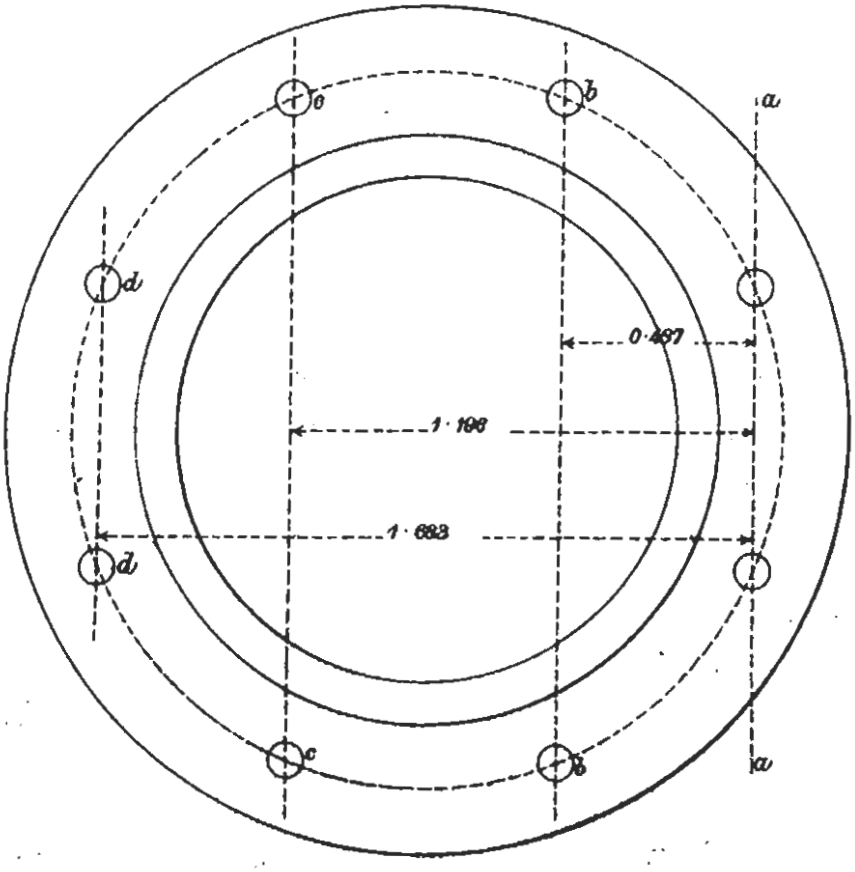


Scale 3/16ths of an Inch to a Foot.

TAY BRIDGE.



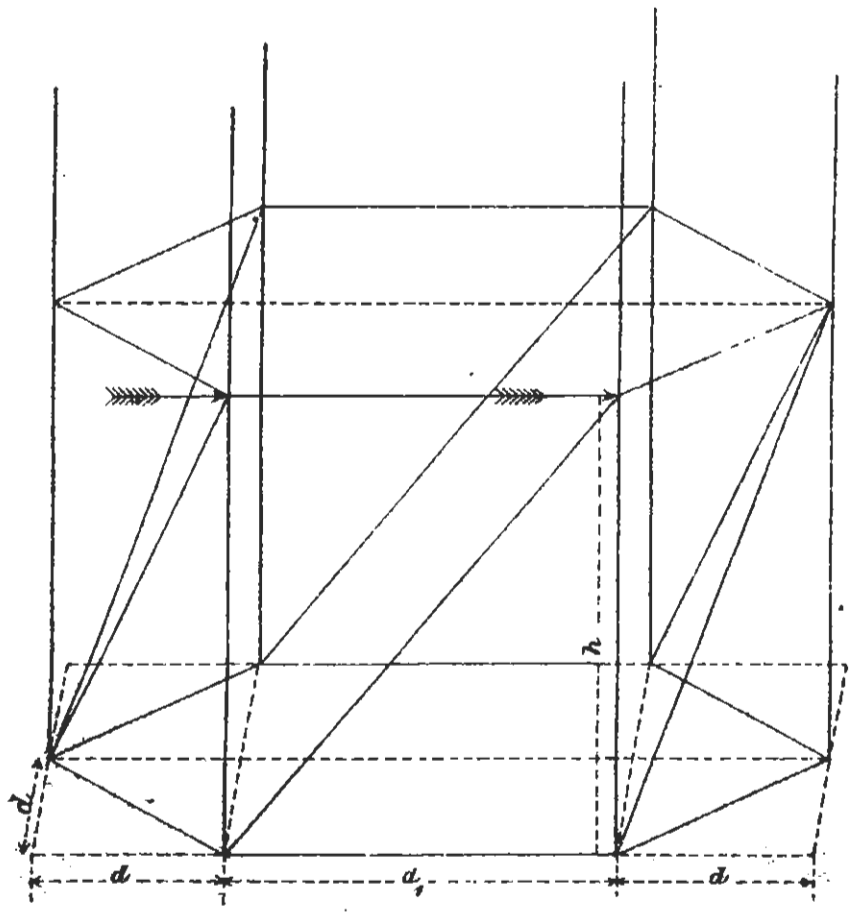
PLAN SHOWING POSITIONS OF BOLTS THROUGH FLANGES OF 15 INCH COLUMNS.



PLAN SHOWING POSITIONS OF BOLTS THROUGH FLANGES OF 18 INCH COLUMNS.

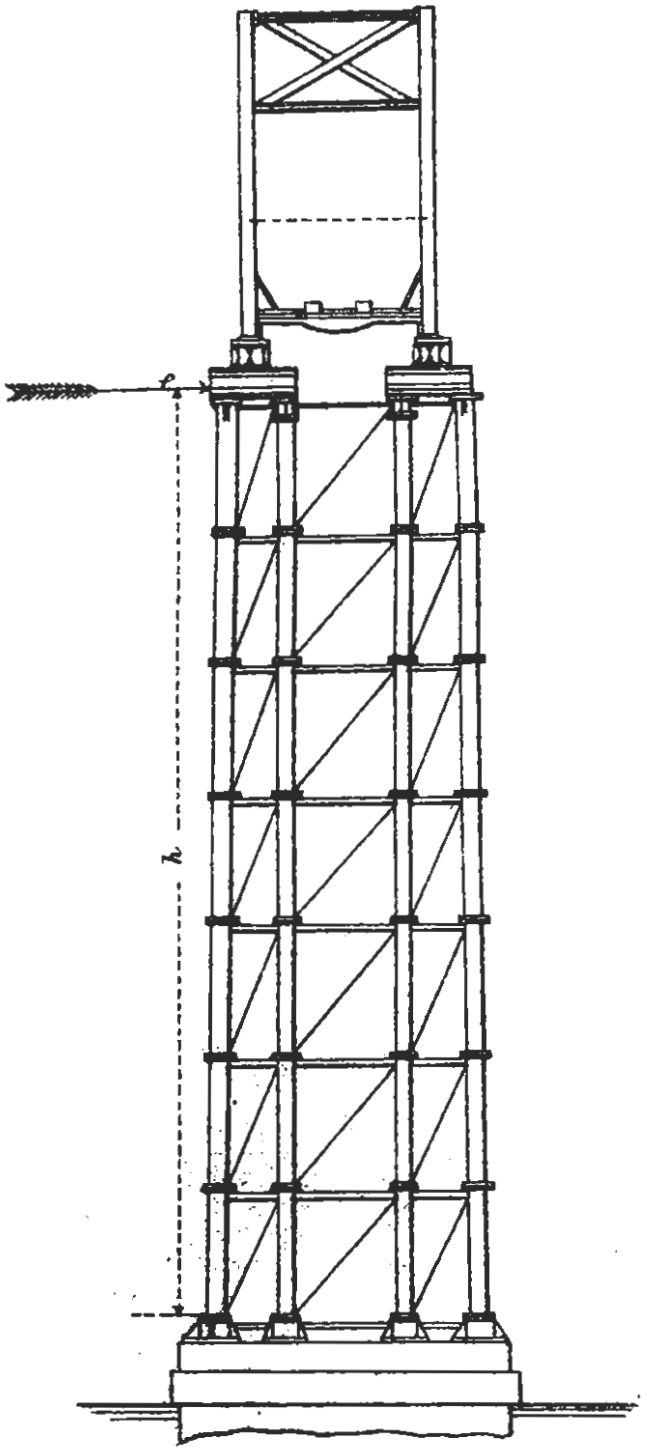
TAY BRIDGE

SKELETON DIAGRAM SHOWING THE STRAINS ON THE TIE BARS.



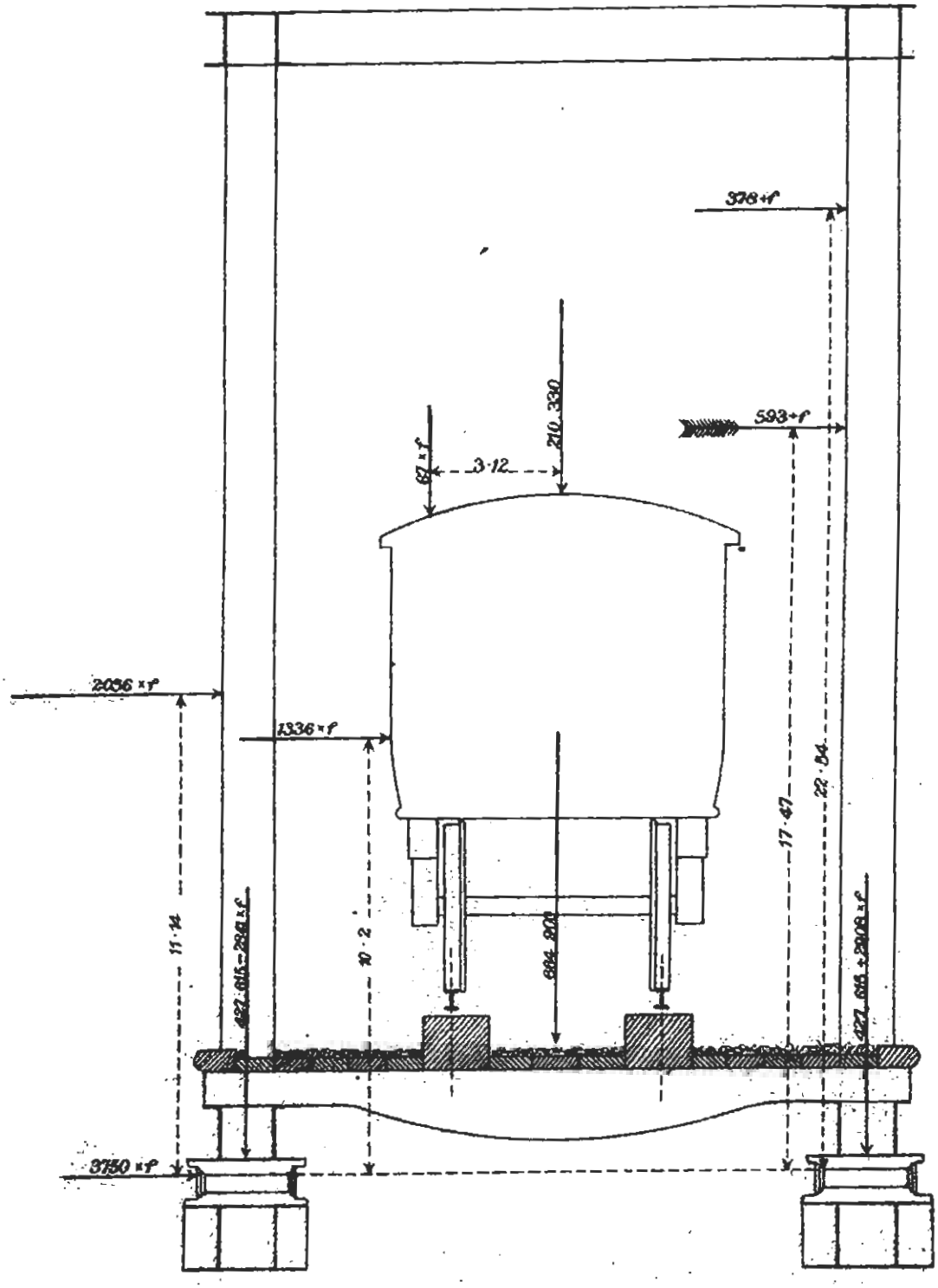
TAY BRIDGE.

SIDE ELEVATION OF ONE OF THE PIERS SHOWING ONLY THE TIE BARS IN TENSION.



TAY BRIDGE.

TRANSVERSE SECTION OF THE SUPERSTRUCTURE SHOWING THE PRESSURES PRODUCED BY THE ACTION OF THE WIND COMBINED WITH THE WEIGHT OF THE STRUCTURE AND TRAIN.



SCALE ¼ OF AN INCH TO A FOOT.

NOTE. The feathered arrow shows the pressure of the wind when

Weight on east rollers :—

Weight of superstructure -	$322,450+2468\times f$
Weight of train - -	$105,165+440\times f$
	$427,615+2908\times f$

Weight on column 1 :—

Weight of column - -	45,570
One-half of weight on west rollers - - -	$213,808-\times f$
	$259,378-1420\times f$

Weight on each of columns 2 and 6 :—

Weight of column - -	35,750
One-fourth of weight on west rollers - - -	$106,904-710\times f$
	$142,654-710\times f$

Weight on each of columns 3 and 5 :—

Weight of column - -	35,750
One-fourth of weight on east rollers - - - -	$106,904+727\times f$
	$142,654+727\times f$

Weight on column 4 :—

Weight of column - -	45,570
One-half of weight on east rollers	$213,808+1454\times f$
	$259,378+1454\times f$

From these formulæ I calculated the following table, which exhibits the pressures to which the several columns would be exposed, both with and without the train, and with wind pressures of 10, 20, 30, and 40 lbs. to the square foot.

Position of Columns.	With Pressure of Wind equal to			
	10 lbs.	20 lbs.	30 lbs.	40 lbs.
Without any Train :—	lbs.	lbs.	lbs.	lbs.
Pressure on column 1 - -	190,855	184,535	173,405	162,275
,, each of cols. 2 & 6	110,727	105,253	99,007	94,102
,, ,, 3 & 5	121,928	127,493	133,058	138,623
,, column 4 - -	217,995	229,055	240,185	251,315
With a Train :—				
Pressure on column 1 - -	245,173	230,968	216,763	202,558
,, each of cols. 2 & 6	133,561	128,449	121,346	113,144
,, ,, 3 & 5	149,924	157,194	164,464	171,734
,, column 4 - -	273,018	288,458	302,996	317,535

2. Forces to overturn Rigid Structure.

a. *Pressure of Wind required to overturn the Pier without a Train and without any holding-down bolts :—*

Moment of stability about centre of column 4 :—

Moment of weight on column $1=21{\cdot}84\times(206,795-1113\times f)$

,, ,, on cols. 2 and $6=15{\cdot}84\times(232,725-1113\times f)$

,, ,, on cols. 3 and $5=6\times(232,725+1113\times f)$

The sum of which is equal to

$$439,520\times21{\cdot}84-31{\cdot}68\times1113\times f$$
$$=9,599,113-35,260\times f$$

which is the moment of stability; then the moment of the wind is $=228,587\times f$, therefore we have

$$9,599,113-35,260\times f=228,587\times f$$

and

$$f=36{\cdot}38 \text{ lbs.}$$

which is the pressure of the wind required to overthrow the structure *without a train upon it*, and unassisted by the bolts.

b. *Pressure of Wind required to overturn the Pier with the Train, but without any holding-down bolts :—*

Moment of stability about centre of column 4 :—

Moment of weight on column $1=21{\cdot}84\times(259,377-1420\times f)$

,, cols. 2 and $6=15{\cdot}84\times(285,308-1420\times f)$

,, cols. 3 and $5=6\times(285,308+1454\times f)$

The sum of which is equal to

$$544,684\times21{\cdot}84-44,800\times f$$
$$=11,895,893-44,800\times f$$

which is the moment of stability, and is equal to $319,052\times f=$the moment of the wind, and therefore we have $f=32{\cdot}69$ lbs., which is the force of wind required to overthrow the structure with the train upon it, and unassisted by bolts.

c. *Pressure of Wind required to overturn the Pier with the Train, and with the columns bolted down :—*

The moment of resistance of the bolts being taken into account we have

$$11,529,390+11,895,893=363,852\times f$$

and $f=64{\cdot}38$ lbs., which would suffice to overthrow the structure, supposing the pier to be rigid and the columns bolted down.

3. Forces to overturn the Pier on the Columns separately.

a. *Pressure of Wind required to overturn the Pier without a Train, the bolts, struts, and tie bars being taken into account :—*

Inserting the values of p_1, p_2, p_3 and p_4, we have

$$M=1{\cdot}683\times413,590+1{\cdot}458\times465,552+8,131,740$$
$$=9,506,441$$

for the moment of stability, and we have

$$9,506,441=228,587\times f$$

and $f=41{\cdot}588$ lbs.

b. *Pressure of Wind required to overturn the Pier with the Train upon it, the bolts, struts, and tie bars being taken into account :—*

In this case we have

$$M=1{\cdot}683\times518,756+1{\cdot}458\times570,616+8,131,740\times107\times f$$
$$=9,834,851+107\times f$$

for the moment of stability, and we have

$$9,834,851=318,945\times f$$

and $f=30{\cdot}84$ lbs.

c. *Additional Wind pressure required to overthrow Pier on columns separately, with an initial strain on the tie bars :—*

Let u=the initial strain put upon each of the tie bars by driving up the keys, then in the case of the ties between the 15-inch and the 18-inch columns, we have

$$u\times28\times0{\cdot}38\times42=446{\cdot}88\times u$$

and in the case of the ties between the 15-inch columns we have

$$u\times14\times0{\cdot}656\times42=385{\cdot}73\times u$$

or for the whole of the tie bars

$$(446{\cdot}88+385{\cdot}73)\times u=832{\cdot}6\times u$$

Then for the additional pressure required to overcome this initial strain we have

$$\frac{832{\cdot}6}{228,587}\times u=0{\cdot}003642\times u$$

with *no train on* the bridge, and

$$\frac{832{\cdot}6}{319,052}\times u=0{\cdot}002096\times u$$

with the train over the pier.

Henry Law.

Mr. Law's detail Calculation of the Wind Force required to overturn the Second-Class Carriage.

Moment of Stability.

Weight of carriage, as stated by Mr. Drummond, 5 tons 19 cwt. - -	13,328 lbs.
Weight of eight passengers, at 140 lbs.	1,120 ,,
Weight of carriages with passengers -	14,448 ,,

Half the width of line, 2·5 feet.

Then moment of stability from weight $=14,448\times2{\cdot}5=36,120$ foot-lbs.

Moment of stability from pressure of wind on roof $=2{\cdot}77\times5{\cdot}62\times f=15{\cdot}6\times f$.

Moment tending to overturn Carriage.

—	Area of surface in square feet. A	Height of centre of surface above rails. B	A × B
Lamp covers, ½ (1·15 × 1 × 2)	1·150	11·35	13·053
,, ,, ½ (0·2 × 1·8 × 2)	0·360	10·70	3·852
Roof, 22·3 × 0·0281 -	0·627	10·24	6·423
Body, 6·9 × 22. - -	151·800	6·40	971·520
Buffers, ½ (0.5 × 3·75) -	0·937	3·33	3·122
Wheels, 1·15 × 3·57 × 2 -	8·211	2·25	18·475
,, 3·75 diameter	11·045	1·00	11·045
	174·100	5·90	1027·487

Then when the carriage is on the point of overturning, we have

$$36{,}120 + 15{\cdot}6 \times f = 1027{\cdot}5 \times f$$
$$36{,}120 = 1011{\cdot}9 \times f.$$

And $f = 35{\cdot}69$ = the force of the wind in lbs. per square foot required to overturn the carriage when *fully exposed*.

And as $\frac{4}{15}$ths of the surface was sheltered by the lattice girders, we have $\frac{35{\cdot}69}{0{\cdot}8667} = 41{\cdot}2$ lbs. = the force of wind required to overturn the second-class carriage when within the girders.

No. 4.

Second Report to the Court of Inquiry by Mr. Law.

5 and 46, Queen Anne's Gate, Westminster,
May 20th, 1880.

Gentlemen,

I have now the honour to report generally on that portion of the Tay Bridge which is still standing.

In compliance with your instructions I have had soundings taken along the centre line of the bridge, and have plotted the same upon the original section of the river bed as sent to the Board of Trade, and the result is shown upon the accompanying section, the black lines in which represent the bed of the river, as shown in the section sent to the Board of Trade, while the red lines and figures show the river bed and the soundings taken for the purposes of this inquiry.

The datum to which the soundings have been reduced is the level of the zero of the gauge at the entrance of the William the Fourth Dock, or 12·7 feet below the high-water line shown on the section sent to the Board of Trade. I have prepared a tabular statement, which is appended hereto, showing the depths of the foundations of the several piers and the depth of the lowest part of the river in their vicinity. It is evident from the recent soundings that the régime of the river at the bridge is not fixed, and that there is a tendency to scour in some places and to deposit in others.

Ever since the completion of the structure the bed of the river in the neighbourhood of the bridge has been carefully watched by Mr. Noble, and wherever he discovered a tendency to scour, he deposited rubble stone, piling the same round the piers in the manner shown upon the section. Notwithstanding this, however, it will be seen that in many places there is still a tendency to scour, and it is evident that it will be necessary to continue the same constant inspection, and to deposit heavy material wherever the bed is found to have been deepened; for, although there is nothing at present to create alarm, there is sufficient to lead to the belief that in time the foundations of some of the piers might become undermined.

After carefully examining the piers I can find no indication of any settlement or sinking of the foundations, but in one or two instances there are vertical cracks in the sides of the hexagonal brick piers, which have probably been occasioned by the expansion of the concrete in setting; these piers consisting of an external wall four bricks in thickness, filled in the interior with Portland cement concrete.

As is evident from the table there is considerable variety both in the mode of constructing the piers and in the details of their foundations.

The 28th and 41st piers, being the last piers on either side of the standing portion of the structure, are of similar construction to those which have fallen, and are so much injured (more particularly the latter one) that it will be necessary to reconstruct them. It is evident that both of these piers have been subjected to a considerable force tending to overthrow them towards the east, as the masonry is disturbed and lifted under the western columns.

The 15th to the 27th piers on the south, and the 42nd to the 48th on the north, generally resemble those which have fallen, but differ in some of the details of construction.

The columns on plan are similarly arranged, but the weight of the superstructure is wholly borne by the four 16″ columns, which are bolted to a foundation plate, and are surmounted by a square wrought-iron box girder or entablature which supports the superstructure. The two external columns are 12″ in diameter, and are carried up perpendicularly until within one storey of the top, when the last or upper column is inclined inwards to form a raking strut to the wrought-iron box girder or entablature. It is evident that in their present condition these external columns are of very little service in strengthening the structure: firstly, because of the very unfavourable angle of the wrought-iron ties which connect them with the 16″ columns; and secondly, because they have no direct tie at the upper part of the perpendicular columns to resist the thrust of the raking columns.

There are indications in one or two of these piers of a considerable force tending to overthrow the piers, having caused a disturbance in the upper courses of the masonry.

The 49th to the 53rd piers consist each of four vertical columns carrying the weight of the superstructure and without any raking columns. At the last-mentioned pier the straight portion of the railway ends and a curve commences with a radius of 22½ chains, the line also having a falling gradient of 1 in 73·56.

The 54th, 57th, 61st, 65th, 69th, 73rd, and 76th piers, each consist of four vertical columns, which carry the weight of the superstructure, with two raking columns on the western side, which serve to resist the centrifugal strain resulting from the curvature of the line.

The intermediate piers consist simply of two vertical and one raking column intended to be in one plane, upon which the lattice girders of the superstructure merely rest without any kind of attachment. The most lofty of these single piers is No. 55; the height from the top of the caisson to the underside of the girder is nearly 55 feet; there is no kind of stay to prevent movement of the head of the columns in the direction of the length of the bridge, and there is no kind of attachment between the girders and the columns, or even (in this particular instance) between the girders, which merely rest upon opposite sides of the top of the columns, without any provision for carrying the weight of the girders and their superincumbent load vertically down through the axis of the column. I observe that in this pier the columns are not in the same vertical plane, and I am decidedly of opinion that some modification should be made in this portion of the structure.

I find that in some cases the lengths of the lattice girders do not correspond with the distances between the centres of the piers, and that as a consequence the joints of the girders are not vertically over the centres of the piers, deviating in some instances to the extent of 18 inches.

I did not consider that my instructions warranted me in making a critical examination of every part of the existing portion of the structure, which would be a work requiring a very large expenditure of time and labour, but the general examination which I have made is sufficient to show the necessity of a very careful and minute inspection being made of every column, tie bar, and strut, since one or two of the columns are cracked, as described by Mr. Noble in his evidence. Some of the tie bars have become loose, and have been packed, and some of the columns exhibit external evidence of inequalities in their thickness.

In making these remarks I have no desire to lead to the inference that I condemn the whole of the existing structure, but I wish very distinctly to state my opinion that every portion of it ought to receive a most thorough and careful inspection, in order that should it be found that the bolts of the tie bars have become crushed or bent, or should the struts not have efficient bearing, these and any other defects may be discovered and remedied, together with those which I have more particularly pointed out.

I have, &c.

(Signed) Henry Law.

To the Commissioners for the
Tay Bridge Casualty.

TABULAR STATEMENT showing the Nature and Depth of the Foundations and the relative Depth of the bed of the River.

No. of pier.	Nature of foundation.	Nature of pier.	Depth of foundation below datum.	Depth of lowest part of river bed adjoining pier.	Distance of lowest point from side of pier.	Alteration in bed.
1	On the land	Rectangular brick pier	—	—	—	—
2	Above low water	" "	—	—	—	—
3	2 iron caissons, 15 ft. 6 ins. diam.	Circular brick piers	5·5	+8·0	—	Deposit.
4	" "	" "	11·8	−10·1	36·5	"
5	" "	" "	24·0	11·5	18·0	"
6	" "	" "	21·8	12·2	18·0	"
7	" "	" "	19·8	14·9	28·0	Scour.
8	" "	" "	22·0	15·5	8·0	Deposit.
9	" "	" "	25·8	15·0	7·0	Scour.
10	" "	" "	23·0	14·7	7·5	Unaltered.
11	" "	" "	26·5	15·9	0·0	Deposit.
12	" "	" "	26·0	16·3	7·0	Scour.
13	" "	" "	26·0	16·6	0·0	"
14	4 " "	" "	25·8	17·7	5·5	"
15	4 " "	6 cast iron columns, 4 16 ins. diam. and 2 12 ins. diam.	30·8	18·0	4·0	"
16	Oval caisson, 22 ft. by 14 ft., with piles.	" "	23·6	19·7	16·5	Deposit.
17	" "	" "	22·8	19·3	17·0	"
18	" "	" "	23·2	20·0	28·5	Scour.
19	" "	" "	23·6	19·9	12·5	Deposit.
20	1 caisson, 31 ft. diam.	" "	33·0	28·0	11·0	Scour.
21	"	" "	33·0	19·6	11·0	Deposit.
22	2 iron caissons, 15 ft. 6 ins. diam.	" "	32·8	23·3	36·0	" and scour.
23	" "	" "	32·3	24·7	42·5	Scour.
24	" "	" "	29·8	22·9	28·5	" and deposit.
25	" "	" "	30·8	19·0	23·5	Deposit.
26	" "	" "	30·8	21·1	27·0	Scour.
27	" "	" "	34·8	19·4	27·0	"
28	1 iron caisson, 31 ft. diam.	6 cast iron columns, 4 16 ins. diam. and 2 18 ins. diam.	33·8	22·5	26·0	"
29	" "	" fallen	34·8	19·7	27·0	"
30	" "	" "	31·0	16·7	24·5	"
31	" "	" "	31·3	25·2	35·0	"
32	" "	" "	30·8	22·2	23·0	"
33	" "	" "	27·6	22·5	30·0	"
34	" "	" "	29·0	22·7	33·0	"
35	" "	" "	28·8	20·5	22·0	Unaltered.
36	" "	" "	28·0	27·0	42·0	Deposit and scour.
37	" "	" "	30·8	24·2	32·5	Scour.
38	" "	" "	31·3	29·2	18·0	"
39	" "	" "	31·0	23·5	25·5	"
40	" "	" "	33·0	23·7	35·0	"
41	" "	" "	34·6	25·2	24·0	Deposit.
42	2 iron caissons, 15 ft. 6 ins. diam.	6 cast iron columns, 4 16 ins. diam. and 2 12 ins. diam.	41·0	25·0	27·0	"
43	" "	" "	46·7	24·5	29·0	"
44	" "	" "	35·6	13·5	19·5	"
45	" "	" "	37·6	8·0	21·0	"
46	" "	" "	36·0	11·7	11·5	"
47	" "	" "	37·3	12·6	15·0	" and scour.
48	" "	" "	35·6	10·8	30·0	Scour.
49	4 iron caissons, 9 ft. diam.	4 cast iron columns	23·6	1·8	16·0	"
50	" "	" "	32·5	4·9	28·5	"
51	" "	" "	36·3	4·5	8·0	"
52	" "	" "	22·9	2·7	3·0	Deposit.
53	" "	" "	23·0	0·1	6·5	" and scour.
54	6 iron caissons, 6 ft. 6 ins. diam.	4 vertical and 2 raking cols.	24·0	2·3	5·0	"
55	3 " "	2 " 1 "	24·0	3·4	5·0	"
56	3 " "	2 " 1 "	22·0	3·5	3·5	"
57	6 " "	4 " 2 "	22·0	+1·3	3·5	"
58	3 " "	2 " 1 "	22·9	+1·1	8·5	"
59	3 " "	2 " 1 "	21·6	−7·0	5·5	" and scour.
60	3 " "	2 " 1 "	22·3	6·0	5·5	" "
61	6 " "	4 " 2 "	21·0	7·3	10·0	" "
62	3 " "	2 " 1 "	20·3	4·7	2·5	" "
63	3 " "	2 " 1 "	20·0	6·3	4·5	" "
64	3 " "	2 " 1 "	20·6	6·5	2·5	" "
65	6 " "	4 " 2 "	20·8	8·6	11·5	Scour.
66	3 " "	2 " 1 "	17·5	4·2	8·5	" and deposit.
67	3 " "	2 " 1 "	17·5	5·8	10·0	Deposit.
68	3 " "	2 " 1 "	17·3	6·6	2·0	" and scour.
69	6 " "	4 " 2 "	17·6	11·0	22·5	" "
70	3 " "	2 " 1 "	16·6	9·7	18·5	Scour.
71	3 " "	2 " 1 "	16·6	11·8	21·5	Deposit.
72	3 " "	2 " 1 "	16·3	9·0	31·0	Scour and deposit.
73	6 " "	4 " 2 "	15·7	9·3	10·5	" "
74	3 " "	2 " 1 "	17·0	11·2	31·5	" "
75	3 " "	2 " 1 "	16·3	11·2	20·0	" "
76	6 " "	4 " 2 "	16·3	7·7	19·0	Deposit.
77	3 " "	2 " 1 "	14·6	8·4	19·0	"
78	2 iron cylinders, 7 ft. diam.	2 iron cylinders, 6 ft. diam.	9·8	6·1	23·0	"

No. 5.

CORRESPONDENCE between the COURT OF INQUIRY and the NORTH BRITISH RAILWAY COMPANY.

Office of the Wreck Commissioner,
Somerset House, London, W.C.,
January 23rd, 1880.

SIR,

IN order that we may be able to form an opinion on the causes which have led to the recent accident to the Tay Bridge, it is necessary that we should receive full information on the several points raised in the enclosed paper. Will you therefore be good enough to lay the same before the Directors of your Company, and request that they will give directions that we be furnished with the required information with as little delay as possible.

Reference was made at the conclusion of the recent sittings at Dundee to a paper which had been read by Mr. Gilkes, the contractor for building the bridge, and to a discussion which had ensued thereon, and we were informed that prints of that paper and a report of the discussion would be sent to us. We shall be glad to receive them at your early convenience.

We shall also be glad to receive from you any statement showing the grounds on which you consider the bridge to have been safe for the passage of trains, and the causes to which you attribute the fall of the bridge, and any written evidence which you may wish to lay before us in support of your views.

Any communications which you may have to make to us should be addressed to the Wreck Commissioner, Somerset House, London, W.C.

We are, &c.
(Signed) H. C. ROTHERY.
W. YOLLAND.
W. H. BARLOW.

The Secretary,
North British Railway Company,
Edinburgh.

INFORMATION is required from the North British Railway Company on the following points in connexion with the Inquiry into the Tay Bridge Casualty.

1. The total weight in each of the spans taken between the centre lines of the piers, distinguishing the weight of (1) the longitudinal girders, (2) cross girders, (3) cross bracing, (4) the permanent way, planking, ballast, &c., and (5) the water pipes and other dead weight.

2. The sectional area of the upper and lower booms of the girders, after deducting the rivet holes, at the centre of each span, and over each pier.

3. The weight of the iron-work, inclusive of the bed plates of the girders in each pier.

4. The estimated vertical strength of the girders of each span; and the maximum stress per square inch on the upper and lower booms and diagonals due to the dead weight and assumed moving load.

5. The estimated surface of girder exposed to wind pressure, and the allowance, if any, for wind pressure; stating also whether any and what allowance was made for the action of the wind on the leeward girder after passing through the openings of the windward girder, and for the resistance arising from the upper horizontal cross bracing, the deck or flooring and the permanent way guard-rails and hand-railing.

6. The estimated surface of the train exposed to wind action, with a drawing of the train in position on a span of the bridge.

7. The total estimated surface of girders and train combined exposed to wind pressure, stating also whether any and what allowance was made for the shelter afforded by the train to the leeward girder.

8. The estimated surface of resistance offered by the iron-work of the piers to the action of the wind.

9. The estimated maximum pressure in tons per square inch on the columns near their bases, arising from the dead weight of the structure and from the additional weight of the engine and train.

10. The estimated increase of pressure brought on the leeward columns near their bases by the action of wind pressure, stating separately its effect in tons per square inch on the outer 18-inch column and on the two inner columns, and assuming pressures of wind of 10 lbs., 20 lbs., 30 lbs., and 40 lbs. per square foot.

11. The estimated diminution of pressure, and the tension (if any) brought on the windward columns with like pressures of wind.

12. The estimated tension (if any), stated in tons per square inch, on the bolts which connect the windward columns with their bases, and on the holding-down bolts, which connect the bases of the columns with the masonry, with like pressures of wind.

13. The above estimates of the effect of wind pressure to be made, first, when there is no train on the bridge; secondly, when the train is on it.

14. The dimensions and mode of fastening the holding-down bolts to the masonry or brickwork, and the weight of masonry or brickwork which would operate in resisting tension (if any) at the bases of each of the windward columns.

15. The net sectional area of the diagonal ties of the piers, after deducting the bolt holes.

16. The estimated maximum stress brought on the diagonal ties in tons per square inch of net sectional area, taking into account the angles at which some of them are placed and assuming pressures of wind of 10 lbs., 20 lbs., 30 lbs., and 40 lbs. per square foot.

17. The estimated maximum stress per ton per square inch brought on to the upper and lower horizontal cross bracings of the girders by wind pressures of 10 lbs., 20 lbs., 30 lbs. and 40 lbs. per square foot.

The North British Railway Company,
General Manager's Office,
Edinburgh, March 5th, 1880.

SIR,

ADVERTING to your letter of the 23rd January, previously acknowledged, enclosing notes of information required by the Court of Inquiry into the circumstances attending the above casualty, a copy of the same was at once transmitted to Sir Thomas Bouch, who has, along with other parties, since been engaged putting in form the necessary particulars, and the same are sent herewith.

I regret I have hitherto failed to get a report of any discussion that may have followed the reading of Mr. Gilkes' paper on the construction of the Tay Bridge.

With reference to the second last paragraph in your communication, as I am not an engineer I am unable to suggest the probable cause of the disaster, but I apprehend such must be found in accidents or incidents that could neither have been foreseen nor avoided in the working of traffic over the bridge.

I am, &c.
(Signed) J. WALKER.

H. C. Rothery, Esq.,
Wreck Commissioner,
Somerset House, London, W.C.

To Sir THOMAS BOUCH.

DEAR SIR,

Edinburgh, February 25th, 1880.

IN compliance with your request we have carefully considered the memorandum of information asked from the North British Railway Company by the Court of Inquiry on various points connected with the Tay Bridge Casualty, and we have to submit the following data in reference thereto:—

We presume that the information is only required with regard to the 13 large spans of the bridge.

By the wording of some of the questions, they would seem to refer to the calculations originally made for the structure; but we may explain that, although the parts were originally designed with full regard to all the strains likely to come upon them, the calculations have not been preserved in such a form as to be available for our present purpose, and we have therefore thought it desirable to repeat the calculations *de novo*, using throughout the most accurate data we can procure. The dimensions of the parts have been taken from the authentic drawings, copies of which have been, we believe, furnished to the Court of Inquiry.

I.

"The total weight of each of the spans, taken between the centre lines of the piers, distinguishing the weight of (1) the longitudinal girders; (2) cross girders; (3) cross bracing; (4) the permanent way, planking, ballast, &c.; and (5) the water pipes and other dead weight."

The total weights of the 13 spans vary, for two reasons, viz.:—

(*a.*) Two of the spans, viz., the 6th and 9th from the south end, are only 227 feet from centre to centre of piers, being 18 feet shorter than the others, which are 245 feet;

(*b.*) The extreme spans of each continuous girder are somewhat larger in the scantling of their bars than the intermediate ones, and therefore somewhat heavier.

The average weight of the 11 245 feet spans is as follows:—

	Tons.	Cwt.
Longitudinal girders - - -	140	6
Cross girders - - - -	30	16
Cross bracing - - - -	15	14
Permanent way, planking, ballast, &c.	86	17
Water pipes (full), &c. - -	11	7
	285	0

This includes some ballast, water mains, telegraph pipes, &c., which have been added since the bridge was constructed, and were not originally contemplated in the design.

II.

"The sectional area of the upper and lower booms of the girders, after deducting for rivet holes, at the centre of each span and over each pier."

The sectional areas at the middle of the length of the several 245 feet girders differ in different spans according to the different magnitudes of the stresses they are subject to, as resulting from the continuity. The areas are greater in the extreme spans of each continuous girder than in the intermediate spans.

The following table gives the information required for all cases:—

——	Total Sectional Area.	Area deducting Rivets.
	Square in.	Square in.
At the middle of the length of each extreme span—		
Top boom - - -	57·5	51·0
Bottom boom - - -	57·5	51·0
At the middle of the length of each intermediate span—		
Top boom - - -	43·5	37·5
Bottom boom - - -	43·5	37·5
Over each pier—		
Top boom - - -	69·85	54·0
Bottom boom - - -	70·6	56·4

III.

"The weight of the ironwork, inclusive of the bed plates of the girders in each pier."

We have as yet no drawings of the piers in sufficient detail to enable us to calculate accurately the weight of the ironwork in them.

But we have received particulars of the final accounts, according to which the contractors were paid for the work, and we believe they may be relied on.

The piers differ somewhat in height, according to the gradients of the railway over them. The 3rd to the 9th piers inclusive, from the south end, are the highest, and the weight of iron in each is given in the accounts above mentioned

$$= 78\tfrac{1}{2} \text{ tons.}$$

The columns are filled with concrete, which is estimated to weigh 31¼ tons, making the whole weight, including concrete = 110 tons.

IV.

"The estimated vertical strength of the girders of each span, and the maximum stress per square inch on the upper and lower booms and diagonals, due to the dead weight and assumed moving load."

The answer to this question must, of necessity, be somewhat complicated. We have not only to assume the weight of the moving load, but also its position on the bridge; for, as a result of the peculiar construction, the same load will have different effects when placed in different positions.

It will doubtless be well known to the members of the Court that in designing this great structure it was thought advisable to take advantage of the *principle of continuity*, by connecting several girders together over the piers. Thus, beginning from the south end, the first five spans are connected together in this way into one group. Then follows a group of four, and then a second group of four, so making up the 13 spans. The advantage of this arrangement is that the strains arising from the loads are more widely distributed than on the ordinary plan, an effect that admits of a considerable economy of material without detriment to the strength of the structure.

The stresses resulting from different loads in different positions are very variable, but they admit of calculation by mathematical analysis, and the proportions of the different parts can be properly adapted to resist them. The maximum weight of the moving load has been taken at 1¾ ton per running foot. This is the weight, we believe, ordinarily assumed as the maximum that can come in a railway bridge, as it is equivalent to that of a number of average locomotives placed close together.*

In order to test the effect of such a load it is necessary to decide which span it shall be put upon. The greatest strain is produced when the load is placed upon one of the *extreme spans of a continuous group*, and this is why (as stated in answer to the first question) the scantlings of these spans are increased.

We have, however, thought it right to give examples of two different positions, first, on an extreme span; and, secondly, on an intermediate span; these have been fully calculated out for all parts of the loaded girders, and the results are given in the diagrams accompanying the Report. It will be seen that the maximum stresses on any parts of the structure, under the assumed load, are—

On the top and bottom members—

	Tons per square inches.
Tension - -	4 2
Compression -	4 0
On the diagonal bracing—	
Tension - -	4 7
Compression -	2 7

In the above calculations, we have assumed only one span to be loaded at a time. If several spans were loaded together, there would be no increase of stress on the middle parts of the girders; on the contrary, the strain would be relieved. But the effect of the continuity would be to throw a greater stress on the parts over the piers. It is, therefore, necessary to investigate this point, for, of course, many trains are of such length as to cover two or even three spans at one time.

But, in considering several spans loaded, it is not necessary to assume the maximum test load of 1¾ tons per running foot, as applied to each span. It is out of the question that any considerable part of such a structure as this could ever be covered with heavy locomotives packed close together; and it would not be reasonable, nor is it, so far as we know, customary to design an exceptionally large bridge, with reference to a continuous load of the weight mentioned, which would be a waste of expensive material.

On this point, therefore, we have thought it sufficient to take as a datum the greatest extended load which can actually come upon the bridge in ordinary working.

We have procured from the North British Company particulars of their heaviest mineral trains, and we find that so far as the waggons are concerned the actual weight, when every waggon is fully loaded, comes under three-fourths of a ton per running foot. A train of this kind may be 700 or 800 feet long, filling three spans of the bridge, and it may be drawn by two engines and tenders, filling about half a span, and weighing, of course, heavier per foot than the rest of the train.

To take exact account of the position of the engines would much complicate the calculations, it will sufficiently provide for them if we assume the load over the whole span they occupy to be increased from three-fourths to one ton per running foot.

With these loads the worst possible case for the stress over a pier is where the engines stand on an extreme span, and the waggons on *one* adjoining intermediate span only, the pier affected lying between these spans. If the waggons extend also to a second intermediate span, the stress over the first pier is diminished thereby.

We have calculated the worst case out fully, and the results are shown in diagram No. 3. The maximum stresses over the pier will be seen to be:—

	Tons per square inch.
Tension—deducting river holes -	4·62
Compression - - -	3·53

* The North British Company have lately made some very heavy special engines, weighing 1¾ ton per foot run; but these are exceptional. The bridge, however, was tested before opening by six of these coupled together and covering one complete span.

V.

"The estimated surface of girder exposed to wind pressure, and the allowance (if any) for wind pressure, stating also whether any or what allowance was made for the action of the wind in the leeward girder, after passing through the openings of the windward girder, and for the resistance arising from the upper horizontal cross bracing, the deck or flooring, and the permanent way, guard rails and handrailing."

This question involves three points for consideration; namely,

(*a.*) The surface offered by the girder and its appurtenances to the action of the wind;

(*b.*) The estimated intensity of the wind pressure;

(*c.*) The lateral resistance of the structure to wind pressure.

The two first of these points involve much difficulty, but we will give in regard to them the best information we can.

(*a.*)

In estimating the surface offered by the girder and its appurtenances to wind pressure, we shall assume the wind to blow in a direction at right angles or nearly so to the direction of the bridge.

The most important element of this surface is of course the front face of the windward girder, which is directly exposed to the wind's action. This is easily calculated, and we make it, including the exposed surfaces of platform, rails, handrails, and standards, &c.=1,950 square feet for one 245 feet span.

We have next to estimate what allowance is to be made for additional wind pressure on the leeward girder.

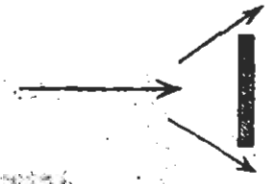
This involves great difficulty, and we do not think it possible to calculate it with any pretension to accuracy. All we can do is to state some of the elements involved in the question, and then form some rough approximation which may serve as a fair estimate in the absence of accurate data.

Supposing the wind to blow precisely in a perpendicular direction, every member of the leeward girder will be theoretically under cover of the corresponding member of the windward one; but we cannot assume that this gives a perfect shelter; for, in the first place, the direction of the wind may be either constantly or occasionally somewhat oblique; and secondly, even if it blew perpendicularly, experience leads us to believe that, when any leeward object is removed a certain distance from its windward cover, there will probably be irregularities in the wind's action, which will still give rise to some amount of pressure on the part behind.

On the other hand, there are some considerations which favour the view that this pressure on the leeward surfaces cannot be very large.

If a current is checked by a series of obstacles in its course, so that only a certain fraction of the fluid can pass through; the velocity of the current beyond the obstacles will be reduced in the same proportion, and (which is of more importance) the *pressure* of the current there will be further reduced in the ratio of the *square*; so that a comparatively small series of obstacles will make a large diminution in the general pressure behind them.

Secondly, it is a common result of observation that when a powerful wind strikes a flat surface perpendicularly, the current is projected off on each side at a considerable angle, thus:—



giving a calm for a considerable space behind the object. This is the explanation of the well-known fact that persons may walk on the top of a pier or a cliff when a furious gale is blowing transversely upon it, without feeling any wind at all, and some remarkable observations of the same nature on the Britannia Bridge are recorded by Mr. Edwin Clark in his well-known work, page 690. It follows from this that a bar in front will produce a much wider shelter behind it than is simply due to its breadth, and that the diversion of the current thus caused may possibly diminish considerably the pressure at a moderate distance behind.

If now we look at the leeward girder, we shall find that the whole of the bottom portion is so well covered by the front girder and the platform, that it may, we conceive, be considered as entirely sheltered from the wind's action, up to about the height of the rails. Above this level the parts of the leeward girder are more exposed, and taking into account the considerations above mentioned, we believe we shall not be *understating* the effect if we assume the various surfaces of this girder to receive *one-half* the amount of pressure that comes on the corresponding surfaces in the windward girder. These surfaces amount to 1,136 feet, for which we may add 568 square feet to the former amount; so that with no train on the bridge we may consider that each 245 feet span offers a surface of (1,950+568) = 2,518 square feet to the full action of a wind blowing perpendicularly to the length of the bridge.

If the direction of the wind deviates much from the perpendicular it catches more the area of the diagonal bars, but its effective force becomes diminished by the oblique angle at which it strikes the general surface, and we may probably take the perpendicular direction as that on the whole most likely to do harm.

(*b.*)

In answering the inquiry, "what allowance, if any, was "made for wind pressure," our simplest way will be to state the nature and extent of the information that the engineer had to guide him at the time the Tay Bridge was designed.

The ordinary source from which estimates of the force of the wind have been usually taken is the well-known table presented by Smeaton to the Royal Society in 1759. This table gives a pressure per square foot of—

6 lbs. for "high winds."
8 or 9 lbs. „ "very high winds."
12 lbs. „ "a storm or tempest."

There are still higher figures for "great storms or hurricanes," but it is stated that these are of doubtful authority, and only apply to tropical meteorology.

Referring to the authentic records of wind pressure gauges, in the heaviest storms that have occurred for many years, it has been found that upon very limited surfaces, and upon very limited times, the pressure of the wind does amount sometimes to 40 lbs. per square foot, or in Scotland probably to more. But the best authorities who have studied these gauges have arrived at a confident opinion that such high pressures are only momentary, arising from some irregular whirlings of the air, which extend to no great distance. And if it is considered as a practical matter, what a lateral pressure of 40 lbs. per square foot really means, and what effect it must produce, common experience must render it very doubtful whether any such pressure can be sustained by objects ordinarily exposed to the wind's action.

For these reasons, in designing the bridge, a maximum wind pressure was assumed acting over the surface of a span and pier, equal to about 20 lbs. per square foot (being more than double what Smeaton allowed for a "very high wind"), and the dimensions were calculated for this pressure with the usual margin of safety.

We have calculated in this Report the effects for 30 lbs. and 40 lbs. wind pressures, as we have been desired, but we have called them "excessive pressure," being beyond that for which the bridge was designed.

(*c.*)

The lateral resistance offered by the girders to wind pressure.—As the effect of the wind is much augmented when a train is on the bridge we propose to postpone our notice of this point till the train is considered, which will be in our answer to Question VII.

VI.

"The estimated surface of the train exposed to wind action, with a drawing of the train in position, on a span of the bridge."

This question doubtless refers to the train which was upon the bridge at the time of the casualty. A drawing of this train has already been furnished to the Court, giving the dimensions and weight of each vehicle, as well as the lateral surface it exposes to the wind.

The total side surface is there stated at 1,759 square feet. But some portion of this is inclined more or less to the wind's directions, such as the large cylindrical parts of the engine, the buffers and lamp covers, and the carriage roofs.

Making allowance for these, we estimate the surface of the train as equivalent to about 1,650 square feet opposed at right angles to the wind. This does not take into account any shelter from the bars of the windward girder.

The position of the train in reference to the girder it will be convenient to leave to a future question.

There is a point connected with the effect of the wind in the train which seems to us of so much importance, that, although not specially mentioned in the inquiries we are answering, we think it right to add some remarks upon it.

This is the resistance which the several vehicles of this train offer to overturning by the action of a heavy side-

wind. We have calculated what maximum force of wind would suffice to overturn each vehicle of the train behind the tender.

We have added to the given weights of the vehicles an allowance for 70 passengers distributed equally in the third-class carriages (there were, we understand, none in the second or first class). Calculating then on these data, we obtain the following results :—

Pressure of side-wind which would suffice to overturn the several carriages of the train.

	When in the open.	Allowing for the shelter of the bridge.
	Lbs. per square foot.	Lbs. per square foot.
No. 1. Third class -	39	43
2. „ „ - -	39	43
3. First „ - -	37	39½
4. Third „ - -	36	39
5. Second „ - -	28¼	30·2
6. Van - -	34·2	36

There are two considerations which give a special importance to this point.

First, if it is true, as the best authorities believe, that in heavy gales there are exceptional gusts of great strength, which act for limited times and on limited areas, it is reasonable to conclude that one of these gusts, acting in the limited surface of a single carriage, might have force enough to overturn it when the pressure on the whole bridge or the whole train would be much more moderate.

Secondly, when once the windward wheel of a carriage was lifted off its rail the stability would proportionately decrease with an increase of tilt, so that if a momentary gust gave a start to the vehicle, a diminished pressure would suffice to complete the overturning to such an extent as to cause the roof to impinge against the leeward girders.

The couplings would do but little, we think, to hold the carriage down, for they might be easily moved through the small distance corresponding to the upset of the vehicle.

VII.

"The total estimated surface of girders and train combined, exposed to wind pressure, stating also any and what allowance was made for the shelter afforded by the train to the leeward girder."

Assuming that this inquiry refers to the train which was passing over the bridge at the time of the casualty, we estimate the surface as follows:—

		Superficial Feet.
Surface of windward girder -		1,950
Surface of train expressed in equivalent flat surface - -	1,651	
Deduct for shelter by the bars of the windward girder (244 less 15 for sheltering inclined surfaces) - - - -	229	
		1,422
Surface of leeward girder as formerly estimated under question 5	1,136	
Deduct for shelter by train as above - - - -	244	
	892	
Take half as effective (as explained under question 5) - -		446
Total surface which may be considered as exposed to the full pressure of the wind - -		3,818

XVII.

"The estimated maximum stress per ton per square inch brought on to the upper and lower horizontal cross bracing of the girders by wind pressures of 10 lbs., 20 lbs., 30 lbs., 40 lbs. per square foot."

We place this question here because it really forms a sequel to No. VII., and we may take it that questions IV., VII., XVII., combined, raise generally the whole subject of the resistance of the girders to a heavy side wind. We will accordingly here explain the calculations we have made on the subject.

The structure of the girder considered with reference to a side pressure consists of two resisting tables. The two upper booms of the girder, connected by horizontal bracing, form one table, which we may call the top wind table; the two lower girder-booms, which are also connected by horizontal bracing (and are further strengthened by the roadway platform), form what we may call the bottom wind table. The action of the wind gives a tensile and comprehensive stress on each of these tables of the same nature as those resulting from the usual vertical loads.

It can be easily shown that the stresses resulting from the wind alone, however fiercely it may blow, are so insignificant as not to merit notice. It is only when combined with other stresses in the same direction caused by the loads that they require attention.

For this reason, in order to judge of the effect of the wind, it is necessary to assume a train of some kind on the bridge, particularly as the side surface of the train considerably augments the wind's action.

There may be two varieties of effect produced. A heavy mineral train will produce the greatest stresses from load, but will offer the least surface to the wind; on the other hand, a light passenger train will produce the greatest wind stresses, but will have the least effect as loading on the girders. We cannot have the two maxima together.

In order to reduce the test to figures, it is necessary to take actual examples, and we have taken one of each kind.

(1.) The heavy mineral train described under the answer to the IVth question; and

(2.) The light passenger train that met with the casualty.

Heavy Mineral Train.

We have already stated the effect of this as load. It remains to estimate the additiun due to the side action of the wind on the girders and the train.

Allowing for this, at the several pressures mentioned in the questions, the results come out as in the accompanying table.

Light Passenger Train.

This train will only fill one span, and to produce with it the greatest strain on the girder, both as regards gravity and wind, we must suppose it placed on one of the extreme spans of a continuous group. The effects will then be as shown in the table.

Table showing the Maximum Effect of Wind on the Girders.

	Stress when there is no wind.	Stresses as increased by a side wind at various pressures per square foot.			
		10 lbs.	20 lbs.	30 lbs.	40 lbs.
Heavy Mineral Train.	Tons per sq. in.			Excessive (Pressures.)	
Tensile stress on top boom over pier, *leeward side* (rivets deducted) - - -	4·62	4·77	4·92	5·07	5·22
Compressive stress on bottom boom over pier, windward side -	3·53	3·78	4·03	4·28	4·53
Light Passenger Train.					
Tensile stress on bottom boom, middle of girder, leeward side (rivets deducted) - -	2·80	3·15	3·50	3·85	4·20
Compressive stress on top boom, middle of girder, windward side -	2·70	2·80	2·91	3·01	3·1

The maximum stress in tons per square inch brought on to the horizontal cross bracing of the girders, we estimate as follows, including the effect of the light passenger train.

	Wind Pressures at			
	10 lbs.	20 lbs.	30 lbs.	40 lbs.
			Excessive Pressures.)	
UPPER BRACING.				
Tension	0·85	1·70	2·55	3·40
Compression	0·70	1·40	2·10	2·80
LOWER BRACING.				
Tension	1·87	3·75	5·62	7·50
Compression	1·50	3·00	4·50	6·00

No credit is taken in these calculations for the stiffening effect of the platform and permanent way, which is so considerable, that it is often deemed sufficient of itself to afford the lateral stiffening necessary.

VIII.

"The estimated *surface of resistance* offered by the iron-work of the piers to the action of the wind."

Each pier consists of 6 columns connected by a great number of bracing bars in various directions, and the determination of the effective surface exposed to the wind's action by such a complicated structure is not possible with any precision. All we can do is to make such an empirical estimate of it as seems reasonable.

The columns form the easiest element for calculation. If we suppose the wind blowing in a direction perpendicular to the length of the bridge it will strike openly upon three of them; but a small deviation from the perpendicular will cause it to strike four, namely, three 15-inch and one 18-inch. We therefore have assumed this condition, and we have estimated the force of the columns according to the rule given by Professor Rankine, namely, by making a reduction of one-half for the rounded surface.

With regard to the bracing bars, and the other two columns which are more or less under shelter, we do not attempt to make any calculation; but we think it will be a reasonable estimate to allow for the action of the wind a surface equal to one-fourth of the entire area of the openings between the columns, as measured perpendicularly to the wind's direction.

It should also be mentioned that the *box-girder forming* the summit of the pier presents surfaces inclined to the wind at an angle of 45°, for which we have made a deduction.

Carrying out these principles, we estimate the surface, which may be considered as exposed effectively to a perpendicular wind action, for the highest pier, at about 400 square feet.

IX.

"The estimated maximum pressure in tons per square inch on the columns near their bases, arising from the dead weight of the structure, and from the additional weight of the engine and train."

In the answer to this question we have taken into account the effect of continuity in varying the pressure on the piers.

With the uniform dead weight of the structure only, the pier most strained is the one between an extreme span and the adjoining intermediate one. This pier bears considerably more than the dead weight of one opening. Adding to this the weight of the portion of the pier above the base plates, we find that the maximum pressure on the columns, near their bases, arising from the dead weight of the structure, will be 1·4 tons per square inch of metal.

As regards the addition of the live load, we must of course fix on some kind of train, as explained in our answer to question IV. We have tried each case there mentioned, and we find that the one which will cause the heaviest downward pressure on the piers, taking account of the effect of continuity, is the heavy mineral train covering two spans, namely, one extreme span and one intermediate span adjoining.

Calculating, therefore, the pressure on the pier between these two spans, and adding, as before, the weight of the pier, we obtain the maximum pressure on the columns near their bases, due to the combined dead and live loads, equal to 2·25 tons per square inch of metal.

X.

"The estimated increase of pressure brought on the leeward columns near their bases by the action of wind-pressure, stating separately its effect in tons per square inch on the outer 18-inch column, and on the two inner columns, and assuming pressures of wind 10 lbs., 20 lbs., 30 lbs., 40 lbs. per square foot."

XI.

"The estimated diminution of pressure, and the tension (if any) brought on the windward columns with like pressure of wind."

XII.

"The estimated tension (if any), stated in tons per square inch, on the bolts which connect the windward columns with their bases, and on the holding-down bolts which connect the bases of the columns with the masonry."

XIII.

"The above estimates of the effect of wind-pressure to be made, first, when there is no train on the bridge; second, when the train is on it."

It will be most convenient to take these four questions together, and give a joint answer to them.

The manner in which the combined vertical and horizontal forces will be distributed between the various legs of the pier is somewhat obscure, but we have made the best estimate we can of the division. The effect of the lateral action of the wind will be most felt on the extreme windward and leeward columns, but at the same time the intermediate ones will aid materially in furnishing the necessary resistance.

According to the usual well-known rule for such structures, if the resultant of the horizontal and vertical forces falls within the base of the pier, it will be stable without any need of tying down to the foundation; and we have, accordingly, when the pier is within this condition, assumed no tension on the bolts on the windward side. If they are put into tension they may be an additional security, and will relieve the compression to leeward; but they are not necessary, and may be removed without endangering the pier.

We find that with no train on the bridge the pier will be stable so long as the wind pressure does not exceed 37·4 lbs. per square foot. Beyond this it must be tied down, and consequently for the extreme pressure of 40 lbs. we have calculated the necessary tension on the bolts, assuming that, by reason of the small compressibility of the concrete, the whole compression will be taken by the extreme leeward column.

In calculating the increased action of the wind on the pier when a train is on the bridge, we have taken the most unfavourable case, that is, a train which, with a comparatively small weight, offers a large side surface to the wind; and we cannot have a more suitable example of such a train than the one which was crossing the bridge at the time of the casualty, of which we have already given particulars.

In answering question XVII. we supposed this train to cover one span; but it will be right here to change its position, that is, to assume it standing directly over one pier, so as to get the most trying effect on that pier.

Under this condition the pier will be stable without bolts till the wind pressure reaches about 34½ lbs., beyond which it must be tied down.

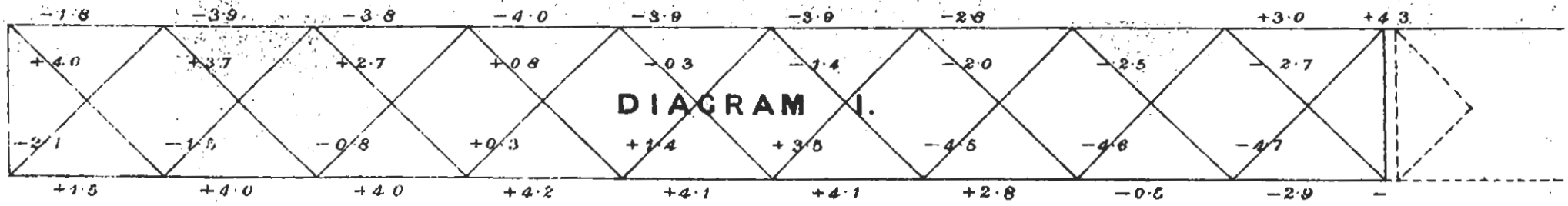
The following are the stresses, in tons per square inch of metal, sustained in the various cases mentioned in the questions:—

	Windward. 18-in. Column.	Two 15-in. Columns.	Two 15-in. Columns.	Leeward. 18-in. Column.
I.—NO TRAIN ON BRIDGE.				
No wind	1·4	1·4	1·4	1·4
Wind, 10 lbs.	0·7	1·1	1·7	2·1
„ 20 „	0	0·7	2·0	2·8
Excessive pressures 30 lbs.	0	0	1·7	4·2
Excessive pressures 40 lbs.	Tension on the bolts. 1·1	0·9	0·8	5·8
II.—LIGHT PASSENGER TRAINS STANDING OVER THE PIER.				
No wind	1·7	1·7	1·7	1·7
Wind, 10 lbs.	0·8	1·3	2·1	2·6
„ 20 „	0	0·8	2·5	3·5
Excessive pressures 30 lbs.	0	0	1·3	6·1
Excessive pressures 40 lbs.	Tension on the bolts. 3·1	2·3	1·0	8·8

FOUR SPAN GIRDER END SPAN; AND THIS ALONE LOADED WITH 1¼ TON PER FOOT RUN

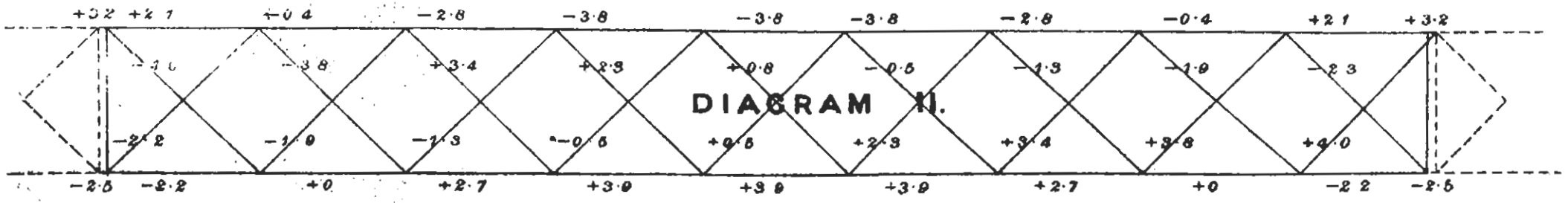
— means Compression
\+ „ Tension

STRESSES. IN TONS PER SQUARE INCH.



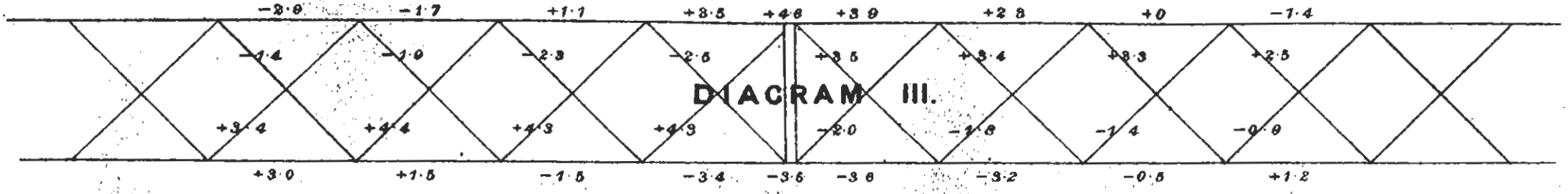
FIVE SPAN GIRDER MIDDLE SPAN AND THIS ALONE LOADED WITH 1¼ TON PER FOOT RUN

STRESSES. IN TONS PER SQUARE INCH.



FIVE SPAN GIRDER. BETWEEN END AND INTERMEDIATE SPANS THERE TWO SPANS ALONE LOADED WITH MINERAL TRAIN

STRESSES IN TONS PER SQUARE INCH



These compressions are given on the supposition that the metal bears the whole weight, nothing being allowed for the bearing power of the concrete filling.

In regard to the bolts which hold down the columns to the masonry of the pier, we are informed that they are four for each column, 1¼ inch diameter. This will give more area than the bolts which connect the flanges of the columns, and the tension on them must be reduced in proportion.

We must again state that we cannot believe the two pressures we have marked "excessive" could ever occur over the whole surface of girders, pier, and train; and that before 40 lbs. could be reached, the train would be overthrown. Hence we believe that practically no tension could arise on the windward column which could affect the safety of the pier.

XIV.

"The dimensions and mode of fastening the holding-down bolts to the masonry or brickwork, and the weight of masonry or brickwork, which would operate in resisting tension (if any) on the bases of each of the windward columns."

We have been informed by Sir Thomas Bouch that the bolts here referred to are "Lewis bolts," 3½ inches in diameter at the lower end, and 1¾ inches diameter at the upper end.

They pass through the cast-iron base pieces and, below these, also through two courses of ashlar coping, together 2 feet 6 inches thick. The bolts were run into the holes with cement.

The weight of masonry which would operate through these bolts in holding the windward columns down depends on the holding power of the cement or mortar, which is usually taken at 10 to 20 tons to the square foot.

It has, however, been explained in the answer to the last question that up to a wind pressure of 20 lbs. per square foot, for which the bridge was designed, there could be no tension on the bolts, and therefore there was no occasion to provide any anchoring under them. Such anchorage as there is, was, we presume, intended to add to the margin for stability without any precise determination of its amount or value. The condition of such a wind pressure as would render anchorage absolutely necessary was not, we believe, contemplated in the design.

XV.

"The nett sectional area of the diagonal ties of the piers, after deducting the bolt holes."

According to the best information we can obtain, the ties were designed to be "4½ × ½," out of which a hole has to be deducted for a 1½ inch bolt. This leaves a nett sectional area = 1·69 square inches.

XVI.

"The estimated maximum stress brought on the diagonal ties in tons per square inch of nett sectional area, taking into account the angles at which some of them are placed, and assuming pressures of wind of 10 lbs., 20 lbs., 30 lbs., and 40 lbs. per square foot."

The stresses on the diagonal ties of the pier are difficult to calculate, seeing that the strains are borne by the concurrent resistances of many bars in different positions.

We have thought the most satisfactory method would be as follows:—

First, we assume a certain small lateral motion of the top plane of the lowest tier of columns, produced by a horizontal force applied thereto.

Secondly, we calculate geometrically what extension this will give in each tie, and we find the stress corresponding to such extension.

Thirdly, we resolve these various stresses into the direction of the force causing the motion of the top plane.

Fourthly, we find what resistance the six columns will offer to an amount of bending corresponding to the lateral motion assumed.

Fifthly, by adding together the resolved stresses of the various ties and the resistance of the six columns, we obtain the total horizontal force corresponding to the assumed small lateral motion, which gives us the relation between any horizontal force applied to the pier, and the stress on any given tie.

The maximum stresses on the diagonal ties in tons per square inch of section are as follows:—

	No Train on the Bridge.	Light Passenger Train over one Pier.
Wind, 10 lbs.	2·6	3·39
„ 20 „	5·21	6·79
Excessive pressures { 30 lbs.	7·81	10·18
{ 40 lbs.	10·41	13·58

We have taken no credit for the stiffening effect of the concrete inside the columns.

We are, &c.
(Signed) WILLIAM POLE.
ALLAN D. STEWART.

DETAILS of CALCULATION of the WIND PRESSURE necessary to overturn the SECOND-CLASS CARRIAGE, made by *DR. POLE and MR. STEWART.*

The weight and dimensions of the carriage are taken from the drawing supplied by Mr. Drummond.

A deduction of 50 per cent. is made for all rounded or inclined surfaces exposed to the wind's action.

I.—EFFECT OF GRAVITY TENDING TO KEEP THE CARRIAGE DOWN.

The weight of the empty carriage is given by Mr. Drummond as 5· 5 =	13,328 lbs.
It is stated there were 8 passengers in it. We estimate these, taking the average of sex and age, at 120 lbs. each =	960 „
Total weight	14,288 „

Assuming the ice wheel to bear on the centre of the rail, and the flank to be pressed close up to the inside edge of the rail, the horizontal distance of the centre line of this carriage from the bearing point will be 2 ft. 5 in. = $2\frac{5}{12}$ ft.

This gives the moment of effect of gravity

$$= 14{,}288 \times 2\tfrac{5}{12}$$
$$= 34{,}529 \text{ foot-lbs.}$$

II.—EFFECT of LATERAL WIND PRESSURE tending to overturn the CARRIAGE.

	Effective surface in square feet.	Height of centre of surface above rails.	Overturning moment for wind pressure of 1 lb. per square foot.
		Feet.	Foot-lbs.
Flat surface of carriage body and under frame, 22 feet long by 7 feet high	154	6·5	1001·0
Flat surface of wheels, axle-boxes, axle-guards, springs, spring attachments, steps, coupling-chains, brake apparatus, and other appurtenances of under frame. (These are not shown on the drawing, but we estimate them at least at 20 square feet, with a mean height of 1 foot 9 inches above the rails)	20	1·75	35·0
Vertical area of curved roof, 22 feet 5 inches long by 6¾ inches = 12·52 superficial feet. Take half as effective, the middle of it being 10 feet 3⅜ inches above the rails	6·26	10·28	64·3
Two lamp covers, each about 1½ square feet. Take half as effective. Centres, 11 feet 3 inches above rails	1·5	11·25	16·9

	Effective surface in square feet.	Height of centre of surface above rails.	Overturning moment for wind pressure of 1 lb. per square foot.
		Feet.	Foot-lbs.
Two buffers and buffer blocks; each about 1 square foot. Take half as effective. Centres, 3 feet 5½ inches above the rail (as stated by Mr. Drummond) - - -	1·0	3·46	3·5
			1120·7
Deduct for the moment of wind force on roof tending to press the carriage down (amount as given by Mr. Law) -	—	—	15·6
Total *moment* of 1 lb. wind to overturn unsheltered carriage - - -	—	—	1105·1

Hence the pressure of wind necessary to overturn the carriage when unsheltered will be $\frac{34,529}{1105 \cdot 1} = 31\frac{1}{4}$ lbs. per square foot.

The amount of shelter the carriage can obtain from the girder in front of it varies in different positions, and we estimate it, at a minimum, as equivalent to reducing the overturning moment by about 56 foot-lbs.

The wind pressure, therefore, necessary to overturn the sheltered carriages will be $\frac{34,529}{1049 \cdot 1} = 32 \cdot 9$ lbs. per square foot.

Wreck Commissioner's Office,
Somerset House, London, W.C.,
March 8th, 1880.

SIR,

WITH reference to the concluding paragraph of your letter of the 5th instant, in which you say that not being an engineer you are not able "to suggest the probable "cause of the disaster," but that you apprehend that "such must be found in accidents or incidents that could "neither have been foreseen or avoided in the working of "traffic over the bridge," I would beg to observe that it is not your own individual opinion that the Court was desirous of having on the questions which were submitted in *our letter of the 23rd of January last*. What we wanted was the deliberate opinion of the Company, with the full knowledge which they must now have of all the facts, more than two months having elapsed since the casualty occurred, and after full consultation with its engineers and officers on the following points, namely, on what grounds they "*consider the bridge to have been safe for the passage of* "trains," and to what causes they "attribute the fall of "the bridge."

I have therefore to request that you will favour me at your earliest convenience with a reply to these questions, or state whether the reply which you have already sent in is the only reply which the Company are prepared to give.

Awaiting your reply.

I am, &c.
(Signed) H. C. ROTHERY,
Wreck Commissioner.

The Secretary,
North British Railway Company,
Edinburgh.

The North British Railway Company,
General Manager's Office,
Edinburgh, March 12th, 1880.

SIR,

I HAVE to acknowledge receipt of your letter of the 8th instant, and with respect to the inquiries therein made I am authorised by the directors of the Company to state, in answer to the first point, viz., "on what grounds they "considered the bridge to have been safe for the passage "of trains," that the bridge, having been designed and constructed under the direction of an engineer of experience, and having been subjected to the severe tests applied to it by the inspecting officer of the Board of Trade, without any weakness or defect having been disclosed, they never did entertain a doubt of its absolute safety for the passage of trains. And in answer to the second point, viz., "to what causes they attribute the fall of the bridge," that, apart from the overpowering violence of the wind, they are not yet aware of any circumstances which in themselves would account for the disaster which befel the bridge on the 28th December. As the inquiry proceeds the Company will place before the Court over which you preside all the evidence calculated to throw light upon the subject which they can command, and they venture respectfully to submit that this is all they can be expected to do towards satisfying the requirements you have made upon them.

I am, &c.
(Signed) J. WALKER.

H. C. Rothery, Esq.,
Wreck Commissioner,
Somerset House, London.

Wreck Commissioner's Office,
Somerset House, London, W.C.,
March 13th, 1880.

SIR,

I SHALL be obliged by your informing me at your earliest convenience of the exact distances between—

(1.) The West Newport and Dundee Stations;
(2.) The West Newport Station and the South cabin;
(3.) The South and North cabins;
(4.) The North cabin and the Dundee Station.

I shall also be glad to know the exact position of the distance signals on the bridge.

I am, &c.
(Signed) H. C. ROTHERY,
Wreck Commissioner.

The Secretary,
North British Railway Company.

The North British Railway Company,
General Manager's Office,
Edinburgh, March 17th, 1880.

SIR,

YOUR letter of the 13th instant, addressed to the secretary, has been handed to me.

The exact distances between the following places are as noted:—

	Miles.	Chains.
I. West Newport to Dundee Stations	4	18½
II. West Newport Station to the South cabin - - - - -	1	42½
III. South cabin to North cabin -	1	77½
IV. North cabin to Dundee Station -	0	58½

The distance signal on the bridge at the north end is 686 yards south of the North cabin, and the distance signal on the bridge at the south end is 680 yards north of the South cabin.

I am, &c.
(Signed) J. WALKER.

H. C. Rothery, Esq.,
Wreck Commissioner,
Somerset House, London, W.C.

No. 6.

CONTRACT with Messrs. de BERGUE & COMPANY for BUILDING the TAY BRIDGE, with Specification.

THIS CONTRACT, entered into and executed by and between the North British Railway Company, incorporated by Act of Parliament (herein-after called "the Company"), of the one part, and Charles de Bergue, of No. 10, Strand, in the County of Middlesex, Civil Engineer, and carrying on business there under the style and firm of Charles de Bergue and Company, and the said Charles de Bergue and Company, for their interest, and executing these presents by Robert Amadeus Heath, of 31, Old Jewry, in the City of London, Merchant, Attorney empowered in that behalf by the said Charles de Bergue, by a power of Attorney of date the Eighteenth day of February, 1871, herein-after called "the Contractors," of the other part;

WITNESSETH that whereas the Company having, in connection with a proposed railway from the Edinburgh, Perth, and Dundee section of the North British Railway, at

Leuchars Junction, to the town of Dundee, and under the powers conferred on them by the North British Railway (Tay Bridge and Railways) Act, 1879, and therein designated as Railway No. 2, proposed to construct a *bridge* over the River Tay, about 1¼ miles above the docks at Dundee, commencing on the Fife side of the river, at or near a point known as Long Craig, a little to the east of Wormit Bay, and terminating on the Forfar side, near Dundee, at Magdalene or Buckingham Point: And whereas twenty-eight plans, sections, and drawings of the said bridge and works, with the exception of providing and laying the permanent rails and chairs, comprising all the works incidental to the perfect construction and completion of the same, numbered respectively 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, and 28, and enumerated in the specification of works annexed hereto, have been prepared by Thomas Bouch, Esq., Civil Engineer, Edinburgh, the Company's engineer, and are docquetted and signed by the said Thomas Bouch, on behalf of the Company, and by the Attorney of the said contractors as relative hereto, and are to remain in the hands of the Company: And whereas the contractors made an offer to construct the said bridge and works incidental to the perfect construction and completion of the same, except as aforesaid, and that in terms of the said specification hereto annexed and docquetted and signed as relative hereto, and according to the said plans, sections, and drawings, and with reference, for the purposes and to the effect aftermentioned, to a detailed estimate of the prices applicable to the several particulars or items of the works of said bridge and works incidental to the perfect construction and completion of the same, except as aforesaid, of which detailed estimate a copy is hereto annexed and docquetted and signed as relative hereto, and under the conditions herein-after written for the sum of 217,099*l.* 18*s.* 6*d.* sterling: And whereas the Company have accepted the aforesaid offer: Therefore the contractors have become bound, and hereby bind and oblige themselves, and their executors, administrators, and successors, all conjointly and severally, that they shall and will well and substantially, and in a good, efficient, lasting, and neat and workmanlike manner, and to the entire satisfaction of the engineer, and of the arbiters herein-after named, both as regards the materials used and the mode of their use, make, execute, and complete the said bridge, with all works incidental to the perfect construction and completion of the same, including the finding and providing all material, permanent and temporary, as well as all labour, carriage of material, workmanship, machinery, vessels, boats, barges, buildings, tools, implements, and other plant whatsoever necessary for setting out, constructing and completing the said bridge and works incidental thereto as aforesaid (excepting the providing and laying the permanent rails and chairs), and that in terms of and in the manner described in the said specification, and according to the plans, sections, and drawings before mentioned, or according to such other altered or explanatory plans, sections, or drawings as may from time to time be furnished to them by the Company's engineer, declaring in writing that the said specification, in so far as not herein expressly altered, shall form an integral part of these presents, and the contractors bind and oblige themselves and their foresaids to abide by and implement the same, and such other orders and instructions as may from time to time be given by the engineer for the pupose, except as aforesaid, of carrying the whole of the works of said bridge and works, incidental thereto as aforesaid, or any alterations thereof or additions thereto or deductions therefrom into effect. Declaring also that though certain descriptions and stipulations may be repeated in different parts of the said specification, and in this contract it shall not thence be inferred that the remaining directions, descriptions, or amplifications are in any wise invalidated. Declaring also that the engineer shall have power at all times to direct that there shall be made any deviations from the line of the bridge as staked out and delineated upon the foresaid plans, sections, and drawings, additional works, or any alterations in addition to or deductions from any of the works herein or in the said specification described or referred to; provided the same shall be within the powers conferred by the said Act, and the Acts incorporated therewith, without vitiating this contract or affecting the said detailed estimate; the value of the works in all such cases of deviations, additional works, alterations, additions, or deductions, to be added to or deducted from the sum due to the contractors, as the case may be, according to the prices mentioned for such works in the said detailed estimate. And it is hereby further specially provided and declared that the contractors shall, at intervals of every month from the commencement of the works under this contract, furnish to the engineer a statement and account of all work done by the contractors during that period, and of all amounts charged or claimed by them for additional or extra work, damages, compensation, or other claims whatsoever, the whole of which statements and accounts and claims shall be investigated, valued, and settled by the engineer, according to the prices in the said detailed estimate, so far as the same are applicable thereto, and where the same are not applicable thereto according to the valuation and assessment of the engineer; or, in the event of dispute, according to the valuation and assessment of the arbiter after named, and the amount of the said account for the said work and claims on the part of the contractors shall, after the amount thereof has been certified in writing as correct by the engineer, be paid to the contractors, after deducting 10 per cent. thereof, which shall remain in the hands of the Company till the completion of the whole works, and upon the completion of the whole works the whole of the said deduction of 10 per cent. shall be paid to the contractors, or their foresaids, upon the certificate of the engineer that the contractors and their foresaids have performed their part of the contract, and the whole obligations incumbent on them under the same, to the satisfaction of the engineer; and upon the further certificate of the engineer that, after taking into consideration the mutual obligations and claims of the Company and the contractors, the amount of such deduction of 10 per cent. is justly due and owing to the contractors, or their foresaids; and it is further agreed that no moneys shall be deemed due or payable to the contractors or their foresaids in respect of any account for work or claims under this contract, or in reference thereto, in any way except the same be certified in writing as correct by the engineer as aforesaid: Such certificate not to be withheld by the engineer when due and applied for by the said contractors, except on stated valid and substantial grounds. And in all settlements of accounts between the contractors or their foresaids and the Company, it is hereby agreed and provided that no payment for extra work or alteration or deviation from the works specified in the said specification, will be allowed by the Company to the contractors or their foresaids, unless the same shall have been done under the written authority of the said engineer or his authorised agents, or by oral directions given to the contractors or their clerk of the works by the said engineer himself, and which authority shall be produced and oral directions proved at the time of the settlement of the account between the contractors or their foresaids and the Company, otherwise the contractors or their foresaids shall have no claim for the said extra work or work caused by said alteration or deviation. And it is hereby agreed that all extra or unspecified works that may be done under this contract shall be done as specified works, on terms of the said specification and detailed estimate, declaring that should any small discrepancies exist between the measurement by the scale attached to the said plans, sections, and drawings and the written dimensions in the said specification, plans, sections, and drawings the written dimensions shall be taken as correct. And it is further agreed that wherever neither the said plans, sections, and drawings nor the said specification contain any notice of minor parts, the intention to include which is clearly to be inferred, and which parts are necessary for the completion and stability of the works, all such additional things are to be done and provided by the contractors and their foresaids and are assumed to be included in the before-mentioned sum of 217,099*l.* 18*s.* 6*d.* sterling, at which they contract for the works shown upon said plans, sections, and drawings, and specified in such specification. And wherever anything is directed to be done or provided, if required, it is understood and agreed that everything so referred to, provided the same is necessary for completing the said works, will be considered as also included in the said sum of 217,099*l.* 18*s.* 6*d.*, the true intent and meaning of this contract being, that whether the same be specially set forth and expressed, or not, herein, or in the said specification, or upon the said plans, sections, and drawings, the contractors and their foresaids shall, unless where it is herein expressly provided to the contrary, provide and furnish, without any extra price or compensation therefore, all the materials and labour (excepting the providing and laying the permanent rails and chairs which shall be done by the Company) requisite for the construction of the said bridge and whole works incidental to the perfect construction and completion of the same, and that in all respects in an efficient and workmanlike manner and to the reasonable satisfaction of the Company's engineer. And it is hereby provided and declared that the contractors and their foresaids shall be at all expense and risk of setting out the works from time to time, and shall allow the engineer or superintendent under him to have any workmen or labourers and to furnish him with all such poles, stakes, boats, and other assistance as he may reasonably require for the purpose of examining or testing the correctness of the work whilst being set out, proceeded with, or as executed

and also shall as provided in the said specification test the materials which are therein required to be tested, and that all without any charge being made for the same, and farther the contractors bind and oblige themselves and their foresaids that the works shall be begun without delay after the signing of this contract, and the said works shall be carried on so that the whole works specified in said specification and shown upon said plans, sections, and drawings, and such additional works and alterations as the engineer may direct to be executed as aforesaid, shall be finished, and the said bridge completed in every respect (the Company only supplying and laying thereon the permanent rails and chairs) within three years from the date of this contract to the end and effect of the said bridge being opened within the said period, with the sanction and approval of the Board of Trade or their inspecting officer. And in the event of the contractors or their foresaids failing to complete the said works within the said period so that the said bridge may be opened as aforesaid, the contractors bind and oblige themselves and their foresaids to pay the Company as a liquidated and agreed on compensation for any delay thereafter the sum of 250*l.* per week for every week during which the said works shall remain unfinished, and no plea in justification of such delay, except as herein-after mentioned, shall be deemed valid, and on the other hand, for each and every week the bridge may be opened for traffic before the expiration of the contract time, the contractors to be paid the sum of 250*l.* per week, declaring that the said payments of 250*l.* per week by the contractors shall not in any way relieve the contractors or their foresaids from their liability for the performance of this contract nor interfere with or be construed as a waiver of the other powers to enforce completion thereof, or of the claims at common law thence arising, conferred on, or competent to the Company, except as herein-after mentioned. And it is hereby specially agreed and provided that the works shall be commenced and carried on at such points, parts, and places as shall be directed and appointed by the Company's engineer. And it is hereby specially conditioned and declared, that if the contractors or their foresaids shall not commence the said works within the period before-mentioned, or shall not uniformly or regularly carry on the same to the reasonable satisfaction of the Company or their engineer, or if it shall appear at any time or from time to time to the Company that a sufficient number of men or material are not employed or used by the contractors in the execution of the works hereby contracted for, or that otherwise the work is not proceeding at such a rate as to ensure the completion of the whole works within the time above specified, or if the engineer shall at any time be otherwise reasonably dissatisfied with the nature or mode of proceeding in the work, or if the contractors shall not adhere to and implement the conditions herein and in the said specification contained, or shall not comply with the orders and directions to be given from time to time by the Company's engineer as aforesaid, or shall from any cause whatever be prevented from, or delayed in proceeding with, or completing the said works according to this contract, except as herein-after mentioned, it shall be lawful to the Company, as often as any such event shall happen, by a written notice, to require the contractors to commence or proceed with the said works, or to provide or employ such additional workmen or material, and for such length of time, and to comply with such orders as the case may be; and in case the contractors shall not, within fourteen days, conform to said notice, or employ such workmen, or provide such material or comply with such orders as may be so given, it shall be lawful to and in the power of the Company to call upon the arbiter herein-after named and appointed, to authorise them; and the said arbiter may thereupon authorise the Company to provide such additional workmen, and to make use of such materials all as the engineer may deem necessary, and to continue to employ such additional workmen for such length of time, and at such wages as the engineer shall think fit; and the payments thus to be made for the same by the Company, including the cost both of labour and material, shall be made and deducted out of the moneys which may then remain due to the contractors, or their foresaid, or which may at any time or times thereafter become due to them. And the Company shall, in the said event, be at liberty to take and use the whole materials, horses, engines, machinery, vessels, boats, barges, building tools, implements, and whole other plant of every description provided by the contractors for carrying on the works, and to provide such additional materials, horses, engines, machinery, vessels, boats, barges, building tools, implements, and other plant of every description, at the expense of the contractors, as may be requisite for proceeding with the same; and in case the balance then due to the contractors or their foresaids, or which may thereafter become due to them, shall be insufficient to cover the said payments and expenses, the contractors bind and oblige themselves and their foresaids, to pay the same to the Company on demand. But it is hereby provided and declared that the possession by the engineer of the power contained in this article shall not in any degree relieve the contractors and their foresaids of their obligations to proceed in the execution of and to complete the works with the required expedition: Or otherwise, if the contractors or their foresaids shall not continue to execute and advance the progress of the works, or any portion thereof, to the satisfaction of the engineer, or if before the completion of this contract, the contractors or their foresaids shall become bankrupt or insolvent, or compound, or propose to compound with their creditors, or carry on business under inspectors appointed on behalf of their creditors, then and in any of these cases the Company may, if they think fit, determine and put an end to this contract, so far as regards the future performance thereof, by or under the direction of the contractors or their foresaids, and forthwith give written notice to the contractors or their foresaids of such determination, and immediately on such notice being given all sums and penalties, if any shall have accrued for non-fulfilment of this contract, shall be forfeited to the Company; and all materials, horses, engines, machinery, vessels, boats, barges, building tools, implements, and whole other plant of every description provided by the contractors may in such a case be taken possession of by the Company; and the Company shall have full power to take the whole works out of the hands of the contractors or their foresaids, and to proceed with the said works, and to complete the same or to employ any other person or persons by contract or otherwise to complete them, and to take and use the materials, horses, engines, machinery, vessels, boats, barges, building tools, implements, and whole other plant of every description which may have been provided by the contractors for the construction of said works, or to provide such other materials, horses, engines, machinery, vessels, boats, barges, building tools, implements, and other plant whatsoever at their own expense, as may be necessary for proceeding therewith, and all extra payments and expenses thereby made or incurred by the Company shall be deducted out of the moneys that may then remain due to the contractors; and in case the said moneys shall be insufficient to cover the same, the contractors bind and oblige themselves and their foresaids to make payment thereof to the Company on demand; and as soon as convenient after the said determination of this contract the engineer shall ascertain and, in case of dispute, with the assistance of the arbiter fix finally and conclusively as to all parties the amount earned by and justly due to the contractors in respect of work done and materials provided; and the value of all materials, horses, engines, machinery, vessels, boats, barges, building tools, implements, and all other plant whatsoever seized and taken and in possession of the Company, and the amount and value of other claims, if any, of the contractors against the Company, of all which claims the contractors shall give notice in writing within twenty-one days after the said determination of the said contract, and the engineer shall credit the contractors in their accounts with the Company with such amounts, and the engineer shall ascertain the sums paid or advanced to the contractors by the Company, and the amount or value of all loss, costs, damages, and claims of the Company against the contractors, whether by reason of the determination of this contract, or the acts, neglects, or defaults of the contractors in reference to this contract or otherwise howsoever, and shall make such allowances and disallowances on both sides of such account as he the engineer, or in case of dispute as he the said arbiter, shall think reasonable, and he shall finally settle the balance of account due to or from the contractors, and it is hereby specially stipulated and agreed that the Company shall have a lien upon all materials as well as upon all horses, engines, machinery, vessels, boats, barges, building tools, implements, and other plant of every description as shall for the time being be brought or left on or near to the site of the said works hereby contracted for as a security for the completion of the said works and otherwise as a security for the due implement and fulfilment by the contractors and their foresaids of their part of this contract, and all such materials, horses, engines, machinery, vessels, boats, barges, building tools, implements, and other plant of every description, shall from the time of their being brought or left on or near the site of the said works, be held to be the property of, and belong to the Company, and shall not, without their consent in writing, be removed or taken away therefrom except in substitution for other materials and things of a similar kind, which shall be considered by the contractors necessary for the proper performance of the works, and they shall be entirely at the

risk of the contractors and their foresaids: Provided always, that upon the whole of the said works being completed as aforesaid, and after payment of all sums due by the contractors or their foresaids to the Company, including penalties if any, and others, the contractors bind and oblige themselves and their foresaids at their own expense, and with the consent of the Company as aforesaid, to remove so much of the said materials as have not been used upon the construction of the works, and also to remove the said plant, declaring with reference to the excavations necessary in erecting the said bridge that should the rock or permanent foundations in any case prove to be at a greater or less depth than is shown on drawing No. 2, all additional works or deductions caused thereby shall be estimated at the prices in said detailed estimate, and form additions to or deductions from the said sum of 217,099*l.* 18*s.* 6*d.* as the case may be: Declaring also that the material excavated from within the bottom circumference of the caissons as they are sunk down for the purpose of founding the piers shall not be thrown into the said river, but, except as to so much of the sand as shall be required by the contractors to be used with cement for the brickwork and stone work of the said piers, or otherwise in the construction of the bridge and works, shall, at the contractors and their foresaids' own expense, be removed in barges and deposited within the bulwark now being formed for reclaiming ground on the foreshore of the Tay, between the pier of the Ferry Harbour, Dundee, and Buckingham Point, and the material so deposited shall not be banked up to a greater height than four feet above high-water level of ordinary spring tides, and declaring also that all staging, scaffolding, or other obstruction to the navigation of the river shall be erected and removed by the contractors and their foresaids, in accordance with the necessary requirements of the public or local authorities in respect of the navigation of the said river, and that at the sole expense of the contractors and their foresaids, and the contractors bind and oblige themselves and their foresaids at their own expense to provide all lights; and light and watch all the works during the construction and until the perfect completion, except as aforesaid of the bridge, and also to erect lights in such positions as may by the Commissioners of the Northern Lights or the Marine Department of the Board of Trade be required for the guidance and protection of the navigation on the said river. And it is hereby provided and declared that the whole of the works in proximity to the Caledonian Railway shall be carried on by the contractors and their foresaids in such a manner as shall not interfere in any way with the traffic of that railway, and if the contractors or their foresaids shall do in the contrary, they shall be responsible for, and free and relieve the Company of all claims which may be made against them, and of all loss and damage which may be incurred thereby. Further, the contractors hereby bind and oblige themselves and their foresaids to provide at their own cost suitable policemen whenever such may be ordered by the engineer, or by any one or more of the magistrates of the district, as the Company or magistrate or magistrates may think necessary for the due preservation of the peace or protection of the property of the contractors, or that of the adjoining owners; and the contractors hereby further bind and oblige themselves and their foresaids at their own expense to provide and pay all compensation for any land they may require for temporary purposes, and to make good all damage to roads, whether public or private, or to the lands of private individuals arising from carting of materials, or from any other cause contingent upon the execution of the works, and to be responsible for and free and relieve the Company of all claims which may be made against the Company, and of all loss and damage which may be incurred thereby: And it is hereby expressly provided and declared that the care of the entire works of the bridge shall remain with the contractors and their foresaids until their completion, except as aforesaid, and the contractors and their foresaids shall be held responsible for all accidents thereto up to the time of such completion and for all defects therein, and shall be bound as they hereby bind and oblige themselves and their foresaids, at their own expense, to make good all damage to, and defects in, the said works, whether arising from bad or insufficient materials, bad workmanship, accidents, carelessness of the workmen employed, or from bad weather, or any other cause whatever, save and except any injuries to the works arising from the act of God, or of the Queen's enemies; and declaring that no certificate or approval by any officer of the Company, except the engineer aforesaid, of any works supposed to have been properly done, shall affect the *right* of the Company against the contractors and their foresaids, or be considered or held as at all conclusive as to the sufficiency of any works or materials. And the contractors hereby bind and oblige themselves and their foresaids, that from the commencement and during the progress of the work hereby contracted for, they shall at all times be present on the works, or, in their absence, they shall provide a competent representative, fully authorised to act in their behalf in all matters relating to this contract; and all instructions and notices given to such representative shall be deemed to be given to the contractors and their foresaids. And the contractors bind and oblige themselves and their foresaids not to assign or sublet, except with the consent of the Company, evidenced by the written authority and consent of their engineer, the contract hereby entered into, or any part thereof. And further it is hereby contracted and agreed that the contractors and their foresaids shall give every reasonable facility to the party or parties who shall contract for the construction of the railway or railways which shall adjoin the said bridge on both sides of the river as may be necessary to enable the said party or parties to execute and maintain the same as embraced under his or their contract or contracts, such accommodation being regulated and directed by the engineer, and no inconvenience, or alleged interruption arising therefrom, shall form any ground for claims of damages by the contractors against the Company, or extension of the time for finishing the work contained in this contract, unless the same shall occur for an unreasonable period, which, in case of dispute between the contractors and the said engineer, shall be decided by the said arbiter. And further declaring that the prices in the said detailed estimate shall be used by the engineer in regulating the monthly payments, and the price of any extra works, additions to, or deductions, exclusions, and dispensations from, or alterations, which may be made upon the works whenever the said detailed estimate contains a price applicable to the description of such extra work, or work so added, deducted, excluded, dispensed with or altered, and declaring that the prices in said detailed estimate shall include all permanent and temporary material, all labour, workmanship, scaffolding, staging, pumping machinery for sinking cylinders by pneumatic or other process, and all other machinery, vessels, boats, barges, carriage of materials, and all other plant whatsoever, and contingent expenses connected with the works to which such prices apply, and the cost of painting the ironwork shall be included in the price per ton for ironwork. *For which causes and on the other part* the Company bind and oblige themselves to make payment to the contractors and their foresaids of the sum of 217,099*l.* 18*s.* 6*d.* sterling, and of such further sum as may be fixed as aforesaid as the price or value of any extra work or additions which the contractors or their foresaids may be directed to perform, and shall perform in terms of the provisions herein-before contained, but, subject on the other hand, to the deductions of the price or value of such portions of the works hereby contracted for as may not be required, or may be omitted to be done, or may have been varied, altered, or dispensed with, or may have been performed by the Company, or others employed by them as aforesaid, in the events above described, all as herein-before provided for, which payments shall be made in manner following, that is to say, the Company bind and oblige themselves at the expiry of every month after the commencement of the said works to pay to the contractors, or their foresaids, the value of the actual quantity of the works which have been executed in the preceding month, as the said quantity shall be ascertained by net measurements to be made by the engineer, such value to be taken in all cases without any allowance for circular or face-work, notwithstanding any general or local custom to the contrary, and of all sums charged or claimed by the contractors, or their foresaids, and certified by the engineer as correct as aforesaid, and that all in manner following, viz., a sum equal to 90 per cent. of the said value as such value and amount shall be estimated and valued, and fixed by the certificate of the engineer who, in estimating the value and amount of the said work, shall take the prices set for the said detailed estimate, so far as the same are applicable thereto. But declaring that the measurements of works upon which the said instalments are struck shall not be patent to the contractors or their foresaids, nor founded upon by them in any way whatever, the said measurements being taken for the satisfaction and information of the engineer, and when the whole work hereby contracted for, including extra or additional work, shall have been completely finished to the reasonable satisfaction of the engineer or arbiter, and after he shall have made a report and granted a certificate to that effect, such certificate not to be withheld except on stated valid and substantial grounds, the Company bind and oblige themselves to pay to the contractors or their foresaids the balance of the said contract price, and extras, if any, which shall be due to them. And all the parties bind and oblige themselves and their foresaids to fulfil this contract to

each other in the whole heads, articles, and clauses thereof, and of the specification appended hereto. And they hereby submit and refer to the final sentence and decree arbitral of Thomas Elliot Harrison, Civil Engineer, London, whom failing John Hawkshaw, Civil Engineer, London, who shall not be disqualified by their or either of them being or becoming a shareholder or shareholders in the said Company, or by their accepting of any office or situation under the said Company, from acting as arbiters, under this submission in all disputes or differences which may arise between the several parties hereto, regarding the true intent and meaning of any of the provisions hereinbefore written, or any of the specifications hereto annexed, or as to the mode of carrying on the works, or the nature of the materials used therefor, or the claims of deduction, or otherwise, competent to the Company against the contractors, including the ascertainment and decerniture for the amount of liquidated and agreed on damages that may be due by the contractors to the Company under this contract for non-completion of the works within the contract time, or the claims for extra works, or otherwise, competent to the contractors against the Company, and generally all disputes and differences, claims, and accountings, by either party, in any way arising out of the execution of or failure to execute the works hereby contracted for, whether hereinbefore submitted or not, and whatever the said arbiters shall direct or decide by any decree, interim or final, pronounced by them, the said parties respectively bind and oblige themselves and their foresaids to execute and abide by. Declaring that this submission shall not fall by the lapse of year and day or by the death of any of the parties hereto, and that the said arbiter shall have full power to award the expenses (including the expenses and fees of himself and his clerk respectively) which may be incurred in all arbitrations between the parties, either in whole or in part, against such of them as he shall think fit. And it is hereby provided that in all cases in which any notice is to be given to the contractors under this contract it shall be sufficient if such notice be signed by the engineer or secretary of the Company, and addressed and given personally to the contractors, or left at their dwelling-house or place of business or last known dwelling place or place of business, or sent to them by registered letter, posted from one of the post offices in Edinburgh, addressed as aforesaid, and such notice shall be held and considered to be sufficient notice. Declaring that the affidavit of and entry in writing, in the ordinary book kept by him for entering postages or deliveries, of the person who may have left the said notice, or who may have put the same into the post office, shall be held to be legal evidence that the said notices have been properly served upon the said contractors, any law or practice to the contrary notwithstanding. And further, it is hereby declared that the word "contractors," or "contractor," used throughout the said specification and these presents, shall mean, and it is hereby declared to mean, the said Charles de Bergue and Charles de Bergue and Company; and the words "Company," or "Railway Company," the North British Railway Company; and the words "engineer," or "Company's engineer," Thomas Bouch, Esq., Civil Engineer, Edinburgh, the present engineer of the Company, or other the engineer of the Company for the time being. And it is hereby also expressly agreed between and by the said parties hereto, and the obligation of the said Company shall be considered in all respects to include it, that in the event of the said Company, after the signing of this contract, not giving to the said contractors, or their foresaids, possession of the land and approaches which they are empowered either permanently or temporarily to acquire, when thereunto from time to time required by the said contractors within 14 days after any such request, or throwing any obstacles in the way of, or otherwise preventing the said contractors or their foresaids from commencing or proceeding with the works referred to in this contract or in the specification hereunto annexed, then and in that case the time limited for the completion of the said works shall be extended to the full extent of the whole of the periods for which the said contractors or their foresaids shall be so delayed, and no penalties for non-completion by the said contractors shall be enforced or enforceable against them under the clauses herein for that purpose contained, in respect of the delay in the completion of the works thereby caused, but proper compensation for the loss and expense incurred by the said contractors or their foresaids in consequence thereof shall be paid by the said Company to the said contractors or their foresaids, the same to be settled in case of difference between the said contractors, and the said engineer by the said arbiter. Provided also, that in the event of any strike of workmen in the district or in any of the trades employed in the construction of the said bridge and approaches, or any injury or delay arising to the works in consequence of the act of God, or of the Queen's enemies, the time within which the said works are hereby agreed to be completed shall be extended for a period equivalent to the time for which the said works shall be delayed by such causes as aforesaid. And both parties consent to the registration hereof, and of the said specification and detailed estimate, and of the said decrees arbitral, interim, or final for preservation and execution. In witness whereof these presents, printed upon this and the five preceding pages, the word "eighteenth," on the tenth line counting from the top of page first hereof being written by William Henry Gribble Poland, clerk to Messieurs. Wilkins, Blyth, and Marsland, Solicitors, No. 10, St. Swithin's Lane, London, are sealed in duplicate with the common or corporate seal of the said North British Railway Company, and signed by John Walker, secretary of the said North British Railway Company, and delivered at London the 8th day of May, in the year 1871, before these witnesses, Thomas Peddie, of No. 78, George Street, Edinburgh, Civil Engineer, and Alexander Law, of No. 1, Register Place, Edinburgh, clerk in the solicitor's office of the said North British Railway Company, and are signed, sealed, and delivered, in duplicate, for and on behalf of the said Charles de Bergue and Charles de Bergue and Company, by the said Robert Amadeus Heath, their attorney, empowered in that behalf as aforesaid, at London, the said 8th day of May, in the year last above-mentioned, before these witnesses, the said William Henry Gribble Poland and Alexander Law: Declaring that the testing clause hereof, from and after the words "in witness whereof," is written by the said Alexander Law.

(Seal of the North British Railway Company.)

(Signed) J. WALKER, Secretary, N. B. Ry. Co.

Sealed with the common or corporate seal of the NORTH BRITISH RAILWAY COMPANY, and delivered this 8th day of May 1871, in the presence of

(Signed) THOMAS PEDDIE, of No. 78, George Street, Edinburgh, Civil Engineer, witness.
ALEXANDER LAW, of No. 1, Register Place, Edinburgh, clerk in the solicitor's office of the North British Railway Company, witness.

(Signed) P. P. C. DE BERGUE and P. P. C. DE BERGUE & Co.

ROBERT A. HEATH. (Seal.)

Signed, sealed, and delivered by the above-named CHARLES DE BERGUE, and CHARLES DE BERGUE and COMPANY, by ROBERT AMADEUS HEATH, attorney for the said CHARLES DE BERGUE, this 8th day of May 1871, in the presence of

(Signed) W. H. G. POLAND, witness, Clerk to Messrs. Wilkins, Blyth, and Marsland, solicitors, 10, St. Swithin's Lane, London.

ALEXANDER LAW, witness.

NORTH BRITISH RAILWAY.—TAY BRIDGE.

SPECIFICATION OF WORKS to be executed in the construction of the proposed Bridge for carrying Railway No. 2, authorised by the North British Railway (Tay Bridge and Railways) Act, 1870, over the River or Firth of Tay. The line of the proposed bridge will be the same as shown on the Parliamentary Plan of said Railway No. 2, commencing on the Fife bank of the Tay near Long Craig Point, and terminating on the Forfar side of the Tay, near Dundee, at the point known as *Magdalene or Buckingham Point*, the length being 3,440 yards, or thereabouts.

Description of Bridge.

The bridge is to be constructed for a single line of railway. The total number of spans will be 89. Commencing at the Fife side, there are—first 3 spans of 60 feet, then 2 spans of 80 feet, 22 spans of 120 feet, 14 spans of 200 feet, 18 spans of 120 feet, 25 spans of 66 feet, 1 span of 160 feet (on the safest), and 3 spans of 27 feet each. The eight central 200 feet spans to have a clear height of 88 feet

above the level of high-water, ordinary spring tides. The spans on either side of the said eight 200 feet spans will gradually decrease in height above high-water level as they approach the land; the gradient descending from the north end of those spans to the north shore at the rate of 1 in 73·56; and from the south end of those spans to the 80 feet spans at the rate of 1 in 353·68—the 80 feet spans being level, and the 60 feet spans rising therefrom with a gradient of 1 in 100.

The piers for the spans of 60, 80, 120, and 200 feet, and the land pier of the 27 feet spans, to be of brickwork, in cement; those for the 120 and 200 feet spans to be permanently encased in iron cylinders, up to the level of low-water. The piers for the 160 feet span to be cast iron cylinders, six feet diameter, filled in with brickwork. Those for the remainder of the spans to consist of three cast iron columns, braced together with malleable iron bracing. The abutment on the Fife side to be of stonework.

The superstructure to be of malleable iron girders and timberwork. The whole of the main girders to be on the lattice principle, except those for the 160 feet span, which are to be bow-string, and those for the 27 feet spans, which are to be plate. In the 200 feet and 160 feet spans, the roadway will be between the main girders, and these spans have plate cross girders. In the whole of the other spans the roadway will be on the top of the main girders, and the cross bearers will be of timber: timber way-beams and planking being laid the whole length of bridge.

Contract Drawings, &c.

The contract to which this specification refers will, with the exception of providing and laying the permanent rails and chairs, consist of all the works incidental to the perfect construction and completion of the bridge being executed to the entire satisfaction of the engineer, and in accordance with the drawings undermentioned, and numbered 1 to 28 inclusive, subject to any modifications (whether deductions, additions, or variations) that the engineer may deem necessary during the carrying out of the works. It will also include the finding and providing all material, permanent and temporary, as well as all labour, carriage of material, workmanship, machinery, vessels, boats, barges, &c. necessary to complete the bridge in the most workmanlike manner.

List of Drawings above referred to.

No. 1. General Plan and Longitudinal Section.
„ 2. General Plan and Elevation of Bridge.
„ 3. Details of Caisson for Piers for 200 feet spans.
„ 4. „ „ „ Nos. 17 to 26 and 42 to 49 inclusive, for 120 feet spans.
„ 5. „ „ „ Nos. 5 to 16 and 50 to 53 inclusive, for do.
„ 6. „ „ „ Nos. 54 to 57 inclusive.
„ 7. Elevation of Piers for 200 feet spans.
„ 8. „ „ for Piers, Nos. 17 to 26 and 42 to 49 inclusive, 120 feet spans.
„ 9. „ „ „ Nos. 5 to 16 and 50 to 53 inclusive, for do.
„ 10. „ „ for remaining 120 feet spans, viz., to 54 to 57 inclusive.
„ 11. Details of fixed and moveable bearings for 200 feet spans.
„ 12. Details of fixed and moveable bearings for 120 feet spans.
„ 13. Details of fixed and moveable bearings for 60 and 80 feet spans.
„ 14. Elevation of Pier for 60 and 80 feet spans.
„ 15. Detail of Pier at junction of 200 and 120 feet spans.
„ 16. „ „ „ 120 and 80 feet spans.
„ 17. Details of Cast-iron Piers, Nos. 58 to 69 inclusive.
„ 18. „ „ „ 70 to 77 inclusive.
„ 19. „ „ „ 78 to 81, and 83 to 88 inclusive.
„ 20. Diagram of Cast-iron Piers and bracing, for 66 and 27 feet spans.
„ 21. Elevation and Detail of Piers for 160 feet span.
„ 22. Details of Main and Cross Girders, &c., for 200 and 120 feet spans.
„ 23. „ Girders for 60 feet spans, and for 120 feet spans where not continuous.
„ 24. „ Girders for end spans 200 feet.
„ 25. „ Main and Cross Girders for 160 feet span.
„ 26. „ Girders for 80 feet and 27 feet spans.
„ 27. „ Girders for 66 feet spans.
„ 28. „ Handrail.

The contractor to uphold and keep the works correct in every particular according to these drawings or any other that may be supplied to him by the engineer from time to time, and to be held responsible for the accuracy of the work throughout the whole time occupied in constructing and completing the bridge. All poles, stakes, assistance, boats, &c. necessary for setting out, inspecting, and measuring the works shall be provided by the contractor.

Estimates.

In tendering for the works, contractors will be required to state for what gross sum they offer to undertake the execution of the whole of the works necessary to complete the bridge to the satisfaction of the engineer, and to accompany their tender with a detailed estimate of the same; and no tender will be received by the Company which is not accompanied by such detailed estimate. The prices set opposite to each description of work in the detailed estimate shall also apply to all deductions, additions, or variations, and shall include all permanent and temporary material, all labour, workmanship, scaffolding, staging, pumping, machinery for sinking cylinders by pneumatic or other process, and all other machinery, vessels, boats, barges, carriage of material, and all contingent expenses connected with the works to which such prices apply.

The contractor must also state in his tender the time within which he will undertake to have the bridge completed, after the date of the acceptance of his tender by the Company, under a penalty of £ per week for every week the completion is delayed beyond the time so stated.

Description of Work.

Excavations.

Borings have been made in the bed of the river along the intended line of the bridge, the position and results of which are marked on Drawings Nos. 1 and 2; contractors intending to offer may also inspect the Borer's journal giving the results of these borings.

All the piers for the 120 and 200 feet spans are to be founded at the depth shown on Drawing No. 2, or as otherwise directed by the engineer. Cylinders or caissons, of the description herein-after described, to be sunk in the bed of the river to the depth specified or required, for the purpose of founding these piers, and the material falling within the bottom circumference of these caissons to be excavated as they are sunk down. The material so excavated shall not be thrown into the river, but must be removed in barges and deposited within the bulwark now being formed for reclaiming ground on the foreshore of the Tay, between the pier of the Ferry Harbour, Dundee, and Buckingham Point. The material thus deposited not to be banked up to a greater height than four feet above the high-water level of ordinary spring tides. The cylinders forming the piers of the 160 feet span to be sunk to the depths shown on Drawing No. 21, or to such depth as will secure a perfectly sound and firm foundation. The material excavated for the foundations of the piers last mentioned to be deposited on the ground before described for depositing the material from the foundation of the other piers. The piers for 60 and 80 feet spans, and the land pier on the north side, to be founded in the ordinary manner. Those within high-water level to be carried down to the rock.

Should the depth to which the caissons are sunk be of a greater or less depth than is shown on the Drawing No. 2, all additional works or deductions caused thereby shall be estimated at the prices in the detailed estimates, and form additions or deductions to the estimate, as the case may be.

The whole of the surface of the rock within the bottom circumference of the bell mouth of such of the caissons as may be founded on rock must be carefully dressed to a uniform level, so that the caissons shall stand perfectly vertical, and also for providing a level bed for the brickwork to start from.

Caissons.

The permanent caissons or cylinders within which the brickwork of the piers of the 200 and 120 feet spans below low-water level is to be built, shall be sunk down to the depths shown on the general Drawing No. 2, or to such lesser or greater depth as the engineer shall direct, and they shall in all cases extend from the level of the foundations up to the level of low-water mark ordinary spring tides. Two caissons will be required for each pier, and when sunk the tops of them shall be level with each other and with the low-water line. Piers for the 200 feet spans to be sunk 15 feet 6 inches apart, and for the 120 feet spans 12 feet apart, except those numbered 54 to 57 inclusive, which are 10 feet apart, centre to centre.

The caissons to be of the form and dimensions shown on Drawings Nos. 3, 4, 5, 6. These drawings represent caissons of the average depth, required for the piers of the respective spans, taking the rock as indicated by the borings. The drawing of the caisson for the piers of the 200 feet span shows it to be sunk 17 feet below the bed of the river, and that for the caissons of the 120 feet spans at 16 feet. The greatest depth of the piers for the 200 feet spans below the bed of the river, as indicated by the borings, being 30 feet, and the least 10 feet; and for the 120 feet spans the greatest depth is 31 feet and the least 3 feet.

The bell-monthed portion at the bottom of *each caisson* to be formed of malleable iron plates ½ in. thick, shaped and rolled to the figure of the drawing, and have angle iron 3½ in. by 3½ in. fitted and riveted thereto for the purpose of bolting the plates together. *Bolts to be ¾ in. diameter, and* 8 in. centres. An angle iron 3½ in. by 3½ in. must also be fitted and riveted round the inside of the top edge of the bevelled plate, and have holes bored therein ¾ in. diameter and 8 in. centres, for the purpose of bolting the flange of the upper cylindrical portion of the caisson thereto.

The full height of the malleable bell-mouth in each caisson to be 5 feet, and for the piers of the 200 feet spans, the outside diameter of the *bottom*, and for a height of 2 feet, to be 15 feet; from this height, to the full height of 5 feet, to be tapered to the diameter of the upper cylindrical portion to be fixed thereto, viz., 13 feet 7⅛ inches outside diameter. *The bottom diameter* for the piers of the 120 feet spans, numbered 17 to 26 and 42 to 49 inclusive, to be 10 feet 6 inches for a height of 2 feet, and tapered to 9 feet 7⅛ inches at the full height, and for those piers numbered 5 to 16 and 50 to 53 inclusive, to be 9 feet 6 inches for a height of 2 feet and tapered to 8 feet 7⅛ inches at the full height. The bottom diameter for the remainder of the 120 feet spans, to be 9 feet 6 inches for a height of 2 feet, and tapered to 7 feet 7⅛ inches at the full height. The piers are numbered in Drawing No. 2.

The cylindrical portion of the caisson above the bell-mouth to be 13 feet 7⅛ inches outside diameter for the piers of the 200 feet spans; 9 feet 7⅛ inches in diameter for the piers of the 120 feet spans, numbered 17 to 26 and 42 to 49 inclusive; and for those piers numbered 5 to 16 and 50 to 53 inclusive, the diameter to be 8 feet 7⅛ inches; and 7 feet 7⅛ inches in diameter for the piers of the remainder of the 120 feet spans. This portion of the caissons to be of cast iron, cast in segments, having flanges inside for the purpose of being bolted together in the usual manner with screw-bolts. The metal in all cases to be 1 inch in thickness below the bed of the river, and bolts ¾ in. diameter, and between the bed of the river and low-water mark the metal to be ¾ of an inch in thickness, and bolts ¾ in. diameter. Bolt holes in flanges to be 8 in. centres. The segments at the top of the caisson to have the top flange cast on the outside for the purpose of bolting thereto the temporary cylinders, to be provided for sinking the caissons and building the piers up to high-water mark.

The whole of the joints in both the malleable and cast iron portions of the caissons, as well as the joining of the two, to be carefully fitted and bolted together, so that they may be made perfectly watertight. The joints to be planed, or left rough and made good with rope wheeze or iron rust, as the contractor may elect.

The contractor shall provide for temporary use in sinking the caissons and in building the piers up to the level of high-water mark, additional cylinders, which shall extend from the top of the permanent caissons to the level of high-water mark at least; which temporary cylinders may be of malleable or cast iron, as the contractor may prefer. These cylinders shall be of the same diameter as the permanent caissons, to which they are to be fixed, and form a continuation thereof. The flanges to be outside, and the whole of the joints to be made perfectly watertight, as in the caissons. These cylinders to be so fixed to the caissons, and to be of such make, strength, and workmanship as shall ensure the permanent work, for the execution of which they are to be provided, being carried out in the most perfect manner. When any one pier for which they have been used shall have been built up to high-water mark, they may be removed and similarly used for other piers, provided they have not been in any way damaged.

When the temporary cylinders have been detached from the caissons, the caissons shall be connected together at low-water level by a plate 4 feet in breadth, and bolted to the flanges thereof, as shown on drawing.

Cylinders for 160 Feet Spans.

The four cylinders forming the piers of the 160 feet span to be according to Drawing No. 21; to be placed 17 feet 6 inches apart on the square, and sunk to the depth shown, or to such other depth as shall be necessary to secure a firm foundation. They will be 6 feet outside diameter cast in 5 feet lengths, and extend up to the level of the lower member of main girders. The top or caps of the cylinders to be cast *separately, have mouldings as shown* on drawing, and a bearing formed for girders resting thereon. The thickness of the metal to be 1 inch, and the bolts for bolting together the 5 feet lengths of the cylinders to be ¾ *in. diameter and 6 in. centres. The joints to be* planed, carefully fitted, and be made perfectly watertight.

Piers for 66 and 27 Feet Spans.

Each pier for the 66 and 27 feet spans to be formed of three cast-iron columns braced together,—two being bearing columns for the main girders, and one a strut column. The bearing columns in each pier when in position to be 9 feet apart at the top, centre to centre. The one on the up river side of the centre line of bridge to be sunk vertical, and the strut column to be bolted to the top thereof, raking downwards therefrom with a batter of 1 in 3. The bearing column on the down river side of centre line to be a raking column having a batter of 1 in 8.

The diameter of the columns in the 12 piers nearest the 120 feet spans to be 1 foot 8 inches in diameter; the diameter of those in the next 8 piers, 1 foot 6 inches, and of the remainder, 1 foot 4 inches. The bottom lengths or portions extending below low-water level, and herein-after referred to as the piles of the columns, to be sunk to the depths shown on drawings. The piles to be of such length that, when sunk, their tops will, as near as possible, be level with low-water, or with the bed of the river where its level is above low water. The foot of the pile of each column to have an extended base or disc 3 feet 10 inches in diameter, having serrated feathers as shown on drawings. The piles to be sunk by means of a jet of water forced by steam pumps through a tube or pipe inserted in the inside and through the bottom of the pile, similar to the mode adopted in sinking the piles of the columns for the promenade piers at Southport in Lancashire and Portobello.

The flanges of each length of casting for the piles and columns to be turned on the face, and have 8 bolt holes 1½ in. diameter, accurately drilled therein to or through a gauge, so that any two flanges being applied to each other the bolt holes would be true and fair, the lengths may be properly fitted and bolted together. The lengths of the castings for columns to be 11 feet, with making-up pieces regulated as to length to suit the level of the piles when sunk, and the height of the respective piers. Snugs to be cast on the columns at the flanges, as shown for bolting and keying the bracing thereto.

The tops of the bearing columns to have moulding as on drawing, and the seat for the girders planed. The girder seat on raking column to be square to a vertical line. The tops of the strut columns to be formed to suit the circumference of the vertical bearing columns to which they are to be bolted, and must be accurately fitted thereto, and abut against the underside of the moulding.

The columns and piles forming each pier, when in permanent position, shall be square to the tangent of the curve of the bridge, range in line with each other, and be in exact position in relation to centre line, and suit the respective spans.

The columns to be braced as shown on drawing—the horizontal bracing being T iron 6 inches by 6 inches, and the diagonal bracing angle iron 3½ inches by 3½ inches. The bracing to be formed at the ends to enter between the snugs of the columns, and be secured thereto with bolts at one end and keyed into them with gibs and cottars at the other end.

The columns and bracing to have four coats of the best oil paint of such colour as the engineer may determine. The cost of painting to be included in the price per ton for the ironwork.

All proper guards, guides, rings, bolts, water-tight fixings, &c. requisite for the safe and expeditious sinking of the caissons and piles to be provided. Proper staging and appliances shall also be provided and erected for sinking the whole of the caissons and piles in their position, and the greatest care and skill shall be exercised by the contractor to ensure that the sinking is executed truly vertical, or in the case of the raking piles, at the proper angle, and in the exact line and position shown in the drawings.

All staging, scaffolding, or other obstruction to the navigation of the river shall be erected and removed in accordance with the necessary requirements of the river authorities.

The contractor shall also provide all lights, and light and watch all the works during the construction and until the perfect completion of the bridge, and erect lights in such positions as may be required by the Board of Trade or the

Commissioners of Northern Lights for the guidance and protection of the navigation of the river.

Cast Iron.

The iron of which the castings for the cylinders, piles, and columns are to be made shall be melted in a cupola furnace, and shall be of such mixture of pig that a bar cast therefrom, with a transverse section 2 inches by 1 inch, and placed edgeways on bearings 3 feet apart, will not break with a less weight on the centre than 3,000 lbs.; and bars of the above dimensions shall from time to time, on the demand of the engineer, be cast and tested, at the sole expense of the contractor, in the manner before mentioned. The whole of the castings shall be of the same mixture of metal, to be clean and smooth in the skin, free from all defects, and perfectly true to the dimension and figure of the drawings.

Brickwork.

The brickwork to be built inside the caissons, unless permitted by the engineer, shall not be commenced until the caissons have been accurately sunk in permanent position and securely brought to bearing on the foundations hereinbefore specified, or as may be directed by the engineer; so that each pair is perfectly vertical, the exact distance apart, and in the proper line of the bridge. The piers for the 60 and 80 feet spans, and the land pier on the north side, are rectangular in section, and will be founded in the ordinary way. The contractor to provide all temporary materials.

The whole of the brickwork—*i.e.*, from the foundations to the underside of the impost or girder bed—shall be of the very best description, both in respect of material and workmanship, and set in the best Portland cement.

The bricks used throughout in building the piers to be hard burnt, well-shapen, and of good average size, each brick to contain about 140 cubic inches. Where the piers become from 10 to 6 feet in diameter, the heading and stretching bricks must be made to radiate in the joints, and be moulded to form a portion of the circle on the face to suit the circumference of the piers.

All bricks immediately before being used must be thoroughly saturated with water, and all dust or dirt removed from their surface.

All bats brought upon the work to be at once rejected.

The brickwork shall be built in the caissons to their full diameter, except a space of about 2 inches all round, which shall be left and filled in with cement mixed in the proportion of 1 of cement to 1 of sand, and filled in when in a fluid state and well rammed with iron bars, so that the work from the foundation to the top of the caissons shall be perfectly water-tight.

The brickwork to be built within the temporary cylinders up to high-water mark shall be perfectly plumb, so that when these cylinders are removed, the brickwork will be found truly cylindrical, presenting no projections or uneven surface on the face.

The two columns of brickwork forming each pier having been brought up vertical to the level of high-water mark, shall be continued to the impost at the top of the piers with a batter or taper on each column suited to meet the top diameter of the respective piers. The columns of the 200 feet spans to be connected at high-water level, and of the 120 feet spans at low-water level, by a web or centre wall of brickwork, which wall shall be 2 feet thick, and continued up to the full height of the columns; and which shall be of the same description of work as the columns, and to be properly bonded therewith.

The whole of the brickwork required for the bridge shall be laid or set in cement when the cement is in a soft state, and the beds and joints to be thoroughly filled, and each course to be grouted, with cement. The thickness of the cement in the beds shall not exceed ¼ of an inch.

In the construction of the piers it shall be in the option of the engineer to substitute concrete for brickwork to such extent as he may direct; and such concrete, if so used, shall be composed of one part of Portland cement of the best quality, one part of sand, and three parts of gravel or broken stone.

Cement.

The whole of the cement for this work, and herein-before referred to, shall be Portland cement of the best quality, well burnt, and ground extremely fine, and weighing not less than 112 lbs. to the imperial (struck) bushel. It is to be brought on to the works in a state fit for use, and not used therein until it has been tested by taking samples out of at least every tenth (two bushel) sack. These samples to be gauged in moulds, and placing the cement at once in water, in which it is to remain for seven clear days, and testing it at the end of that time by the application of a weight or lever. All cement that shall not bear a tensile strain of 250 lbs. to the square inch of section shall be peremptorily rejected, and forthwith removed from the works.

The cement shall be used fresh made, in such small quantities as may be from time to time required, and to be well mixed with sand in the proportion of 1 of cement to 1 of sand; no water shall be added after it has once been mixed, and no cement to be used or mixed up with any other cement after it has once begun to set. It must also be carefully preserved from moisture until actually used.

The sand to be used in mixing with the cement to be very clean and sharp, entirely free from silt and earthy substances. The water used in mixing the cement and sand shall be clean salt water.

Stonework.

The stone required for the string-course of the piers of the 200 feet spans at the level of high water, and the impost or girder bed of all the brick piers, to be of the best and strongest description.

The belt of stonework for the piers of 200 feet spans, and shown on drawings at high-water level, to extend the full diameter of each column. Each stone to have as large a superficial content as possible, and the joints made to radiate and fit close the full distance of each bed. These stones to be in thickness not less than 2 feet 6 inches, and chisel dressed on all beds and joints, and moulded on the face to plan. The stone connecting the columns at this level to be of the same thickness and workmanship as the belt, and to extend into each column not less than 2 feet.

The impost or girder bed of all the brick piers to be also of stone chisel-dressed on beds and joints, and moulded as shown on drawing. The impost for the piers of the 200 and 120 feet spans to be formed of two stones well jointed and cramped together, and must be prepared on the top for the bed-plates which are to be let into the stone, holes to be also drilled for bolting down the girders and bed-plates where fixed bearings are adopted. Impost to be 18 in. in thickness.

The abutment on the Fife side to be built of stonework. The stone used to be of a good sound description, and set in good lime mortar.

The foundation to be carried down to the depth shown on drawing, or to such depth as will secure a firm foundation, and cut out to as near the size of the masonry as possible.

The foundation courses to be of selected flat-bedded stones 9 in. thick, and having an area of not less than 8 square feet, to be well fitted at the joints, and dressed top and bottom, so that they shall have a level and uniform surface to build upon.

The abutments to be built of square rubble, with common rubble backing of the following description.

The face work to be constructed of what is technically called square rubble—that is, stones containing not less than one third of a cubic foot, and to be carefully chisel-dressed on beds and joints, so as to make the closest possible work, but may be rock-faced, and there must be one through in every square yard of face-work so as to bind the backing and face-work effectually together. The backing to be of common rubble, well bonded to the face-work. Each stone shall be bedded in mortar when laid, and the whole brought to a level at every 18 inches in height, and then grouted.

The stones forming the corners to have an area of 4 superficial feet, and be 18 in. in thickness.

The impost coping and bearing blocks to be chisel-dressed ashlar, and of the dimensions shown on drawings.

Malleable Iron Girders.

The main girders for the whole of the spans to be constructed on the lattice principle, except those for the 160 feet span, which are to be bow-string, and the 27 feet spans, which are to be plate. Those for the 200 feet spans to be placed 14 feet 9 in. apart, and for the 160 feet span 17 feet 6 in. apart on the square, centre to centre, with cross girders of plate bolted to the bottom members. Those for the spans of 120, 80, 66, 60, and 27 feet to be placed 9 feet apart, centre to centre. The cross bearers for these spans to be of timber, and placed on the top members of the girders.

The girders for the 200 and 120 feet spans to be erected in sets of continuous girders of four spans each, with the exceptions shown on general elevation drawing, No. 2. The exceptions being where two girders are shown to be continuous in place of four.

Each set of continuous girders, of four spans each, shall be fixed to their centre pier, and have moveable bearings

on the other piers. It is to be observed that the dimensions of the first and fourth differ from the second and third girders in each set as shown. Between each of these girders there is to be a space of 3 inches—at the lower member a 3-inch cast-iron plate is to be inserted between the ends of the girders and fixed with bolts as shown—the top members of these girders to be connected with malleable iron plates; but before riveting these, the further end of each girder to be lifted up a height to be afterwards decided upon, in order to bring the continuity into action. Fixed bearings to be placed on the piers between the 200 and 120 feet spans, between the 120 and 66 feet spans, and between the 120 and 80 feet spans, and two girders of each adjacent span to be fixed thereto as shown. The girders for the 66 and 27 feet spans to be erected in sets of continuous girders of three spans each, having fixed bearings on both piers for centre girder of each set, and moveable bearings on the other piers.

The cross girders for the 200 and 160 feet spans to be plate girders and fixed to the bottom member.

The whole of the girders to be made in accordance with the respective drawings, the shape and dimensions to be carefully worked to, and the various parts well and accurately fitted together. The material and workmanship must be of the best description.

The wrought iron plates, bars, angle and T irons used in the construction of the girders for this bridge must be of such make and quality as shall be specially approved by the engineer, and of such strength that one square inch of sectional area shall support a tensile strain of 21 tons without breaking. Such bars as the engineer may select from time to time must be torn asunder in the presence of himself or his deputy, and if any break under a less tensile strain than 21 tons per square inch, as before mentioned, none of the plates, bars, &c. supplied by the same iron company shall be allowed to be used in these girders.

The girder work must be of the best description and more of the nature of engine work than that usually applied to bridges.

The rivet holes in the whole of the plates, bars, angle irons, &c. must be punched quite true and fair, and when the parts of the girders to be riveted together are fitted in position, the rivet holes must be perfectly true and fair with each other. All rivets to be made of C crown iron or such other as shall be approved by the engineer. The riveting must be executed in the most careful and workmanlike manner, care being taken that the rivets exactly fill the holes. The heads of the rivets to be finished off in the best style.

All bolts to be made of Lowmoor iron, or such other make as shall be specially sanctioned by the engineer, and to be neatly finished, head and nut, and not projecting more than half an inch through the nuts; to be carefully forged and screwed and made to fill the bolt holes.

All the ironwork to be painted four coats of the best oil paint, of such colour as the engineer may determine. The cost of painting to be included in the price per ton for ironwork.

Bed Plates and Expansion Rollers.

The bed plates, expansion rollers to be made in accordance with Drawing Nos. 11, 12, 13, and to be of cast iron of the best quality. The rollers to have frames of malleable iron. The bed plates of the fixed bearings to be bolted to the impost as shown.

Timber.

The timber to be used in the cross-bearers, way-beams, and planking to be of the best crown Memel or red pine, neatly jack-planed and dressed to the dimensions of the drawings.

The cross-beams, 12 inches by 9 inches, to be bolted to the top member of the girders with ¾-inch bolts.

The way-beams, 14 inches by 14 inches, to be bolted to the cross-girders by ¾-inch bolts. The way-beams, 14 inches by 7 inches, to be bolted to the cross-beams by ¾-inch bolts.

The planking to be 12 inches by 3 inches, and spiked to the cross-beams by spikes 7 inches long and ⅝ inch square at the head, and pointed. In the case of cross-girders, the planking to be fixed to the top flange by ½-inch bolts having dogheads.

Hand Railing.

The hand-railing to be according to drawing. To be 3 feet 6 inches high; having cast-iron standards placed 6 feet apart, formed of four feathers ½-inch in thickness, having heads made to receive gas-pipe for hand-rail. The gas-pipe to be 2½ inches outside diameter, and joinings to be made gas-tight. The standards to be bolted to the timber-work with ½-inch bolts.

General Conditions, &c.

1. The contractor shall complete the whole of the works herein specified, and such additional works as the engineer may direct to be executed, so as to render the bridge complete in every respect, except the laying of the permanent rails and chairs, within three years from the date of the acceptance of his tender by the Company.

The contractor shall be bound to give to the contractor for the railway in continuation of the bridge at either end free access and every reasonable facility to such portion of the bridge and ground as may be necessary to enable the latter to execute the work embraced in his contract, such access and accommodation being regulated and directed by the engineer; and no inconvenience or alleged inconvenience arising therefrom shall form any ground for claim of damages by the contractor against the company.

All matters and things required to be done or observed by the contractor in this specification, or his contract, deed, or agreement, shall be taken to be included in the amount for which the contractor undertakes to execute the work, although not specially named or included in the schedule of quantities, it is to be deemed conclusive that he based his estimate and prices upon the knowledge that all such matters and things must be fully done, observed, and borne by him, and at his own cost.

The works, and the mode of execution, are described at length in the specification of each particular work, and their forms and dimensions described in the accompanying drawings, which are referred to in this specification; but should any discrepancies exist between the measurement by the scale attached and the written dimensions, the latter are to be taken as correct. Anything contained in the drawings or specification shall be considered as contained in both.

The written dimensions are those by which the contractor shall make his estimate.

And wherever neither the drawings nor the specification contain any notice of minor parts, the intention to include which is nevertheless clearly to be inferred, and which parts are necessary for the completion and stability of the work, all such additional things are to be done and provided by the contractor, and are assumed to be included in the sum at which he contracts for the works; and wherever anything is directed to be done, or "to be provided if required," or words of similar import, it must be understood that everything so referred to will be considered as included in the tender.

The contractor will be bound strictly to comply with the provisions of the Act of Parliament obtained in session 1870, for making the bridge and railways in connexion therewith, and to satisfy all claims made against the Company, in consequence of any violation of, or departure from, the provisions of such Act by him in so far as it relates to the works in his contract.

Whenever the words "the Company" are used, those words shall mean throughout the whole of this specification the North British Railway Company, and similarly the words "the engineer" shall mean Thomas Bouch, Civil Engineer, Edinburgh.

The whole of the works in proximity to the Caledonian Railway are to be carried on in such a manner as shall not interfere in any way with the traffic of that railway.

The contractor shall, at his own cost, provide suitable policemen whenever it may be ordered by the engineer, or by any one or more of the magistrates of the district, as the company or magistrates or magistrate may think necessary for the due preservation of the peace or protection of the property of the contractor, or that of the adjoining owners.

The contractor to provide and pay all compensation for any land he may require for temporary purposes, and shall make good all damage to roads, whether public or private, or to the lands of private individuals, arising from carting of materials, or from any other cause contingent upon the execution of the works.

The care of the entire works of the bridge shall remain with the contractor until their completion, and he shall be held responsible for all accidents thereto, and shall make good all damage and defects to the said work, whether arising from bad or insufficient materials, bad workmanship, or any other cause whatever. No certificate or approval by any officer of the Company of any works supposed to have been properly done shall affect the right of the Company against the contractor, or be considered or held as at all conclusive as to the sufficiency of any works or materials.

The contractor shall from time to time make any alterations in the works which the engineer may think necessary,

whether by additions or deductions or deviations, or the omission of any works herein contracted for, or any part of them, or for new or extra works, and such alterations or additions shall not vacate this contract; the value of such alterations or additions shall be ascertained by admeasurement, and shall be added or deducted, as the case may be, at the prices set forth in his estimate. The contractor shall not in any case be considered as having any claim upon the Company for extra or additional payments for or on account of any such works, unless he can produce the authority in writing, signed by the Company's principal engineer, for such alterations or additions. The contractor shall not sub-let the whole or any part of the work herein contracted for without the previous sanction of the engineer in writing.

The engineer will provide from time to time the detail and other drawings of the various works.

The whole of the works are to be paid for according to the actual quantity executed, at the price opposite each description of work in the estimate. Net measurements to be taken in all cases, without any allowance for circular or face work, notwithstanding any general or local custom to the contrary.

The contractor shall, at all times, be present on the works; or, in his absence, he shall provide a competent representative, fully authorised to act in his behalf, in all matters relating to this contract.

The contractor shall, at all times, by day and night, provide and use, at his own cost, all overlookers, labour and materials, of every description whatever, that may be required for proceeding with, and completing the works in a workmanlike manner; and shall proceed therein at the rate of progress that may be from time to time required by the engineer.

It is to be understood that though certain descriptions and stipulations are repeated or implied in different parts of this specification, and in the contract to be entered into for the fulfilment of the same, it shall not be thence inferred that the remaining directions, descriptions, or amplifications are in any wise invalidated.

The contractor shall, at intervals of every month, furnish to the engineer a statement and account of all work done by him during that period; and of all amounts charged or claimed by him for additions, extras, damages, compensation, or other claims whatsoever, all which shall be investigated, valued, and settled by the engineer, according to the estimate prices, so far as the same is applicable thereto, and where not applicable according to the valuation and assessment of the said engineer; and the amount of such account, after being certified in writing by the engineer, shall be paid to the contractor after deducting 10 per cent. off the amount, which shall remain in the hands of the Company, till the completion of the works, when the whole of such drawback shall be paid to the contractor upon the certificate of the engineer that the contractor has performed this contract, and all his obligations arising therefrom satisfactorily, and that (taking into consideration all claims on both sides) such balance is justly due and owing to the contractor, and no moneys shall be deemed due, or payable on, or for any account to the contract, or under this contract or for any claims arising out of, or in any way incident thereto, or to the works, except the same be certified in writing by the engineer as aforesaid, and in all settlements of accounts between the contractor and company, it is hereby declared that no extra work, or alteration from the work specified, will be allowed by the Company to the contractor, unless the same shall have proceeded under the written authority of the engineer, and which authority shall be produced at the time of the settlement of accounts.

And should the engineer be at any time dissatisfied with the nature or mode of proceeding in, or the rate of progress of the work, or any part thereof, he shall have full power to procure and make use of all labour and materials which he may deem necessary, deducting the cost of such labour and material from the money that may be due, or become due to the contractor. But it is hereby expressly declared that the possession of this power by the engineer shall not, in any degree, relieve the contractor of his obligations to proceed in the execution of, and to complete the works with the required expedition.

In case the contractor shall not continue to execute and advance the progress of the works, or any part thereof, to the satisfaction of the engineer, or his deputy, or if before the completion of this contract, the contractor shall become bankrupt or insolvent, or compound or propose to compound with his creditors, or carry on business under inspectors appointed on behalf of creditors, then and in any of these cases, the Company may, if they think fit, determine this contract, so far as respects the future performance thereof, by or under direction of said contractor, and forthwith give notice to the said contractor of such determination, and immediately on such notice all penalties and sums for non-fulfilment of contract shall be forfeited to the said Company, and all materials, horses, engines, machinery, vessels, boats, buildings, tools, implements, and plant provided by the contractor shall also in such case become the property of and may be seized and taken by the Company. And as soon as convenient after the determination of the said contract as aforesaid, the engineer shall ascertain and fix finally and conclusively as to all parties, the amount earned by and justly due to the contractor in respect of work done and materials provided, and the value of all materials, horses, engines, machinery, vessels, boats, buildings, tools, implements, and plant, seized and taken and in possession of the said Company, and the amount and value of other claims, if any, of the said contractor against the Company, of all which claims the contractor shall give notice within six days of the determination of the said contract, and such engineer shall credit the contractor in his accounts with the Company with such amounts. And said engineer shall ascertain the sums paid or advanced to the contractor by the Company, and the amount and value of all loss, costs, damages, and claims of the Company against the contractor, whether by reason of the determination of the said contract, or the acts, neglects, or defaults of the said contractor, in reference to this contract or otherwise howsoever, and shall make such allowances and disallowances on both sides of such account as he, the said engineer, thinks reasonable, and he shall finally settle the balance of account due to or from the said contractor, and such balance so settled shall be final and recoverable by the party entitled thereto under this agreement.

It is to be distinctly understood that the engineer may, at all times, direct that there shall be made any deviations from the line of the bridge as now staked out, additional works, or any alterations in, additions to, or deductions from, any of the works herein described or referred to; all which shall be valued or estimated by the engineer, and by him certified in manner herein-before mentioned, and payable upon such certificate only, according to the prices in the contractor's estimate attached to his tender; and that the prices inserted in the estimate shall be considered as including all labourage, materials, and all contingent expenses connected with the works, to which such prices apply.

It is also to be distinctly understood that the whole of the works are in every particular to be executed to the entire satisfaction of the engineer.

All matters and questions as to the true intent and meaning of this specification, or as to what shall be considered carrying on the work in a proper, uniform, and regular manner, or as to the expense of any additional work, or deduction from that specified, or any alterations which may be more or less expensive than the work specified—all or any of which may be ordered by the directory or their engineer (and which they reserve power to do), or as to what constitutes extra or diminished work, or as to the proper maintenance of the works, or as to any other matter connected with this specification or contract to follow hereon—shall be decided by Thomas Elliot Harrison, Civil Engineer, London; whom failing, John Hawkshaw, Civil Engineer, London; and the decision, interim or final, of the said Thomas Elliot Harrison, whom failing, the said John Hawkshaw, shall be finally binding and conclusive on both parties.

No. 7.

Contract with Messrs. Hopkins, Gilkes, & Company, for the Building of the Tay Bridge, with Specification.

This Contract, entered into and executed by and between the North British Railway Company, incorporated by Act of Parliament, of the one part, and Hopkins, Gilkes, and Company, Limited, a Company established and incorporated under "The Companies' Act, 1862," and carrying on business as ironmasters, founders, and engineers, at Middlesboro'-on-Tees, of the other part:

Witnesseth that whereas by contract, dated the 8th day of May 1871, between the North British Railway Company (herein-after called "the Company"), and the now deceased Charles Louis Aimé de Bergue, therein called Charles de Bergue, of No. 10, Strand, in the county of Middlesex, civil engineer, and carrying on business there under the style and firm of Charles de Bergue and Company, and the said Charles de Bergue and Company, the said Charles de Bergue, and Charles de Bergue and Company undertook to construct a bridge over the River Tay, about 1¼ mile above the docks at Dundee, in connexion with the railways authorised by "The North British (Tay Bridge and Railways) Act, 1870," and that according to 28 plans, sections and drawings of the said bridge and works numbered as therein mentioned, and a specification of works annexed to the said contract and authenticated as relative thereto at the prices and upon the terms and conditions therein particularly set forth: And whereas the said Charles de Bergue and Company entered upon the construction of the said bridge, and since the death of the said Charles de Bergue upon the 10th April 1873, the works have been carried on by his executrixes: And whereas in the progress of the said works certain arrangements were made between the Company and the said Charles de Bergue and Company or the said executrixes of the said Charles de Bergue, for altering and modifying certain parts of the works of the said bridge as shown and described in certain additional drawings, and for increasing the contract prices of certain portions of the said works: And whereas the whole business, property, contracts and rights of the said Charles de Bergue and Company, including the contract for the aforesaid bridge over the Tay, have been transferred to De Bergue and Company Limited, a Company established and incorporated under "The Companies' Act, 1862": And whereas the Company have agreed with De Bergue and Company Limited to put an end to the said contract for the construction of the said bridge over the Tay, as at the 1st day of May last: And whereas the said Hopkins, Gilkes, and Company Limited (herein-after called the contractors) have agreed with the Company to take up the aforesaid contract as at the 1st of May last, and from thence to carry on and complete the whole works remaining to be executed under the same upon the terms and conditions under written: And whereas the contractors have arranged with the Company and the said De Bergue and Company Limited, to take over the whole unapplied material and plant at the works of the said bridge according to a valuation thereof to be made by John Anderson, Civil Engineer, Middlesboro'-on-Tees: And whereas the joint committee acting under the agreement between the Company and the subscribers to the Tay Bridge undertaking have given their sanction and approval to the said arrangements as testified by the endorsement hereon under the hand of their secretary: Therefore the said parties have agreed and bind and oblige themselves with and to each other as follows: That is to say, the contractors hereby bind and oblige themselves and their executors, administrators and successors, all conjunctly and severally to take over and pay the Company for the whole materials upon the ground not permanently applied in the structure of the said bridge as at the 1st day of May last, and also the materials delivered since and including that date, and prior to their entering into actual possession, including the inside malleable iron caissons and additional bracings for girders assigned to the Company under their agreement with the said De Bergue and Company Limited according to the valuation to be made as aforesaid and all as adjusted and settled in so far as relates to the quantity of such materials by the engineer of the Company. And the contractors bind and oblige themselves and their foresaids to pay or account for to the Company the value of the whole of the said materials by periodical instalments, as such materials are progressively incorporated with the works, or are otherwise applied or disposed of by the contractors, and the quantity of such materials so used or disposed of shall be adjusted and fixed by the engineer of the Company and stated in the monthly measurements to be made by him: And further the contractors bind themselves to repay to the Company all sums of money expended by the said De Bergue and Company Limited for labour performed and materials used in the construction of the works since the 30th day of April last: And the contractors also bind themselves and their foresaids to pay to the Company the value of the whole plant, buildings, jetties, steamers, barges, boats, machinery, and other general plant, on the said River Tay, or the banks thereof, at the bridge works, engaged, erected, or employed by the said former contractors in carrying out the said contract according to the valuation thereof to be made as aforesaid, and that by granting bills for the amount of such value, including interest, payable to the Company at negotiable dates: And the contractors further bind and oblige themselves that they shall forthwith enter upon the said works, and thereupon they shall and will well and substantially, and in a good, efficient, lasting, and neat and workmanlike manner, and to the entire satisfaction of the engineer, and of the arbiters herein-after named, both as regards the materials used and the mode of their use, make, execute, and completely finish the said bridge, with all works incidental to the perfect construction and completion of the same, including the restoration of the work erected by the former contractors, which has failed through bad foundations, and also including the finding and providing all material permanent and temporary as well as all labour, carriage of material, workmanship, machinery, vessels, boats, barges, buildings, tools, implements, and other plant whatsoever necessary for setting out, constructing, and completing the said bridge and works incidental thereto as aforesaid (excepting the providing and laying the permanent rails and chairs), and that in terms of, and in the manner described in the specification and according to the plans, sections, and drawings, all subscribed by the said parties as relative hereto, or according to such other altered or explanatory plans, sections, or drawings as may from time to time be furnished to them by the Company's engineer, declaring that the said specification, in so far as not herein expressly altered, shall form an integral part of these presents, and the contractors bind and oblige themselves and their foresaids to abide by and implement the same, and such other orders and instructions as may from time to time be given by the engineer for the purpose, of carrying the whole of the works of the said bridge and works, incidental thereto as aforesaid, or any alterations thereof or additions thereto or deductions therefrom into effect. Declaring also that though certain descriptions and stipulations may be repeated in different parts of the said specification, and in this contract it shall not thence be inferred that the remaining directions, descriptions, or amplifications are in anywise invalidated. Declaring also that the engineer shall have power at all times to direct that there shall be made any deviations from the line of the bridge as staked out and delineated upon the foresaid plans, sections, and drawings, additional works, or any alterations in addition to or deductions from any of the works herein or in the said specification described or referred to, provided the same shall be within the powers conferred by the said Act, and the Acts incorporated therewith, without vitiating this contract or affecting the prices in the said schedule of prices annexed and subscribed as relative hereto. And it is hereby further specially provided and declared that the contractors shall, at intervals of every month from the commencement of the works to be executed by them under this contract, furnish to the engineer a statement and account of all work done by the contractors during that period, and of all amounts charged or claimed by them for extra or unspecified work, damages, compensation, or other claims whatsoever, the whole of which statements and accounts and claims shall be investigated, valued, and settled by the engineer, according to the prices in the said schedule of prices, so far as the same are applicable thereto, and where the same are not applicable thereto according to the valuation and assessment of the engineer, or, in the event of dispute, according to the valuation and assessment of the arbiter after named, and the amount of the said account for the said work and claims on the part of the contractors shall, after the amount thereof has been certified in writing as correct by the engineer, be paid to the contractors, after deducting 10 per cent. thereof, until the 10 per cent. thereof shall amount to 10,000*l.*, which shall remain in the hands of the Company till the completion of the whole works, and upon the completion of the whole works the whole of the said deduction of 10,000*l.* shall be paid to the contractors, or their foresaids, upon the certificate of

the engineer that the contractors and their foresaids have performed their part of the contract, and the whole obligations incumbent on them under the same, to the satisfaction of the engineer; and upon the further certificate of the engineer that, after taking into consideration the mutual obligations and claims of the Company and the contractors, the amount of such deduction is justly due and owing to the contractors, or their foresaids; and it is further agreed that no moneys shall be deemed due or payable to the contractors or their foresaids in respect of any account for work or claims under this contract, or in reference thereto, in any way except the same be certified in writing as correct by the engineer as aforesaid: Such certificate not to be withheld by the engineer when due and applied for by the said contractors, except on stated valid and substantial grounds. And in all settlements of accounts between the contractors or their foresaids and the Company, it is hereby agreed and provided that no payment for extra or unspecified work or alteration or deviation from the works specified in the said specification, will be allowed by the Company to the contractors or their foresaids, unless the same shall have been done under the written authority of the said engineer or his authorised agent, or by oral directions given to the contractors or their clerk of the works by the said engineer himself, and which authority shall be produced and oral directions proved at the time of the settlement of the account between the contractors or their foresaids and the Company, otherwise the contractors or their foresaids shall have no claim for the said extra work or work caused by said alteration or deviation. And it is hereby agreed that all extra or unspecified works that may be done under this contract shall be carried out in like manner with the specified works, in terms of the said specification, declaring that should any small discrepancies exist between the measurement by the scale attached to the said plans, sections, and drawings and the written dimensions in the said specification, plans, sections, and drawings the written dimensions shall be taken as correct. And it is further agreed that wherever neither the said plans, sections, and drawings nor the said specification contain any notice of minor parts, the intention to include which is clearly to be inferred and which parts are necessary for the completion and stability of the works, all such additional things are to be done and provided by the contractors and their foresaids and are assumed to be included and covered by the prices for specified work contained in the said schedule of prices, at which they contract for the works shown upon said plans, sections, and drawings, and specified in such specification; the true intent and meaning of this contract being, that whether the same be specially set forth and expressed, or not, herein, or in the said specification, or upon the said plans, sections, and drawings, the contractors and their foresaids shall, unless where it is herein expressly provided to the contrary, provide and furnish, without any extra price or compensation therefor, all the materials and labour (excepting the providing and laying the permanent rails and chairs which shall be done by the Company) requisite for the construction of the said bridge and the whole works incidental to the perfect construction and completion of the same, and that in all respects in an efficient and workmanlike manner and to the reasonable satisfaction of the Company's engineer. And it is hereby provided and declared, that the contractors and their foresaids shall be at all expense and risk of setting out the works from time to time and shall allow the engineer or superintendent under him to have any workmen or labourers and to furnish him with all such poles, stakes, boats, and other assistance as he may reasonably require for the purpose of examining or testing the correctness of the work whilst being set out, proceeded with or as executed, and also shall as provided in the said specification test the materials which are therein required to be tested, and that all without any charge being made for the same, and farther the contractors bind and oblige themselves and their foresaids, that the works yet to be done shall be commenced without delay after the signing of this contract, and the said works shall be carried on so that the whole works specified in said specification and shown upon said plans, sections, and drawings, and such additional works and alterations as the engineer may direct to be executed as aforesaid shall be finished, and the said bridge completed in every respect (the Company only supplying and laying thereon the permanent rails and chairs) within two years from the 11th day of November next to the end and effect of the said bridge being opened within the said period with the sanction and approval of the Board of Trade or their inspecting officer. And it is hereby specially agreed and provided that the works shall be commenced and carried on at such points, parts, and places as shall be directed and appointed by the Company's engineer. And it is hereby specially conditioned and declared, that if the contractors or their foresaids shall not commence the said works within the period beforementioned, or shall not uniformly or regularly carry on the same to the reasonable satisfaction of the Company or their engineer, or if it shall appear at any time or from time to time to the Company that a sufficient number of men or material are not employed or used by the contractors in the execution of the works hereby contracted for, or that otherwise the work is not proceeding at such a rate as to ensure the completion of the whole works within the time above specified, or if the engineer shall at any time be otherwise reasonably dissatisfied with the nature or mode of proceeding in the work, or if the contractors shall not adhere to and implement the conditions herein and in the said specification contained, or shall not comply with the orders and directions to be given from time to time by the Company's engineer as aforesaid, or shall from any cause whatever be prevented from, or delayed in proceeding with, or completing the said works according to this contract, except as herein-after mentioned, it shall be lawful to the Company, as often as any such event shall happen, by a written notice, to require the contractors to commence or proceed with the said works, or to provide or employ such additional workmen or material, and for such length of time, and to comply with such orders as the case may be; and in case the contractors shall not, within fourteen days, conform to said notice, or employ such workmen, or provide such material, or comply with such orders as may be so given, it shall be lawful to, and in the power of the Company, to call upon the arbiter herein-after named and appointed, to authorise them; and the said arbiter may thereupon authorise the Company to provide such additional workmen, and to make use of such materials all as the engineer may deem necessary, and to continue to employ such additional workmen for such length of time and at such wages as the engineer shall think fit; and the payments thus to be made for the same by the Company, including the cost both of labour and material, shall be made and deducted out of the moneys which may then remain due to the contractors, or their foresaids, or which may at any time or times thereafter become due to them. And the Company shall, in the said event, be at liberty to take and use the whole materials, horses, engines, machinery, vessels, boats, barges, building tools, implements, and whole other plant of every description provided by the contractors for carrying on the works, and to provide such additional materials, horses, engines, machinery, vessels, boats, barges, building tools, implements, and other plant of every description, at the expense of the contractors, as may be requisite for proceeding with the same; and in case the balance then due to the contractors or their foresaids, or which may thereafter become due to them, shall be insufficient to cover the said payments and expenses, the contractors bind and oblige themselves and their foresaids, to pay the same to the Company on demand. But it is hereby provided and declared, that the possession by the engineer of the power contained in this article, shall not in any degree relieve the contractors and their foresaids of their obligations to proceed in the execution of, and to complete the works with the required expedition: Or otherwise, if the contractors or their foresaids shall not continue to execute and advance the progress of the works, or any portion thereof, to the satisfaction of the engineer, or if before the completion of this contract, the contractors or their foresaids shall become bankrupt or insolvent, or compound, or propose to compound with their creditors, or carry on business under inspectors appointed on behalf of their creditors, then and in any of these cases the Company may, if they think fit, determine and put an end to this contract, so far as regards the future performance thereof, by or under the direction of the contractors or their foresaids, and forthwith give written notice to the contractors or their foresaids of such determination, and immediately on such notice being given all sums of money due and unpaid to the contractors shall be forfeited to the Company; and all materials, horses, engines, machinery, vessels, boats, barges, building tools, implements, and whole other plant of every description provided by the contractors may, in such a case, be taken possession of by the Company; and the Company shall have full power to take the whole works out of the hands of the contractors or their foresaids, and to proceed with the said works, and to complete the same or to employ any other person or persons by contract or otherwise to complete them, and to take and use the materials, horses, engines, machinery, vessels, boats, barges, building tools, implements, and whole other plant of every description which may have been provided by the contractors for the construction of said works, or to provide such other materials, horses, engines, machinery, vessels, boats, barges,

building tools, implements, and other plant whatsoever at their own expense, as may be necessary for proceeding therewith, and all extra payments and expenses thereby made or incurred by the Company shall be deducted out of the moneys that may then remain due to the contractors; and in case the said moneys shall be insufficient to cover the same, the contractors bind and oblige themselves and their foresaids to make payment thereof to the Company on demand; and as soon as convenient after the said determination of this contract the engineer shall ascertain and, in case of dispute, with the assistance of the arbiter fix finally and conclusively as to all parties the amount earned by and justly due to the contractors in respect of work done and materials provided; and the value of all materials, horses, engines, machinery, vessels, boats, barges, building tools, implements, and all other plant whatsoever seized and taken and in possession of the Company, and the amount and value of other claims, if any, of the contractors against the Company, of all which claims the contractors shall give notice in writing within 21 days after the said determination of the said contract, and the engineer shall credit the contractors in their accounts with the Company with such amounts, and the engineer shall ascertain the sums paid or advanced to the contractors by the Company, and the amount or value of all loss, costs, damages, and claims of the Company against the contractors, whether by reason of the determination of this contract, or the acts neglects or defaults of the contractors in reference to this contract or otherwise howsoever, and shall make such allowances and disallowances on both sides of such account as he the engineer, or in case of dispute as he the said arbiter, shall think reasonable, and he shall finally settle the balance of account due to or from the contractors; and it is hereby specially stipulated and agreed that the Company shall have a lien upon all materials as well as upon all horses, engines, machinery, vessels, boats, barges, building tools, implements, and other plant of every description as shall for the time being be brought or left on or near to the site of the said works hereby contracted for as a security for the completion of the said works and otherwise as a security for the due implement and fulfilment by the contractors and their foresaids of their part of this contract, and all such materials, horses, engines, machinery, vessels, boats, barges, building tools, implements, and other plant of every description, shall from the time of their being brought or left on or near the site of the said works, be held to be the property of, and belong to the Company, and shall not, without their consent in writing, be removed or taken away therefrom except in substitution for other materials and things of a similar kind, which shall be considered by the contractors necessary for the proper performance of the works, and they shall be entirely at the risk of the contractors and their foresaids: Provided always that upon the whole of the said works being completed as aforesaid, and after payment of all sums due by the contractors or their foresaids to the Company, including penalties if any and others, the contractors bind and oblige themselves and their foresaids at their own expense, and with the consent of the Company as aforesaid, to remove so much of the said materials as have not been used upon the construction of the works, and also to remove the said plant, and declaring also that all staging, scaffolding or other obstruction to the navigation of the river shall be erected and removed by the contractors and their foresaids, in accordance with the necessary requirements of the public or local authorities in respect of the navigation of the said river, and that at the sole expense of the contractors and their foresaids, and the contractors bind and oblige themselves and their foresaids at their own expense to provide all lights; and light, and watch all the works during the construction and until the perfect completion except as aforesaid of the bridge, and also to erect lights in such positions as may by the Commissioners of the Northern Lights or the Marine Department of the Board of Trade be required for the guidance and protection of the navigation on the said river. And it is hereby provided and declared that the whole of the works in proximity to the Caledonian Railway shall be carried on by the contractors and their foresaids in such a manner as shall not interfere in any way with the traffic of that railway, and if the contractors or their foresaids shall do in the contrary, they shall be responsible for, and free and relieve the Company of all claims which may be made against them, and of all loss and damage which may be incurred thereby. Further the contractors hereby bind and oblige themselves and their foresaids to provide at their own cost suitable policemen whenever such may be ordered by the engineer, or by any one or more of the magistrates of the district, as the Company or magistrate or magistrates may think necessary for the due preservation of the peace or protection of the property of the contractors, or that of the adjoining owners; and the contractors hereby further bind and oblige themselves and their foresaids at their own expense to provide and pay all compensation for any land they may require for temporary purposes, other than the land already taken up for such purposes by the Company, and to make good all damage to roads, whether public or private, or to the lands of private individuals arising from carting of materials, or from any other cause contingent upon the execution of the works, and to be responsible for and free and relieve the Company of all claims which may be made against the Company, and of all loss and damage which may be incurred thereby: And it is hereby expressly provided and declared that the care of the entire works of the bridge shall remain with the contractors and their foresaids until their completion, except as aforesaid, and the contractors and their foresaids shall be held responsible for all accidents thereto up to the time of such completion and for all defects therein, and shall be bound as they hereby bind and oblige themselves and their foresaids, at their own expense to make good all damage to, and defects in, the said works, whether arising from bad or insufficient materials, bad workmanship, accidents, or carelessness of the workmen employed. But the contractors shall not be responsible for any injuries to the works arising from the act of God, or of the Queen's enemies; and declaring that no certificate or approval by any officer of the Company, except the engineer aforesaid, of any works supposed to have been properly done, shall affect the right of the Company against the contractors and their foresaids, or be considered or held as at all conclusive as to the sufficiency of any works or materials. And the contractors hereby bind and oblige themselves and their foresaids, that from the commencement and during the progress of the work hereby contracted for, they shall at all times be present on the works, or, in their absence, they shall provide a competent representative, fully authorised to act in their behalf in all matters relating to this contract; and all instructions and notices given to such representatives shall be deemed to be given to the contractors and their foresaids. And the contractors bind and oblige themselves and their foresaids not to assign or sublet, except with the consent of the Company, evidenced by the written authority and consent of their engineer, the contract hereby entered into, or any part thereof. And, further, it is hereby contracted and agreed that the contractors and their foresaids shall give every reasonable facility to the party or parties who shall contract for the construction of the railway or railways which shall adjoin the said bridge on both sides of the river as may be necessary to enable the said party or parties to execute and maintain the same as embraced under his or their contract or contracts, such accommodation being regulated and directed by the engineer, and no inconvenience, or alleged interruption arising therefrom, shall form any ground for claims of damages by the contractors against the Company, or extension of the time for finishing the work contained in this contract, unless the same shall occur for an unreasonable period, which, in case of dispute between the contractors and the said engineer, shall be decided by the said arbiter. *For which causes and on the other part* the Company bind and oblige themselves to make payment to the contractors and their foresaids for and in respect of the works of the said bridge hereby contracted for and actually executed by them according to the said schedule of prices hereunto annexed, so far as the same are applicable thereto, and when the same are not applicable thereto, according to the valuation and assessment of the engineer or the arbiter herein-after appointed, which payment shall be made in manner following, that is to say, the Company bind and oblige themselves at the expiry of every month after the commencement of the said works to pay to the contractors, or their foresaids, the value of the actual quantity of the works which have been executed in the preceding month, as the said quantity shall be ascertained by net measurements to be made or weight ascertained by the engineer, such value to be taken in all cases without any allowance for circular or face work, notwithstanding any general or local custom to the contrary, and of all sums charged or claimed by the contractors, or their foresaids, and certified by the engineer as correct as aforesaid, and that all in manner following, viz., a sum equal to 90 per cent. of the said value as such value and amount shall be estimated, and valued, and fixed by the certificate of the engineer who, in estimating the value and amount of the said work shall take the prices set forth in the schedule of prices so far as the same are applicable thereto, and when such prices are not applicable then in manner aforesaid, and after the sums retained by the Company shall amount to 10,000*l.* as aforesaid, the Company shall at the expiration of each month pay to the contractors the full amount of the value of the work done in that month

valued and fixed as aforesaid: But declaring that the measurements of works upon which the said instalments are struck shall not be patent to the contractors or their foresaids, nor founded upon by them in any way whatever, the said measurements being taken for the satisfaction and information of the engineer, and when the whole work hereby contracted for, including extra or additional work, shall have been completely finished to the reasonable satisfaction of the engineer or arbiter, and after he shall have made a final statement of the price due to the contractors for the whole works as completed, estimated, valued, and fixed in manner aforesaid, and granted a certificate to that effect, such certificate not to be withheld except on stated valid and substantial grounds, the Company bind and oblige themselves to pay to the contractors or their foresaids the balance brought out in their favour in the said final statement, and extras, if any, which shall be due to them. And all the parties bind and oblige themselves and their foresaids to fulfil this contract to each other in the whole heads, articles, and clauses thereof, and of the specification appended hereto. And they hereby submit and refer to the final sentence and decree arbitral of Thomas Elliot Harrison, Civil Engineer, London, whom failing, Sir John Hawkshaw, Civil Engineer, London, who shall not be disqualified by their or either of them being or becoming a shareholder or shareholders in the said Company, or by their accepting of any office or situation under the said Company, from acting as arbiters, under this submission in all disputes or differences which may arise between the several parties hereto, regarding the true intent and meaning of any of the provisions herein-before written, or of the specifications hereto annexed, or as to the mode of carrying on the works, or the nature of the materials used therefor, or the claims competent to the Company against the contractors, or the claims for extra or unspecified works, or otherwise, competent to the contractors against the Company, and generally all disputes and differences, claims, and accountings, by either party, in any way arising out of the execution of or failure to execute the works hereby contracted for, whether herein-before submitted or not, and whatever the said arbiters shall direct or decide by any decree, interim or final, pronounced by them, the said parties respectively bind and oblige themselves and their foresaids to execute and abide by. Declaring that this submission shall not fall by the lapse of year and day or by the death of any of the parties hereto, and that the said arbiter shall have full power to award the expenses (including the expenses and fees of himself and his clerk respectively) which may be incurred in all arbitrations between the parties, either in whole or in part, against such of them as he shall think fit. And it is hereby provided that in all cases in which any notice is to be given to the contractors under this contract it shall be sufficient if such notice be signed by the engineer or secretary of the Company, and addressed and given personally to the contractors, or left at their dwelling-house or place of business or last known dwelling place or place of business, or sent to them by registered letter, posted from one of the post offices in Edinburgh, addressed as aforesaid, and such notice shall be held and considered to be sufficient notice. Declaring that the affidavit of and entry in writing, in the ordinary book kept by him for entering postages or deliveries, of the person who may have left the said notice, or who may have put the same into the post office, shall be held to be legal evidence that the said notices have been properly served upon the said contractors, any law or practice to the contrary notwithstanding. And further, it it is hereby declared that the word "contractors," or "contractor," used throughout the said specification and these presents, shall mean, and it is hereby declared to mean, the said Hopkins, Gilkes, and Company, Limited; and the words "Company," or "Railway Company," the North British Railway Company; and the words "engineer," or "Company's engineer," Thomas Bouch, Esq., Civil Engineer, Edinburgh, the present engineer of the Company, or the engineer of the Company for the time being. And it is hereby also expressly agreed between and by the said parties hereto, and the obligation of the said Company shall be considered in all respects to include it, that in the event of the said Company, after the signing of this contract, not giving to the said contractors, or their foresaids, possession of the land and approaches which they are empowered either permanently or temporarily to acquire, when thereunto from time to time required by the said contractors within 14 days after any such request, or throwing any obstacles in the way of, or otherwise preventing the said contractors or their foresaids from commencing or proceeding with the works referred to in this contract or in the specification hereunto annexed, then and in that case the time limited for the completion of the said works shall be extended to the full extent of the whole of the periods for which the said contractors or their foresaids shall be so delayed. Provided also, that in the event of any strike of workmen in the district or in any of the trades employed in the construction of the said bridge and approaches, or any injury or delay arising to the works in consequence of the act of God, or of the Queen's enemies, the time within which the said works are hereby agreed to be completed shall be extended for a period equivalent to the time for which the said works shall be delayed by such causes as aforesaid, and such extension of time, in the event of difference, shall in all cases be regulated and fixed by the arbiter herein-before appointed. And both parties consent to the registration hereof, and of the said specification and schedule of prices, and of the said decrees arbitral, interim, or final for preservation and execution. In witness whereof these presents, printed upon this and the four preceding pages, are subscribed by and sealed with the common seal of said Hopkins, Gilkes, and Company, Limited (the signature of the said firm being adhibited by Edgar Gilkes, one of the managing partners of that Company), at Middlesboro'-on-Tees, the 26th day of June, in year 1874, in presence of John Tate, accountant to the said Company Limited, and Thomas Balfour, clerk to Adam Johnstone, solicitor to the said North British Railway Company, and residing in Edinburgh. And are also sealed with the common seal of the said North British Railway Company, at London the 27th day of the said month of June and year last above-mentioned, in presence of the said Adam Johnstone and the said Thomas Balfour. And are also subscribed by George Harrison, merchant, Edinburgh, and William Muir, merchant, Leith, two of the directors of the said North British Railway Company at Edinburgh, the 6th day of July in the year last above-mentioned, before these witnesses James Fergusson and Robert Jackson, both clerks in the head office of the North British Railway Company, Edinburgh. Declaring that this testing clause is written by the said Thomas Balfour.

(Signed) GEO. HARRISON, Director.
WILLIAM MUIR, Director.
(Seal of North British Railway Company.)

(Signed) J. FERGUSSON, witness.
R. JACKSON, witness.

Sealed with the common or corporate seal of the North British Railway Company, and delivered this 27th day of June 1874, in presence of

(Signed) AD. JOHNSTONE, Solicitor to the North British Railway Company, witness.
THO. BALFOUR, Clerk to the said Adam Johnstone, witness.

(Signed) HOPKINS, GILKES, & Co., LIMITED.
EDGAR GILKES.
(Seal of Hopkins, Gilkes, & Co., Limited.)

Sealed with the common seal of Hopkins, Gilkes, & Co., Limited, and delivered this 26th day of June 1874, in presence of

(Signed) JOHN TATE, Accountant.
THO. BALFOUR, witness.
Clerk to the said Adam Johnstone.

CONTRACT for COMPLETION of TAY BRIDGE.

SCHEDULE of PRICES applicable to each description of Work in the construction and completion of the Tay Bridge Work required to be performed in accordance with the Specification and Contract.

		£	s.	d.
Excavation inside caissons or cylinders	per cubic yard	1	6	9
Dressing surface of rock inside of do.	per sup. yard	0	10	0
Malleable iron in base of caissons	per ton	25	0	0
Cast iron in bell-mouth of do. and cylinders	"	17	0	0
Cast iron in inside tubes of caissons and cylinders	"	28	7	0
Brickwork in caissons and piers	per cubic yard	2	8	0
Concrete in foundations	"	1	13	0

		£	s.	d.
Concrete in bags laid by diver	per cubic yard	2	5	0
Cast iron in base of pier columns	per ton	17	0	0
Cast iron in columns	„	17	0	0
Malleable iron in bracings and bolts for do.	„	28	7	0
Malleable iron in impost box girders on top of columns prepared for bed plates	„	28	7	0
Cast iron in bed plates, bearing plates and rollers	„	17	0	0
Malleable in roller frames, countersunk bolts, and holding-down bolts	„	28	7	0
Malleable iron in girders, fitted and fixed	„	28	7	0
Malleable iron in girders, in bracing of do.	„	28	7	0
Timber in cross beams, way beams, and planking	per cubic foot	0	2	9
Cast-iron standards of hand railing	per ton	17	0	0
Malleable iron bolts for fixing do.	„	28	7	0
Malleable iron gas pipes, 2½ inch diameter, including fixing and joints	per lineal yard	0	5	0
Ashlar in string course at level of high water	per cubic foot	0	3	6
Rubble stones laid around caissons	per cubic yard	0	12	0

The above is the Schedule of Prices referred to in the foregoing Contract between the North British Railway Company and Hopkins, Gilkes, & Co., Limited, dated the 26th and 27th days of June and 6th day of July 1874.

(Signed) THOMAS BOUCH, C.E.
HOPKINS, GILKES, & Co., LIMITED.
EDGAR GILKES.
GEO. HARRISON.
WILLIAM MUIR.

Edinburgh, 6th July 1874.

As authorised by the Joint Committee of the Tay Bridge undertaking of the North British Railway Company, I hereby, on their behalf, sanction and approve of the foregoing Contract, and of the whole provisions and arrangements therein expressed or referred to.

(Signed) G. B. WIELAND,
Secretary to the Joint Committee.

SPECIFICATION of Works to be executed by HOPKINS, GILKES, & Co., dated 1st May 1874 (sent to the Solicitor to the Board of Trade by the Solicitor to the North British Railway Company by letter, dated 11th February 1880).

NORTH BRITISH RAILWAY.—TAY BRIDGE.

SPECIFICATION OF WORKS to be executed or completed in the construction of the proposed Bridge for carrying Railway No. 2, authorised by the North British Railway (Tay Bridge and Railways) Act, 1870, over the River or Firth of Tay. The line of the proposed Bridge will be the same as shown on the Parliamentary Plan of the said Railway No. 2, commencing on the Fife bank of the Tay near Long Craig Point, and terminating on the Forfar side of the Tay near Dundee, at the Point known as Magdalene or Buckingham Point, the length being 3,440 yards or thereabouts.

Description of Bridge.

The bridge is to be constructed for a single line of railway.

The total number of spans will be 89, or a lesser or greater number as the engineer may determine. Commencing at the Fife side, there are—first 3 spans of 60 feet, then 2 spans of 80 feet, 22 spans of 120 feet, 14 spans of 200 feet, 16 spans of 120 feet, 25 spans of 66 feet, 1 span of 160 feet (on the askew), and 6 spans of 27 feet each. The eight central 200 feet spans to have a clear height of 88 feet above the level of high-water, ordinary spring tides. The spans on either side of the said 200 feet spans will gradually decrease in height above high-water level as they approach the land; the gradient descending from the north end of those spans to the north shore at the rate of 1 in 73·56; and from the south end of those spans to the 80 feet spans at the rate of 1 in 353·68—the 80 feet spans being level, and the 60 feet spans rising therefrom with a gradient of 1 in 100.

The piers for the spans of 60, 80, and 6 of the 120 feet spans, to be of brickwork in cement; those for the remaining 120 and 200 feet spans to be of brickwork in the lower part and cast-iron columns in the upper. Those for the 66 feet spans to consist of three cast-iron columns set in concrete within cast-iron cylinders, braced together with malleable iron bracing. The abutment on the Fife side to be of stonework.

The superstructure to be of malleable iron girders and timberwork. The whole of the main girders to be on the lattice principle, except those for the 160 feet span, which are to be bow-string, and those for the 27 feet spans, which are to be plate. In the 200 feet and 160 feet spans, the roadway will be between the main girders, and these spans have plate-cross girders. In the whole of the other spans the roadway will be on the top of the main girders, and the cross-bearers will be of timber; timber way beams and planking being laid the whole length of bridge.

Contract Drawings, &c.

The contract to which this specification refers will, with the exception of providing and laying the permanent rails and chairs, consist of all the works incidental to the perfect construction and completion of the bridge being executed to the entire satisfaction of the engineer, and in accordance with the drawings undermentioned, subject to any modifications (whether deductions, additions, or variations) that the engineer may deem necessary during the carrying out of the works. It will also include the finding and providing all material, permanent and temporary, as well as all labour, carriage of material, workmanship, machinery, vessels, boats, barges, &c. necessary to complete the bridge in the most workmanlike manner.

List of Drawings above referred to.

No. 3. Details of Caissons for 200 feet spans, 23 feet diameter.
„ 3¹. „ Caissons for 200 feet spans, oval.
„ 4 & 5. „ Piers, Nos. 16 to 26, and 42 to 52, for 120 feet spans.
„ 6. „ Piers, from Nos. 53 to 57, for do.
„ 7. Elevation of lower part of Piers for 200 ft. spans.
„ 7¹. „ upper „ „
„ 8. „ lower part of Piers, Nos. 16 to 26 and 42 to 52 inclusive, for 120 feet spans.
„ 8¹. „ upper part of Piers for do.
„ 9. „ for remaining Piers of 120 feet spans.
„ 10. Details of fixed and moveable Bearings for 200 feet spans.
„ 11. Details of fixed and moveable Bearings for 120 feet spans.
„ 13. Detail of Pier at junction of 200 and 120 feet spans.
„ 14. Details of Cast-iron Piers, Nos. 58 to 79 inclusive.
„ 15. Elevation of Cast-iron Piers, Nos. 58 to 79 inclusive.
„ 16. Details for Main and Cross Girders, &c. for 200 and 120 feet spans.
„ 18. „ of Girders for End Spans of 200 feet.
„ 19. „ „ for 66 feet Spans.
„ 20. „ handrail.

A general plan and elevation, in conformity with the foregoing detailed drawings, to be furnished by the engineer of the company.

The contractor to set out and keep the works correct in every particular according to these drawings, or any other that may be supplied to him by the engineer from time to time, and to be held responsible for the accuracy of the work throughout the whole time occupied in constructing and completing the bridge. All poles, stakes, assistance, boats, &c. necessary for setting out, inspecting, and measuring the works shall be provided by the contractor.

DESCRIPTION OF WORK.

Excavations.

All the piers for the 120 and 200 feet spans are to be founded at the depth shown on Drawing No. 2, or as otherwise directed by the engineer. Cylinders or caissons, of the description herein-after described, to be sunk in the bed of the river to the depth specified or required, for the purpose of founding these piers, and the material falling within the bottom circumference of these caissons to be excavated as they are sunk down.

The whole of the surface of the rock within the bottom circumference of the bell mouth of such of the caissons as may be founded on rock must be carefully dressed to

a uniform level, so that the caissons shall stand perfectly vertical, and also for providing a level bed for the brickwork or concrete.

Where the caisson will not stand on rock the whole interior of the bell mouth must be cleared of all débris, and the bottom of caisson must be level before being concreted or built in.

Caissons.

The permanent caissons or cylinders on which the brickwork of the piers of the 200 and 120 feet spans below low-water level is to be built, shall be sunk down to the depths shown on the general Drawing No. 2, or to such lesser or greater depth as the engineer shall direct. Two caissons will be required for each pier, and when sunk the tops of them shall be level with each other, and joined with an arch of brickwork near the low-water line.

The caissons to be of the form and dimensions shown on Drawings Nos. 3, 4, 5, 6. These drawings represent caissons of the average depth required for the piers of the respective spans. The drawing of the caisson for the piers of the 200 feet span shows it to be sunk 17 feet below the bed of the river, and that for the caissons of the 120 feet spans at 16 feet. The greatest depth of the piers for the 200 feet spans below the bed of the river, as indicated by the borings, being 30 feet, and the least 10 feet; and for the 120 feet spans the greatest depth is 31 feet, and the least 3 feet.

The bell-mouthed portion at the bottom of each caisson to be formed of malleable iron plates, shaped and rolled to the figure of the drawing. Bolts to be ¾ in. diameter, and 8 in. centres. Angle iron must be fitted and riveted round the inside of the top edge of the base plate, and have holes bored therein ¾ in. diameter and 8 in. centres, for the purpose of bolting the lower flange of the conical portion of the caisson thereto when cast-iron conical plates are used. The sizes of all the malleable and cast iron in the caissons are marked in the respective drawings.

The caissons for the piers of the 200 feet spans are to be entirely of malleable iron, according to Drawing No. 3.

The whole of the joints in both the malleable and cast-iron portions of the caissons, as well as the joining of the two, to be carefully fitted and bolted together, so that they may be made perfectly watertight. The joints to be planed, or left rough and made good with rope wheeze or iron-rust, as the contractor may elect.

The contractor shall provide for temporary use in sinking the caissons, and in building the piers up to the level of high-water mark, additional cylinders, which shall extend from the top of the permanent caissons to the level of high-water mark at least; which temporary cylinders may be of malleable or cast iron, as the contractor may prefer. These cylinders to be so fixed to the caissons, and to be of such make, strength, and workmanship as shall ensure the permanent work, for the execution of which they are to be provided, being carried out in the most perfect manner.

Piers for 66 Feet Spans.

Each pier for the 66 feet spans to be formed of three cast-iron columns braced together,—two being bearing columns for the main girders, and one a strut column set into cast-iron cylinders according to Drawing Nos. 14 and 15, excepting piers, 58, 65, 69, 73, 77, and 80, which are to be double.

The flanges of each length of casting for the piles and columns to be turned on the face, and to have eight bolt holes 1½ in. diameter, accurately drilled therein to or through a gauge, so that any two flanges being applied to each other the bolt holes would be true and fair, the lengths may be properly fitted and bolted together. The lengths of the castings for columns to be 11 feet, with making-up pieces regulated as to length to suit the level of the piles when sunk, and the height of the respective piers. Snugs to be cast on the columns at the flanges, as shown for bolting and keying the bracing thereto.

The tops of the bearing columns to have moulding as on drawing, and the seat for the girders planed. The girder seat on raking column to be square to a vertical line. The tops of the strut columns to be formed to suit the circumference of the vertical bearing columns to which they are to be bolted, and must be accurately fitted thereto, and abut against the underside of the moulding.

The columns and piles forming each pier, when in permanent position, shall be square to the tangent of the curve of the bridge, range in line with each other, and be in exact position in relation to centre line, and suit the respective spans.

The columns to be braced as shown on drawing. The bracing to be formed at the ends to enter between the snugs of the columns, and be secured thereto with bolts and keyed together with gibs and cotters.

The columns and bracing to have four coats of the best oil paint of such colour as the engineer may determine. The cost of painting to be included in the price per ton for the ironwork.

All proper guards, guides, rings, bolts, watertight fixings, &c., requisite for the safe and expeditious sinking of the caissons and piles, to be provided. Proper staging and appliances shall also be provided and erected for sinking the whole of the caissons and piles in their position, and the greatest care and skill shall be exercised by the contractor to ensure that the sinking is executed truly vertical, or in the case of the raking piles, at the proper angle, and in the exact line and position shown in the drawings.

All staging, scaffolding, or other obstruction to the navigation of the river shall be erected and removed in accordance with the necessary requirements of the river authorities.

The contractor shall also provide all lights, and light and watch all the works during the construction and until the perfect completion of the bridge, and erect lights in such positions as may be required by the Board of Trade or the Commissioners of Northern Lights for the guidance and protection of the navigation of the river.

Cast Iron.

The iron of which the castings for the cylinders, piles, and columns are to be made shall be melted in a cupola furnace, and shall be of such mixture of pig that a bar cast therefrom, with a transverse section 2 inches by 1 inch, and placed edgeways on bearings 3 feet apart, will not break with a less weight on the centre than 3,000 lbs.; and bars of the above dimensions shall, from time to time, on the demand of the engineer, be cast and tested, at the sole expense of the contractor, in the manner before mentioned. The whole of the castings shall be of the same mixture of metal, to be clean and smooth in the skin, and free from all defects, and perfectly true to the dimension and figure of the drawings.

Brickwork.

The whole of the brickwork, *i.e.*, from the foundations to the underside of the imposts or base of pier column, shall be of the very best description, both in respect of material and workmanship, and set in the best Portland cement.

The bricks used throughout in building the piers to be hard burnt, well shapen, and of a good average size, each brick to contain about 140 cubic inches. Where the piers become from 10 to 6 feet in diameter, the heading and stretching bricks must be made to radiate in the joints, and be moulded to form a portion of the circle on the face to suit the circumference of the piers.

All bricks immediately before being used must be thoroughly saturated with water, and all dust or dirt removed from their surface.

All bats brought upon the work to be at once rejected.

The brickwork to be built outside the temporary cylinders up to high-water mark shall be perfectly plumb.

The whole of the brickwork required for the bridge shall be laid or set in cement when the cement is in a soft state, and the beds and joints to be thoroughly filled, and each course to be grouted with cement. The thickness of the cement in the beds shall not exceed ¼ of an inch.

In the construction of the piers it shall be in the option of the engineer to substitute concrete for brickwork to such extent as he may direct; and such concrete, if so used, shall be composed of one part of Portland cement of the best quality, one part of sand, and three parts of gravel or broken stone.

Cement.

The whole of the cement for this work, and herein-before referred to, shall be Portland cement of the best quality, well burnt, and ground extremely fine, and weighing not less than 112 pounds to the imperial (striked) bushel. It is to be brought on to the works in a state fit for use, and not used therein until it has been tested by taking samples out of at least every tenth (two bushel) sack. These samples to be gauged in moulds and placing the cement at once in water, in which it is to remain for seven clear days, and testing it at the end of that time by the application of a weight or lever. All cement that shall not bear a tensile strain of 250 lbs. to the square inch of section shall be peremptorily rejected, and forthwith removed from the works.

The cement shall be used fresh made, in such small quantities as may be from time to time required, and to be well mixed with sand in the proportion of one of cement to one of sand; no water shall be added after it has once been mixed, and no cement to be used or mixed up with any other cement after it has once begun to set. It must

also be carefully preserved from moisture until actually used.

The sand to be used in mixing with the cement to be very clean and sharp, entirely free from silt and earthly substances. The water used in mixing the cement and sand shall be clean salt water.

Stonework.

The stone required for the string-course of the piers of the 200 feet spans at the level of high water, and the impost for bases of pier columns of all the brick piers, to be of the best and strongest description.

The belt of stonework for the piers of 200 feet spans, and shown on drawings at high-water level, to extend the full diameter of each column. Each stone to have as large a superficial content as possible, and the joints made to radiate and fit close the full distance of each bed. These stones to be in thickness not less than 2 feet 6 inches, and chisel-dressed on all beds and joints, and moulded on the face to plan. The stone connecting the columns at this level to be of the same thickness and workmanship as the belt, and to extend into each column not less than 2 feet.

Malleable Iron Girders.

The main girders for the whole of the spans to be constructed on the lattice principle, except those for the 160 feet span, which are to be bowstring, and the 27 feet spans, which are to be plate. Those for the 200 feet spans to be placed 14 feet 9 inches apart, and for the 160 feet span 17 feet 6 inches apart on the square, centre to centre, with cross girders of plate bolted to the bottom members. Those for the spans of 120, 80, 66, 60, and 27 feet to be placed 9 feet apart, centre to centre. The cross bearers for these spans to be of timber, and placed on the top members of the girders.

The girders for the 200 and 120 feet spans to be erected in sets of continuous girders of four spans each, with the exceptions shown on general elevation Drawing No. 2. The exceptions being where two girders are shown to be continuous in place of four.

Each set of continuous girders, of 4 spans each, shall be fixed to their centre pier, and have moveable bearings on the other piers. It is to be observed that the dimensions of the first and fourth differ from the second and third girders in each set as shown. Between each of these girders there is to be a space of 3 inches—at the lower member a 3-inch cast-iron plate is to be inserted between the ends of the girders and fixed with bolts as shown—the top members of these girders to be connected with malleable iron plates; but before riveting these, the further end of each girder is to be lifted up a height to be afterwards decided upon, in order to bring the continuity into action. Fixed bearings to be placed on the piers between the 200 and 120 feet spans, between the 120 and 66 feet spans, and between the 120 and 80 feet spans, and two girders of each adjacent span to be fixed thereto as shown. The girders for the 66 and 27 feet spans to be erected in sets of continuous girders of three spans each, having fixed bearings on both piers for centre girder of each set, and moveable bearings on the other piers.

The cross girders for the 200 and 160 feet spans to be plate girders and fixed to the bottom member.

The whole of the girders to be made in accordance with the respective drawings, the shape and dimensions to be carefully worked to, and the various parts well and accurately fitted together. The material and workmanship must be of the best description.

The wrought-iron plates, bars, angle and T irons used in the construction of the girders for this bridge must be of such make and quality as shall be specially approved by the engineer, and of such strength that one square inch of sectional area shall support a tensile strain of 21 tons without breaking. Such bars as the engineer may select from time to time must be torn asunder in the presence of himself or his deputy, and if any break under a less tensile strain than 21 tons per square inch, as before mentioned, none of the plates, bars, &c. supplied by the same iron company shall be allowed to be used in these girders.

The girder work must be of the best description, and more of the nature of engine work than that usually applied to bridges.

The rivet holes in the whole of the plates, bars, angle irons, &c. must be punched quite true and fair, and when the parts of the girders to be riveted together are fitted in position, the rivet holes must be perfectly true and fair with each other. All the rivets to be made of C crown iron or such other as shall be approved by the engineer. The riveting must be executed in the most careful and workmanlike manner, care being taken that the rivets exactly fill the holes. The heads of the rivets to be finished off in the best style.

All bolts to be made of Lowmoor iron, or such other make as shall be specially sanctioned by the engineer, and to be neatly finished, head and nut, and not projecting more than ¼ inch through the nuts: to be carefully forged and screwed and made to fill the bolt holes.

All the ironwork to be painted four coats of the best oil paint, of such colour as the engineer may determine. The cost of painting to be included in the price per ton for ironwork.

Bed Plates and Expansion Rollers.

The bed plates, expansion rollers to be made in accordance with Drawings Nos. 11, 12, 13, and to be of cast iron of the best quality. The rollers to have frames of malleable iron. The bed plates of the fixed bearings to be bolted to the impost as shown.

Timber.

The timber to be used in the cross-bearers, way-beams, and planking to be of the best crown Memel or red pine, neatly jack-planed and dressed to the dimensions of the drawings.

The cross-beams, 12 inches by 9 inches, to be bolted to the top member of the girders with ¾ inch bolts.

The way-beams, 14 inches by 14 inches, to be bolted to the cross-girders by ¾ inch bolts. The way-beams, 14 inches by 7 inches, to be bolted to the cross-beams by ¾ inch bolts.

The planking to be 12 inches by 3 inches, and spiked to the cross-beams by spikes 7 inches long and ½ inch square at the head, and pointed. In the case of cross-girders, the planking to be fixed to the top flange by ½ inch bolts having dogheads.

Hand-railing.

The hand-railing to be according to drawing. To be 3 feet 6 inches high; having cast-iron standards placed 6 feet apart, formed of four feathers ¾ inch in thickness, having heads made to receive gas-pipe for hand-rail. The gas-pipe to be 2½ inches outside diameter, and joinings to be made gas-tight. The standards to be bolted to the timber-work with ¾ inch bolts.

General Conditions, &c.

1. The contractor shall complete the whole of the works herein specified, and such additional works as the engineer may direct to be executed, so as to render the bridge complete in every respect, except the laying of the permanent rails and chairs, within two years from the 11th day of November 1874.

The contractor shall be bound to give to the contractor for the railway in continuation of the bridge at either end, free access and every reasonable facility to such portion of the bridge and ground as may be necessary to enable the latter to execute the work embraced in his contract, such access and accommodation being regulated and directed by the engineer; and no inconvenience or alleged inconvenience arising therefrom shall form any ground for claim of damages by the contractor against the Company.

The works, and the mode of execution, are described at length in the specification of each particular work, and their forms and dimensions described in the accompanying drawings, which are referred to in this specification; but should any discrepancies exist between the measurement by the scale attached and the written dimensions, the latter are to be taken as correct. Anything contained in the drawings or specification shall be considered as contained in both.

And wherever neither the drawings nor the specification contain any notice of minor parts, the intention to include which is nevertheless clearly to be inferred, and which parts are necessary for the completion and stability of the work, all such additional things are to be done and provided by the contractor, and are assumed to be included in the prices at which he contracts for the work.

The contractor will be bound strictly to comply with the provisions of the Act of Parliament obtained in session 1870, for making the bridge and railways in connexion therewith, and to satisfy all claims made against the Company, in consequence of any violation of, or departure from, the provisions of such Act by him in so far as it relates to the works in this contract.

Whenever the words "the Company" are used, these words shall mean throughout the whole of this specification the North British Railway Company, and similarly the words "the engineer" shall mean Thomas Bouch, Civil Engineer, Edinburgh.

The whole of the works in proximity to the Caledonian Railway are to be carried on in such a manner as shall not interfere in any way with the traffic of that railway.

The contractor shall, at his own cost, provide suitable policemen whenever it may be ordered by the engineer, or by any one or more of the magistrates of the district, as the Company or magistrates or magistrate may think necessary for the due preservation of the peace or protection of the property of the contractor, or that of the adjoining owners.

The contractor to provide, and pay all compensation for any land he may require for temporary purposes other than the land already provided, and shall make good all damage to roads, whether public or private, or to the lands of private individuals, arising from carting of materials, or from any other cause contingent upon the execution of the works.

The care of the entire works of the bridge shall remain with the contractor until their completion, and he shall be held responsible for all accidents thereto, and shall make good all damage and defects to the said work, whether arising from bad or insufficient materials, bad workmanship, or any other similar cause whatever. No certificate or approval by any officer of the Company (except the engineer) of any works supposed to have been properly done shall affect the right of the Company against the contractor, or be considered or held as at all conclusive as to the sufficiency of any works or materials.

The contractor shall from time to time make any alteration in the works which the engineer may think necessary, whether by additions or deductions or deviations, or the omission of any works herein contracted for, or any part of them, or for new or extra works, and such alterations or additions shall not vacate this contract; the value of such alterations or additions shall be ascertained by admeasurement, and shall be added or deducted, as the case may be, at the prices set forth in the schedule of prices at which the contractor undertakes the construction of the works. The contractor shall not in any case be considered as having any claim upon the Company for extra or additional payments for or on account of any such works, unless he can produce the authority of the Company's principal engineer for such alterations or additions. The contractor shall not sub-let the whole or any part of the work herein contracted for without the previous sanction of the engineer in writing.

The engineer will provide from time to time the detail and other drawings of the various works.

The whole of the works are to be paid for according to the actual quantity executed, at the price opposite each description of work in the said schedule. Net measurements to be taken in all cases, without any allowance for circular or face work, notwithstanding any general or local custom to the contrary.

The contractor shall, at all times, be present on the works; or in his absence he shall provide a competent representative fully authorised to act in his behalf in all matters relating to this contract.

The contractor shall, at all times, by day or night, provide and use at his own cost, all overlookers, labour and materials, of every description whatever, that may be required for proceeding with and completing the works in a workmanlike manner; and shall proceed therein at the rate of progress that may be from time to time required by the engineer.

It is to be understood that though certain descriptions and stipulations are repeated or implied in different parts of this specification, and in the contract to be entered into for the fulfilment of the same, it shall not be thence inferred that the remaining directions, descriptions, or amplifications are in anywise invalidated.

The contractor shall, at intervals of every month, furnish to the engineer a statement and account of all work done by him during that period; and of all amounts charged or claimed by him for additions, extras, damages, compensation, or other claims whatsoever, all of which shall be investigated, valued, and settled by the engineer, according to the estimate prices, so far as the same is applicable thereto, and where not applicable according to the valuation and assessment of the said engineer; and the amount of such account, after being certified in writing by the engineer, shall be paid to the contractor after deducting 10 per cent. off the amount until the sums so deducted shall amount to the sum of 10,000*l*., after which the whole sum certified shall be paid; and the amount so retained shall remain in the hands of the Company till the completion of the works, when the whole of such drawback shall be paid to the contractor upon the certificate of the engineer that the contractor has performed this contract, and all his obligations arising therefrom satisfactorily, and that (taking into consideration all claims on both sides) such balance is justly due and owing to the contractor, and no moneys shall be deemed due, or payable on, or for any account to the contractor, or under this contract, or for any claims arising out of, or in any way incident thereto, or to the works, except the same be certified in writing by the engineer as aforesaid, and in all settlements of accounts between the contractor and Company, it is hereby declared that no extra work, or alteration from the work specified, will be allowed by the Company to the contractor, unless the same shall have proceeded under the written authority of the engineer, and which authority shall be produced at the time of the settlement of accounts.

And should the engineer be at any time dissatisfied with the nature or mode of proceeding in, or the rate of progress of the work, or any part thereof, he shall have full power to procure and make use of all labour and material which he may deem necessary, deducting the cost of such labour and material from the money that may be due, or become due to the contractor. But it is hereby expressly declared that the possession of this power by the engineer shall not, in any degree, relieve the contractor of his obligations to proceed in the execution of and to complete the works with the required expedition.

In case the contractor shall not continue to execute and advance the progress of the works, or any part thereof, to the satisfaction of the engineer or his deputy, or if before completion of his contract, the contractor shall become bankrupt or insolvent, or compound or propose to compound with his creditors, or carry on business under inspectors appointed on behalf of creditors, then, and in any of these cases, the Company may, if they think fit, determine this contract, so far as respects the future performance thereof, by or under direction of said contractor, and forthwith give notice to the said contractor, of such determination, and immediately on such notice all penalties and sums for non-fulfilment of contract shall be forfeited to the said Company, and all materials, horses, engines, machinery, vessels, boats, buildings, tools, implements, and plant provided by the contractor shall also in such case become the property of and may be seized and taken by the Company. And as soon as convenient after the determination of the said contract as aforesaid, the engineer shall ascertain and fix finally and conclusively as to all parties the amount earned by and justly due to the contractor in respect of work done and materials provided, and the value of all materials, horses, engines, machinery, vessels, boats, buildings, tools, implements, and plant, seized and taken and in possession of the said Company, and the amount and value of other claims, if any, of the said contractor against the Company, of all which claims the contractor shall give notice within six days of the determination of the said contract, and such engineer shall credit the contractor in his accounts with the Company with such amounts. And said engineer shall ascertain the sums paid or advanced to the contractor by the Company, and the amount and value of all loss, costs, damages, and claims of the Company against the contractor, whether by reason of the determination of the said contract, or the acts, neglects, or defaults of the said contractor, in reference to this contract or otherwise howsoever, and shall make such allowances and disallowances on both sides of such account as he, the said engineer, thinks reasonable, and he shall finally settle the balance of account due to or from the said contractor, and such balance as settled shall be final and recoverable by the party entitled thereto under this agreement.

It is to be distinctly understood that the engineer may, at all times, direct that there shall be made any deviations from the line of the bridge as now staked out, additional works, or any alterations in, additions to, or deductions from, any of the works herein described or referred to; all which shall be valued or estimated by the engineer, and by him certified in manner herein-before mentioned, and payable upon such certificate only, according to the prices in the said schedule; and that the prices inserted in the schedule shall be considered as including all labourage, materials, and all contingent expenses connected with the works, to which such prices apply.

It is also to be distinctly understood that the whole of the works are in every particular to be executed to the entire satisfaction of the engineer.

All matters and questions as to the true intent and meaning of this specification, or as to what shall be considered carrying on the work in a proper, uniform, and regular manner, or as to the expense of any extra or unspecified work, or deduction from that specified, or any alterations which may be more or less expensive than the work specified—all or any of which may be ordered by the directory or their engineer (and which they reserve power to do), or as to what constitutes extra or diminished work, or as to the proper maintenance of the works, or as to any other matter connected with this specification, or contract to follow hereon—shall be decided by Thomas

Elliot Harrison, Civil Engineer, London; whom failing, Sir John Hawkshaw, Civil Engineer, London; and the decision, interim or final, of the said Thomas Elliot Harrison, whom failing, the said Sir John Hawkshaw, shall be finally binding and conclusive on both parties.

Edinburgh, May 1st, 1874.

What is contained on this and the 11 preceding pages are the specifications referred to in the contract between the North British Railway Company and Hopkins, Gilkes, and Company, Limited, for the completion of the works of the railway bridge over the Tay at Dundee, dated the 26th and 27th days of June and 6th day of July 1874.

(Signed) THOMAS BOUCH, C.E.
HOPKINS, GILKES, & Co., LIMITED.
EDGAR GILKES.
GEO. HARRISON.
WILLIAM MUIR.

No. 8.

REPORT of GENERAL HUTCHINSON upon his INSPECTION of the TAY BRIDGE.

SIR, Newcastle-on-Tyne, March 5th, 1878.

I HAVE the honour to report, for the information of the Board of Trade, that in compliance with the instructions contained in your Minute of the 15th ultimo, I have inspected the Tay Bridge, forming a portion of the Tay Bridge Railway of the North British system.

The Tay Bridge Railway, in conjunction with the Firth Bridge Railway, for which an Act of Parliament has been obtained, will shorten the existing route between Edinburgh and Dundee (viâ Stirling) by 28 miles; and by means of these two railways and a new railway about to be constructed between Arbroath and Montrose the journey between Edinburgh and Aberdeen will be reduced by 23 miles.

In consequence of the magnitude of this bridge, of which T. Bouch, Esq., M.I.C.E., is the engineer, it was considered desirable to have it inspected before the lines north and south of it were ready for traffic. The inspection of the bridge accordingly took place on the 25th, 26th, and 27th ultimo, the weather, fortunately, being favourable.

The Tay Bridge carries a single line of rails, is 3,450 yards in length, and consists of 85 spans of the following descriptions:—

11	spans of	245 feet	each, lattice girders.
2	„	227	„ „
1	„	166	„ bowstring girders.
1	„	162·8	„ lattice girders.
13	„	145	„ „
10	„	129·25	„ „
11	„	129	„ „
2	„	87	„ „
24	„	67·5	„ „
3	„	67	„ „
1	„	66·7	„ „
6	„	28·9	„ „
85			

In addition to which there are adjoining the north end of the bridge

1 span of 100 feet bowstring girders.
3 „ 29 „ plate girders.

In the 15 spans exceeding 145 feet and with the 100 feet bowstring girders wrought-iron cross girders have been employed; for the other spans cross girders of timber.

In the 13 spans of 227 feet and upwards, and in the bowstring girder spans, the roadway is carried on the bottom booms of the girders; in the other spans on the tops of the girders.

The girders are arranged in continuous groups, generally of four, five, or six each, with proper provision for expansion.

They are supported on piers of varied construction, the foundation in all cases being formed of iron cylinders lined with brickwork and concrete; counting from the south end.

Piers 1 to 14 are entirely of brick in cement.
Piers 15 to 48 are brick for 5 feet above high-water mark, finished with a stone belting, upon which are carried groups of cast-iron columns braced together.
Piers 49 to 77 consist of groups of cast-iron columns braced together, starting from the cylinders and encased in brickwork to a height of 5 feet above high-water mark.
Piers 78 and 79 are cast-iron cylinders throughout, filled with concrete.
Piers 80 to 84 are cast-iron columns.
Piers 85 to 89 of brick in cement.

The greatest height from the level of the rails to high-water mark spring tides is 92 feet; this occurs at the centre of the large spans, whence towards the north side there is a sharply falling gradient of 1 in 74, with a gentler fall towards the south end; at each end of the bridge there are curves of 20 chains radius.

The permanent way consists of double-headed rails, fished at the joints, in 24-feet lengths, weighing 75 lbs. to the yard, secured by oak keys in cast-iron chairs weighing 80 lbs. each, fixed at 3 feet average intervals to longitudinal timbers 17 inches wide, and varying in depth between 7 and 14 inches. There are four spikes in each chair. Throughout the length of the bridge each rail is provided with a guard rail.

Between the longitudinals, the floor of the bridge consists of 3-inch planking covered with a waterproof composition.

A substantial handrail is carried along each side of the bridge.

For the purpose of adequately testing the structure, the North British Company placed at my disposal six new goods engines, weighing 73 tons each, and each measuring 48½ feet over all. The total weight employed being thus 438 tons, and the total length of engines 291 feet, or as nearly as possible 1½ tons to the running foot. Under this test the deflections were as follows:—

				Inch.		Inch.
Of the	227 and 245 feet girders varied between			1·8	and	1·2
„	166 (bow string)		„	1·2	„	0·9
„	163	„	„	0·6	„	0·6
„	145	„	„	1·0	„	0·6
„	129·25	„	„	0·6	„	0·6
„	129	„	„	0·9	„	0·6
„	87	„	„	0·6	„	0·6
„	67·5 and 67 and 66·7		„	0·3	„	0·3
„	28·9	„	„	0·2	„	0·2
„	100 (bowstring)	„	„	0·6	„	0·6
„	29	„	„	0·2	„	0·2

These results are, in my opinion, to be looked upon as satisfactory.

The lateral oscillation, as observed by the theodolite with the engines running over at speed, was very slight, and the structure altogether showed great stiffness.

The dimensions of the various parts of the girders have been carefully worked out, and the iron has in no case been submitted to a greater strain than 5 tons to the inch.

Upon a careful examination of the brickwork and masonry, they appear to be of a substantial character, and to be showing no signs of settlement. The ironwork has been well put together, both in the columns and girders.

The following are the only requirements that come under my notice:—

1. Transoms and ties for preserving the gauge should be provided between the longitudinals.
2. The fireproof covering of the floor requires repair in several places.
3. Some slack places in the rails require adjusting.

To reduce as much as possible the expansion of the girders in hot weather, I should strongly recommend their being painted white.

It will not be desirable that trains should run over the bridge at a high rate of speed, and I would suggest 25 miles an hour as a limit which should not be exceeded.

A certificate will have, of course, to be given that the single line shall be worked with the train staff and block system.

Very careful attention will be required to ascertain from time to time that no scouring action is taking place in the foundations, particularly in the case of those piers which are subjected to a strong current.

When again visiting the spot I should wish, if possible, to have an opportunity of observing the effects of high wind when a train of carriages is running over the bridge.

Subject to the above requirements and remarks, I see no reason why, so soon as the adjoining railways are completed and inspected, the Board of Trade should object to the railway on the Tay Bridge being used for passenger traffic.

I have, &c.

The Secretary,
Railway Department,
Board of Trade.

C. S. HUTCHINSON,
Major-General, R.E.

No. 10.

REPORT of MR. DRUMMOND, Locomotive Foreman to the North British Railway Company, upon condition of Train after accident.

REPORT on Train in Accident to TAY BRIDGE on the 28th December 1879.

Locomotive Engineer's Office,
Glasgow, April 15th, 1880.

MY DEAR SIR,

I BEG to inform you I have examined the whole of the remaining portions of the train referred to, and find them in the following condition :—

224 Engine.—Throttle valve full open, and reversing lever standing in the sixth notch from full forward gear, or in the third notch from centre. The lever on motion shaft (carrying the valve motion) connected to the reversing lever on the west or left side of engine is broken close to the shaft. Left or west side spring beams of bogie are broken in centre. 10 feet of the foot plating is slightly displaced, and the end of the foot plate at smoke box end lifted up 2 feet of its length. Buffer beam and angle iron broken close to the main framing, and the buffer carried off. Sand box underneath foot plate broken, and footstep at foot plate bent. Westinghouse break on left or west side complete. Cleading plates and handrail destroyed, caused by slinging round the boiler for lifting the engine.

East side.—7 feet of foot plating slightly damaged, Westinghouse pump bracket broken at bottom, and air break cylinder cover for engine broken, footstep and handrail bent, panel on foot plate broken at end at an angle of 2 feet from top corner. The east side of engine is much less damaged than the west side. The injector steam cock on east side and engine cab were pulled off by one of the anchor hawsers, which had got fastened round the cab when the brig "Henry" was drifting down the river with the engine slung. When the engine was lifted at first the whole of the steam-pipe connexions on the boiler, as well as the cab, were uninjured.

224 Tender.—Break screws full off; east side of tender uninjured except two footsteps broken off. The left or west side of tender trailing axle box slightly broken, and the tender tank plate, next the foot plate, cracked about 12 inches in length. The Westinghouse connexion to train in good order. Break connecting rods on left side broken.

579 Four-wheeled Third-class Carriage.—Under framing complete, except one pair of wheels missing. One pair of wheels with bent axle still in carriage. The body of carriage is almost complete, with the exception of the roof, which is off, and windows broken. Coupling links next engine complete, except coupling screw, which is slightly bent. Westinghouse break work has received no damage. Coupling link next first-class carriage broken.

414 Six-wheeled First-class Carriage, built by the Birmingham Carriage Company in 1879.—Only centre wheels remaining with axle bent. Body partly remaining. Break gearing completely gone. Otherwise the under frame is uninjured.

Four-wheeled Third-class Carriage at West Ferry.—Westingbouse break damaged. Both wheels in carriage with axles bent. Top and body gone. Footstep hangers bent and broken. Coupling link next first-class carriage broken.

Four-wheeled Third-class Carriage, built at Cowlairs in 1878.—Part of top frame next engine and end standing under frame uninjured. Two step hangers broken, and three bent on east side. Westinghouse break destroyed—break cylinder cover broken on end next break van. Axles both bent. One axle box broken. The connecting break pipe next the break van is off.

Second-class Carriage built by the Metropolitan Carriage Company.—Under frame next break van and end buffer beam on west side broken; east side of under frame uninjured. Step hangers bent and broken. No break fitted on this carriage. One buffer socket broken on end next engine on west side. No part of this carriage body left on under frame. One pair of wheels gone and one pair left with axle bent.

146 Break Van.—No Westinghouse break fitted on this van. Hand break full off. Body all gone, except the left bottom part of guard's outlook or "dookit" on the west side of frame. Step hangers on east side broken. One remaining whole at second from rear end. West side of break van under frame bent. Broken and bent footstep hangers. Break gear slightly twisted. The main bar for carrying the break blocks on the west side is broken. Both axles bent.

(Signed) D. DRUMMOND.

Adam Johnstone, Esq., Solicitor,
2, Great College Street, Westminster.

No. 13.

CORRESPONDENCE between SIR THOS. BOUCH and the NORTH BRITISH RAILWAY COMPANY as to the Maintenance of the Tay Bridge.

CORRESPONDENCE between MR. JOHN WALKER and SIR THOMAS BOUCH.

DEAR SIR,

Tay Bridge, May 9th, 1878.

I HAVE the pleasure to inform you that the two iron workers who have been engaged in the examination of the iron columns will have completed their work to-day. The bolts and bracings of the columns, also the rivets that required looking to, are now in a perfect state of security.

I remain, &c.
(Signed) H. A. NOBLE,
Inspector of Tay Bridge.

J. Walker, Esq.

DEAR SIR,

May 10th, 1878.

I ANNEX for your information copy of a letter I have received from Mr. Noble, dated 9th instant, along with his pay bill.

Yours, &c.
(Signed) J. WALKER.

Thomas Bouch, Esq.,
111, George Street.

DEAR SIR,

June 21st, 1878.

Now that the maintenance of the Tay Bridge Railways has been taken over by Mr. Bell, I should feel obliged if you would send me for his information and guidance the following :—

1. Plans and sections of the Tay Bridge, showing the depth of each pier, and also the extent of the rubble stones laid down to protect the same.

2. Plan of Dundee Station, showing the position of drains, pipes, &c., and other underground works.

Yours, &c.
(Signed) J. WALKER.

Thomas Bouch, Esq., C.E.,
111, George Street.

The North British Railway Company,
General Manager's Office.
Edinburgh, June 22nd, 1878.

DEAR SIR,

REFERRING to your letter of the 20th instant, I have to-day seen Mr. Bouch, and arranged that the maintenance and repair of the piers and foundations of the Tay Bridge shall remain in his hands for the next nine or twelve months, or at least until he shall give me notice that he wishes to be relieved of the responsibility. Inspector Noble will therefore continue to act under the orders of Mr. Bouch so far as relates to this work, and you need not trouble yourself to communicate with him on the subject.

I have also arranged that the painting of the bridge is to be completed under Mr. Bouch's orders, and he will send me a plan in the course of a day or two of the Dundee Station, showing the position of the drains, pipes, and other underground works, which will be handed to you on receipt.

Yours, &c.
(Signed) J. WALKER.

Jas. Bell, Esq.,
Engineer.

The North British Railway Company,
General Manager's Office,
Edinburgh, June 22nd, 1878.

My dear Sir,

I enclose for your information copy letter I have to-day sent to Mr. Bell, in terms of arrangement made at our interview, and you will, of course, give the matter your attention.

Will you be good enough to consider, and let me know before the 4th July proximo, the colour you would recommend the bridge should be painted?

Yours, &c.
(Signed) J. Walker.

Thos. Bouch, Esq.,
111, George Street.

The North British Railway Company,
General Manager's Office,
Edinburgh, July 5th, 1878.

Dear Sir,

I reported to the directors at their meeting yesterday the arrangement embodied in my letter to Mr. Bell of the 22nd ult., a copy of which was transmitted to you, whereby you are to undertake the supervision of the piers and foundations of the Tay Bridge, and continue Inspector Noble's services for another year, and I have the pleasure to inform you that the directors approved of this.

Yours, &c.
(Signed) J. Walker,

Thomas Bouch, Esq., C.E.,
111, George Street.

Chambers, 111, George Street,
Edinburgh, December 12th, 1878.

My dear Sir,

In answer to your letter, I have no written report this month from Noble, but I had him over here on other business, and learned from him that everything about the bridge continues satisfactory, and I authorised him to give four of his men notice to leave, as he thinks he will not require them any more. He will, however, require one more cargo of stones, as there is a slight indication of scour at one of the piers, but he thinks this will be the last. I am, myself, however not quite certain of this.

Yours, &c.
John Walker, Esq. (Signed) Thomas Bouch.

Dear Sir,

Edinburgh, June 6th, 1879.

As arranged with you about 12 months ago, I have been paying the half of Mr. Noble's salary as Inspector on the Newport Line, and the North British Company paying the other half, on account of his inspection of the Tay Bridge, but now that the Newport Line is finished his full salary will fall to be paid by the North British Company. His time will be fully occupied looking after the painting and maintenance of the bridge generally for some time to come, and until I can put him on the Forth Bridge works.

I am, &c.
(Signed) Thomas Bouch.

John Walker, Esq.,
General Manager, North British Railway.

Dear Sir,

June 10th, 1879.

The directors, at their last meeting, agreed that the supervision of the Tay Bridge in all respects (except as regards the permanent way laid thereon, which is under the charge of Mr. Bell) should continue in your hands for another year from 5th instant.

In consideration of this they are to allow you 100 guineas, and if you will send along a receipt for this sum, on my return from London, I will give instructions for it being paid to you.

Yours, &c.
(Signed) Per J. Walker,
Jno. Cathles.

Thomas Bouch, Esq., C.E.,
111, George Street, Edinburgh.

Chambers, 111, George Street,
Edinburgh, June 10th, 1879.

Dear Sir,

I have your letter of this date, intimating that the directors wished the supervision of the Tay Bridge to remain in my hands for another year from 5th instant, which I agree to.

I have already received a cheque for 100 guineas.

With many thanks,
Yours, &c.
(Signed) Thomas Bouch,
Per R. D. Roddick.

John Walker, Esq.,
Manager, North British Railway Company.

Rubble Stones, Tay Bridge Piers.

Newport, Fifeshire,
June 23rd, 1879.

Dear Sir,

I enclose account of rubble stones (at reduced prices) brought to Tay Bridge by Mr. Speed, of the s.s. "Elcho Castle." In the early part of April I called your attention to the scour caused by a sunken girder, so much so that I, in diver's gear, could walk underneath it in two places. You called Mr. Walker's attention to it, and recommended filling it with rubble. I have accordingly placed a cargo of stones in each of the holes, and placed a cargo of stones at each of the two piers in the direction of scour, viz., N.E. of No. XIII. b., and S.E. of No. XII. b. I have also found it necessary to place other four cargoes at the following piers:—No. VI. b., No. 46, No. XI. b., and divided a cargo between Nos. I and IV. b., making a total of eight cargoes of stones used at the piers since the month of October last year.

Re-painting the Bridge.

Mr. Bamlet starts the work this morning. He intends to start at both ends, and has engaged two gangs of men to commence immediately.

As Mr. Bamlet's contract takes in the ironwork (including handrail only) I think the Company could get the work painted without other expense than finding the paint from stores at Cowlairs. The men I have with me could paint the whole of the wood portion during the interval, when not required with me sounding, in the same manner that they now employ their time in looking to the bolts, &c., &c.

I remain, &c.
(Signed) H. A. Noble,
Thomas Bouch, Esq., C.E. Inspector.

Chambers, 111, George Street,
Edinburgh, June 24th, 1879.

Dear Sir,

I enclose a letter from Mr. Noble as to rubble placed where the fallen girder was sunk, and also around the piers he mentions, with certified account due Mr. George Speed for the same.

You will observe what he says about getting the wood portion of the bridge painted.

Yours, &c.
(Signed) Thomas Bouch,
Pro. R. D.R.

John Walker, Esq.,
Manager, North British Railway.

My dear Sir Thomas,

June 26th, 1879.

I was duly favoured with your letter of the 24th instant, enclosing one from Inspector Noble recommending that the woodwork of the Tay Bridge should be painted simultaneously with the iron structure. It might have been well if the whole had been embraced in one contract, but as this has not been done I see no objection to Inspector Noble's suggestion being adopted, viz., that he should carry out the work himself under your supervision.

Mr. Robertson, our Stores Superintendent at Cowlairs, will attend to any orders you may pass upon him for paint.

Yours, &c.
Sir Thomas Bouch, C.E., (Signed) J. Walker.
111, George Street.

The North British Railway Company,
General Manager's Office.
Edinburgh, July 10th, 1879.

Dear Sir Thomas,

I beg to annex a list of Inspector Noble's staff, and the wages paid to each man.

I presume the deposit of rubble at the piers is now nearly completed, and perhaps you will let me know whether the present staff is likely to be permanent, or if it can be reduced.

Yours, &c.
Sir Thomas Bouch, C.E., (Signed) J. Walker.
111, George Street, Edinburgh.

List of Staff referred to.

W. Nicoh, fireman - -	4s. 2d. per day.
D. Bell, boatman - -	3s. 6d. ,,
C. McKinney, lamplighter, &c.	21s. 0d. per week.

Chambers, 78, George Street,
DEAR SIR, Edinburgh, July 18th, 1879.

REFERRING to your letter of the 10th instant in regard to Inspector Noble's staff,—

There are no rubble stones required at present for the piers, but I propose to have soundings taken in the month of September next at every pier, the result of which will determine whether any more rubble is then required. In the meantime two of the men are fully employed every day in tightening and renewing nuts and washers of the bolts which secure the way beams on which the permanent rails are laid, the lamplighter giving them assistance with the scaffolding, &c.

The whole number of men employed on the bridge by both Mr. Bell and myself is five. This number for two miles of railway is only about the average per mile you employ for the maintenance of your main lines, but of Mr. Bell's two men, one only is employed in tightening up the fish plates, bolts, and keys during the day. The man employed during the night is, I apprehend, more a policeman, to see there is no obstruction on the bridge.

Of the three men under Mr. Noble, one is employed principally in attending to the lights and lamps, 28 in number. The consumption of gas would be very large if not regularly attended to, and, to reduce it to a minimum, Mr. Noble takes advantage of all the daylight he can get, and has the gas put out, at this season of the year, as early as 3 o'clock a.m., and re-lit again at 9.30 p.m. The lamplighter has this to do on Sundays as well as week days, and I do not see how we can dispense with his services. As before-mentioned, he is employed during the day assisting the other men with scaffolding, &c.

In regard to your inquiry whether the present staff is likely to be permanent, I would not recommend any change being made so long as the bridge remains under my charge.

Yours, &c.
(Signed) THOMAS BOUCH.

John Walker, Esq.

DEAR SIR THOMAS, July 19th, 1879.

I AM obliged by your letter of yesterday's date with respect to the staff employed by Inspector Noble.

Yours, &c.
(Signed) J. WALKER.

Sir Thomas Bouch, C.E.,
111, George Street, Edinburgh.

Chambers, 111, George Street,
DEAR SIR, Edinburgh, November 20th, 1879.

I HAVE had Noble the last two months taking soundings around every pier, and find that of all those which were metalled, the result is very satisfactory; there is no change whatever excepting in two, where the sand is actually accumulating; but at some of the smaller spans at each end of the bridge, where no stone was deposited, there is indication of a slight scour, and I have given Noble orders to stop it, by depositing more stone.

The cost of this will be about 275*l*.

Yours, &c.
John Walker, Esq., (Signed) THOMAS BOUCH.
Manager, North British Railway.

No. 14.

REPORTS by MR. NOBLE to SIR THOS. BOUCH as to his Inspection of the Tay Bridge.

REPORTS by INSPECTOR NOBLE, from 31st July 1878 to 11th April 1879.

Chambers, 111, George Street,
DEAR SIR, Edinburgh, August 16th, 1878.

I HAVE yours of yesterday, and as requested enclose you Mr. Noble's report on the foundation and piers to 31st July.

I am, &c.
(Signed) THOMAS BOUCH,
John Walker, Esq., Per H. B. RODDICK.
Manager, North British Railway.

EXAMINATION, and placing RUBBLE around FOUNDATION of PIERS.

DEAR SIR, July 31st, 1878.

DURING the present month I have placed rubble around most of those piers you pointed out to me on the drawing at the interview you granted me at the Tay Bridge Station on the 2nd of present month. I have also made up with rubble, to the height of ordinary low-water mark, all the piers from No. 81 to No. 73 (north side of river). I have entirely surrounded these piers with an embankment of rubble that will defy the scour of having any effect on the piers for years. My reasons for so doing are two-fold; in the first place, the cylinders or bases of these piers are not sunk so deep in the original bed of river as those further out; and secondly, I find that the engine drivers always pull up at this part of the curve, and the breaks are applied to the carriages to enable the man on the engine to snatch his orders from the hand of the signalman before he can proceed onward, thus causing a drag which was felt below. This fine weather has enabled the steamer which brings the rubble to deposit it at the exact spot without fear of striking the columns, and can only be done at high water. Since the rubble has been banked up around these piers, the heaviest train makes no perceptible motion below, and if it was not for the noise you would not believe a train had passed over.

I should like to entirely surround the other cylinders with stones, from No. 73 to No. 61, up to low-water mark; also by so doing it would take in the whole of the curve, and as the sand-banks from 61 to 57 are level, and in places a little above low water, we should have at low water the whole of the north side of the bridge in sight, so that if scour took place at this most particular part of the structure, it could be seen at once, and dealt with accordingly.

Formerly the sand-banks were level with low-water mark, now we have between 6 and 7 feet of water from low water to bank at those piers I have named, viz., from 73 to 61. From 61 to 53 the sand-banks are generally in sight at low-water mark. If this was done during the autumn it would be a capital job, and a great saving to the North British Company in the future. It would take nearly 3,000 tons to carry out this suggestion at a cost of 750*l*.

I would now call your attention, Sir, to a statement I made in your presence at Edinburgh in the month of January of present year. Mr. Stirling, the chairman, asked how much stone it would take to secure the piers. I replied about 5,000 tons, at a cost of 6*s*. per ton, including working expenses, &c. Nearly that quantity was used, and economically laid down at the time of seeing you at the station on the 2nd. Since then I find that I have exceeded the quantity by 670 tons. I merely mention this to set myself right with you and the gentlemen present at that meeting. I am happy to say that the piers are not only secured at the price named, but upon a strict scrutiny made every day there is not the slightest sign of a settlement at any of the piers. My staff of men who work the steamboat are always busy overlooking bracings, &c., while I am attending to the Newport Branch. At high and low water I never neglect in fine weather to keep the sounding lines going between the tides. I go over the Newport Railway in the interval between the tides, so you see I have a pretty busy time of it.

I remain, &c.
(Signed) H. A. NOBLE,
Thomas Bouch, Esq., C.E. Inspector.

Rubble used and deposited during the month of July 1878:—

	Tons.
July 2, "Elcho Castle" (s.s.), south side, No. III.B,	70
„ 3, "Elcho Castle" (s.s.), around, No. 81	70
„ 4, "Elcho Castle" (s.s.), around, No. 80	70
„ 5, "Elcho Castle" (s.s.), around, No. 79	70
„ 8, "Elcho Castle" (s.s.), around, No. 79	70
„ 9, "Elcho Castle" (s.s.), north side, No. III.B.	70
„ 10, "Elcho Castle" (s.s.), north side, No. VI.B.	70

	Tons.
July 13, "Elcho Castle" (s.s.), around, No. 78 and 77	70
„ 15, "Elcho Castle" (s.s.), south side of, No. VI.B.	70
„ 16, "Elcho Castle" (s.s.), around, No. 74	70
„ 18, "Elcho Castle" (s.s.), around, No. 73	70
„ 19, "Elcho Castle" (s.s.), north side, No. XI.B.	70
„ 22, "Elcho Castle" (s.s.), north side, No. VIII.B.	70
„ 24, "Elcho Castle" (s.s.), north side, No. IX.B.	70
„ 25, "Elcho Castle" (s.s.), around, No. 75	70
„ 26, "Elcho Castle" (s.s.), around, No. 74	70
Total tons	1,120

P.S.—If you do not fill up the north side, as suggested, I shall only require about four cargoes for the ensuing month.

H. A. N.

Chambers, 111, George Street,
Edinburgh, September 3rd, 1878.

DEAR SIR,

I ENCLOSE you Mr. Noble's report for last month.

I am, &c.
(Signed) THOMAS BOUCH,
Per H. D. RODDICK.

John Walker, Esq.,
Manager, North British Railway.

II.

Tay Bridge, August 31st, 1878.

DEAR SIR,

I HAVE received enclosed account from Mr. Speed, who supplies the rubble stones for the piers of the bridge, and find the account correct.

Amount of rubble and where deposited during the month ending August 31st included :—

	Tons.
Aug. 7, Steamship "Elcho Castle," north side of XIV.B.	70
„ 9, Steamship "Elcho Castle," north side of 50	70
„ 13, Steamship "Elcho Castle," north side of 51	70
„ 15, Steamship "Elcho Castle," south side of XIII.B.	70
„ 17, Steamship "Elcho Castle," north side of IX.B.	70
„ 20, Steamship "Elcho Castle," north side of III.B.	70
„ 26, Steamship "Elcho Castle," south side of 47	70
„ 27, Steamship "Elcho Castle," south side of I.B.	70
Total	560

I have very little to say in regard to the bridge, only to reiterate my former statement, viz., that there is not the slightest appearance of weakness at any of the piers. Every part of the work, from the foundations to the superstructure, seem to be doing its work well, and there is not the least doubt in my mind but will continue so to do.

I remain, &c.
(Signed) H. A. NOBLE,
Inspector.

Thomas Bouch, Esq., C.E.

Chambers, 111, George Street,
Edinburgh, October 5th, 1878.

DEAR SIR,

I ENCLOSE Mr. Noble's report for the past month.

Yours, &c.
(Signed) THOMAS BOUCH,
Per H. D. RODDICK.

John Walker, Esq.,
Manager, North British Railway.

III.

Examination of Piers.

Newport, Fife, October 1st, 1878.

DEAR SIR,

I HAVE received enclosed account from Mr. Speed, who supplies the rubble stones for the piers of the bridge, and find the account correct.

Amount of rubble and where deposited for month ending September 30th inclusive :—

	Tons.
Sept. 3, "Elcho Castle" (s.s.), E., S.E., and N.E. of I.B.	70
„ 9, "Elcho Castle" (s.s.), south side and S.E. I.B.	70
„ 30, "Elcho Castle" (s.s.), north side and N.E. of No. 46	70
Total for September month	210

You will perceive by the above that I have used a very small quantity of rubble this month. I thought it advisable to wait till the equinoxial gales were over. We had a fair specimen of them since the 13th of present month. On Sunday the 15th it blew a hurricane quite as severe as it did when the girders fell. I am now going over all the piers again to see if there is any difference in the bed of the river, and shall act accordingly.

I remain, &c.
(Signed) H. A. NOBLE,
Inspector.

Thomas Bouch, Esq., C.E.

Chambers, 111, George Street,
Edinburgh, November 2nd, 1878.

MY DEAR SIR,

ACCORDING to your request I enclose as usual Mr. Noble's report on the state of the Tay Bridge, which is very satisfactory.

Can you use your influence in the proper quarter to get Mr. Speed's account paid.

Yours, &c.
(Signed) THOMAS BOUCH.

John Walker, Esq.

IV.

Examination of Piers.

Newport, Fifeshire,
November 1st, 1878.

DEAR SIR,

IN my last letter to you, dated September 30th, I enclosed Mr. Speed's account of rubble stones brought to Tay Bridge by him and deposited at their several places named by me during September month. It appears that he has not received the cash for the same. He has now sent to me the enclosed account for the last month and the month of October, and finding them correct I have signed them as usual, previous to sending them to you.

In my last letter or report, dated September 30th, I told you I was going over the whole of the soundings once more to see if the September gales had any effect in causing scour around the piers, I am happy to be enabled to state that the severe gales we have experienced here during the last six weeks at intervals have made no perceptible alteration in the bed of the river, so far as I have been able to accomplish up to present time. From south side of bridge toward north, as far as No. 48, the bed of the river is about the same. From 48 to Magdalene Green I have not gone over yet since the gales, but intend doing so every calm day, although I have no fear of the result.

The rubble I have had laid down these last two months completes those piers you marked down on the drawing when I presented the plan to you at our meeting at Dundee in July month, and where it was very necessary it should be laid. The following is the account of rubble used for the months of September and October :—

	Tons.
Sept. 3, "Elcho Castle" (s.s.), E., S.E., and N.E. of No. I.B.	70
„ 9, "Elcho Castle" (s.s.), south side of No. I.B.	70
„ 30, "Elcho Castle" (s.s.), north side and N.E. of No. 46	70
Oct. 15, "Elcho Castle" (s.s.), east, south-east, N.E., and N.W., of No. XIV.B.	70
„ 17, "Elcho Castle" (s.s.), south side and S.E., N.W., and N.E. of No. XIII.B.	70
„ 19, "Elcho Castle" (s.s), S.W. of No. IX., and N.E. of No. VIII.	70
„ 26, "Elcho Castle" (s.s.), S.W. and N.E. of No. VI.B.	70

		Tons.
Oct. 29,	"Elcho Castle" (s.s.), S.W. and N.E. of VII.B. - - -	70
„ 31,	"Elcho Castle" (s.s.), N.N.W. and N.E. of III.B. - -	70
	Total number of Tons -	630

I remain, &c.
(Signed) H. A. Noble,
Thomas Bouch, Esq., C.E. Inspector.

Chambers, 111, George Street,
Dear Sir, Edinburgh, December 19th, 1878.

I beg to enclose you Mr. Noble's report. I have instructed him to give notice to those workmen whose services can now be dispensed with.

Yours, &c.
(Signed) Thomas Bouch.

J. Walker, Esq.,
Manager, North British Railway.

V.

Newport, Fife,
Dear Sir, December 18th, 1878.

I deem it to be my duty to inform you that the number of workmen employed under my directions in the examination of foundations can now be reduced to two. Two workmen would only be required to assist me in continuing the soundings and examining the bolts and bracings of the columns during my stay here.

In regard to the scour of the bed of the river around the piers, I am happy to inform you that no alteration is perceptible since my last soundings, taken in September and October, and the quantity of rubble stones used since is only two cargoes, one since I saw you at your office and one previous. There will be no more rubble required at the piers, unless something occurs very different from what I expect.

The superstructure stands the traffic first class; there is not the least defect in the entire length of bridge, nor any sign of settlement at any one of the many piers.

I tried the expansion joints between the girders on the 18th day of July last, and the 13th of present month, the hottest and the coldest days this year. The contraction over the whole length of bridge is exactly 1′ 11$\frac{3}{16}$″. There are 18 expansion joints, and the two ends of bridge from abutments makes 20 places tried at precisely the same spot each time.

I am now anxiously watching the effects of the large quantities of ice (with which the river is covered) on the piers. In looking over my diary for 1874 I find we had blocks of ice 12″ in thickness, and no damage was caused, except a slight graze on the brickwork; certainly we only had six piers out on the north side between the shore and No. 57, and of course a greater space for the ice-floes to pass backward and forwards with the current. I shall be as vigilant as I can possibly be over this affair.

If my recommendation to reduce the number of workmen meets with your approval, you will please to notify the same, so that I can give the workmen timely notice.

I remain, &c.
(Signed) H. A. Noble,
Thomas Bouch, Esq., C.E. Inspector.

VI.

Sunken Girder, Tay Bridge.

Newport, Fife,
Dear Sir, April 11th, 1879.

At length I am in a position to inform you that I have succeeded in getting that portion of the sunken girder that was lying in the right-o'-way of vessels, between Nos. XII. and XIII. piers, clear, and I have now 10 feet of water from dead low-water mark to the highest point of fragmentary iron.

It has taken most of the time since March 14th, at which date I engaged the diver, and during the time I have fired off nearly half a cwt. of dynamite in small charges. I cut all the tie plates piece by piece (these plates held up the boom of the girder), till at length the boom sank with its own weight nearly 5 feet; by so doing it gives us, as I said above, 10 feet of water above highest point of sunken girder (taken at dead low-water mark), consequently there is no fear of any danger accruing to vessels which may happen to pass between these piers, and I am now ready to light the whole of the lamps on the bridge directly I receive orders to do so. Everything being ready when you name the time.

Cost.

The amount of money laid out by me for carrying out the work is *23l. 16s. 6d.* This includes every extra expense, such as diver's wage, overtime for permanent hands, dynamite, coils of fuse, detonators, india-rubber cloth, solution, ropes, extra boat bill, &c.

I was obliged to abandon the idea of employing a man with an electric battery. He wanted *3l. 3s.* for the first day, and *1l. 1s.* for every other day when called out. His expenses would have run up to *15l.*, so I gave him up, and bought coils of fuse with caps and fired them off myself.

In consequence of the dynamite agent at Dundee having no dynamite in his stores I had to go personally with my man to the various quarries and buy it; and as there is a heavy penalty if it is known you are carrying it through a town great secrecy had to be adopted. In fact, very few persons know what we have been about, and I paid for everything in connexion with the job ready cash. It was the best and only method I could adopt to get over the affair quietly and economically, and to be within the estimate I mentioned to you in my letter of the 10th March.

It now rests with you, Sir, to remit me the amount I have expended, by so doing you will greatly oblige,

Yours, &c.
(Signed) H. A. Noble,
Thomas Bouch, Esq., C.E. Inspector.

No. 15.

CORRESPONDENCE between HOPKINS, GILKES, AND CO. and the CLEVELAND NUT AND BOLT COMPANY relative to the BOLTS and NUTS for the TAY BRIDGE.

COPIES OF HOPKINS, GILKES, AND CO.'S ORDERS to the CLEVELAND NUT AND BOLT COMPANY for Bolts and Rivets as entered in the Cleveland Nut and Bolt Company's Order Book, showing deliveries, price terms, &c., sent to Solicitor, Board of Trade, by Mr. Hadland, by letter dated April 8th, 1880.

Order No.	Name.	Customer's Order No.	Description.	Weight.	Price.	Date of delivery.	Weight.	Remarks.
				tns. cwt. qr. lb.	£ s. d.		tns. cwt. qr. lb.	
	MAY 1874.							
11	52					May 14	0 1 3 11	
						„ 15	0 4 2 10	
R. 5	Hopkins, Gilkes, and Co., Tees Engine Works, Middlesbro'.	851	⅝ in. by 1⅝ in. cuphead rivets.	0 8 0 0	15 10 0	„ 16	0 8 0 12	Iron to be equal to sample given to them.
			„ 2¼ „	0 6 0 0	„	„ 14	0 6 1 15	
			„ 2⅜ „	0 9 0 0	„	„ „	0 1 0 2	
						„ 22	0 12 0 22	
			„ 3⅛ „	0 1 2 0	„	„ 14	0 1 2 0	
			⅞ in. 2⅜ „	0 6 0 0	„	„ 18	0 6 2 11	
			„ 2¼ „	0 9 0 0	„	„ „	0 8 0 8	
			„ 2½ „	1 2 0 0	„	„ 14	0 4 0 27	
						„ 15	0 2 0 18	
						„ 16	0 15 1 20	
			„ 2⅝ „	0 4 0 0	„	„ 18	0 4 3 10	
			„ 2¾ „	0 11 0 0	„	„ 14	0 0 3 12	
						„ 16	0 12 2 25	
			„ 3¼ „	0 9 0 0	„	„ 18	0 3 0 1	
			„ 3½ „	1 5 0 0	„	„ „	0 5 3 0	
						„ 21	0 19 0 11	
			„ 4¼ „	0 2 0 0	Per ton.	„ „	0 4 1 3	
19	91	905	500 „ 2¼ „		15 10 0	June 11	0 5 1 9	
						„ 19	0 0 3 18	
R. 20			4,300 „ 2¼ „		„	May 26	0 12 3 4	
						June 19	0 1 1 14	
			2,400 „ 2⅜ „		„	„ 8	0 12 0 8	
			2,000 „ 2⅝ „		„	„ 11	0 13 2 23	
			2,300 „ 2¾ „		„	„ 8	0 12 2 18	
						„ 19	0 1 0 18	
			6,000 „ 3¼ „		„	May 27	0 18 2 18	
						„ 30	0 13 3 6	
					„	June 2	0 8 0 4	
						„ 17	0 3 1 26	
			2,000 „ 3¾ „		„	May 27	0 16 1 23½	
						„ 30	0 0 1 25	
					„	June 17	0 1 0 16	
			150 „ 4¼ „		„	„ 11	0 1 0 20	
			3,200 ¾ „ 1⅝ „		„	May 21	0 7 0 0	
						„ 26	0 9 2 12	
			5,300 „ 1⅞ „		„	„ 27	0 14 3 26	
						„ 30	0 10 1 22	
					„	June 16	0 1 0 20	
			1,300 „ 2⅛ „		„	May 30	0 4 2 19	
			1,000 „ 2⅜ „		„	„ 21	0 4 0 21	
			4,000 „ 2⅞ „		„	„ 27	0 7 2 6	
						„ 28	0 10 1 17	
			Good quality.					
	JUNE 1874.							
15	209	1,002	170 rivets, ¾ in. by 1⅝ in. cuphead.		0 15 6	June 17	0 2 2 12	Usual terms.
						„ 27	0 1 1 25	
R. 43			380 „ 2 „		„	July 14	0 4 3 26	
			250 „ 2⅛ „		„	June 29	0 3 1 24	
			2,150 „ 2¼ „		„	„ 18	0 8 0 0*	
			900 „ 2⅜ „		„	„ 27	0 18 0 0*	
						„ 29	0 0 1 22	
			6,400 „ 1¾ „		„	„ 18	0 8 0 0	
						„ 19	0 1 0 20	
					„	„ 27	1 1 2 10	
						July 1	0 0 1 12	
*TA. 452.			*600 „ ½ in. by 1¼ „		0 19 6	„ 4	0 0 3 0	
						June 27	0 0 1 8	
			*200 „ 2¼ „		„			
			120 „ ⅞ in. by 1⅛ in. C.'s R.		0 15 6	„ „	0 0 1 12	
			250 „ „ 2 in. cup.		„	„ 20	0 2 0 3	
			720 „ „ 2⅛ „		„	July 14	0 0 1 18	
			970 „ „ 2¼ „		„	June 22	0 3 2 20	
			120 „ „ 2⅜ in. C.'s R.		„	„ 27	0 0 1 18	

Copies of Hopkins, Gilkes, and Co.'s Orders, &c.—*cont.*

Order No.	Name.	Customer's Order No.	Description.	Weight.	Price.	Date of delivery.	Weight.	Remarks.
				ts. cwt. qr. lb.	£ s. d.		ts. cwt. qr. lb.	
			1,360 rivets ⅞ in. by 2½ in. cup.		0 15 6	Aug. 13	0 0 1 15	
			1,170 „ „ 2⅝ „		„	June 20	0 3 0 15	
						„ 22	0 2 3 23	
					„	July 14	0 1 2 10	
		1,003	400 „ „ 2¾ „		„	Aug. 17	0 2 2 25	
			240 „ „ 3¼ „		„	July 1	0 1 0 26	
						Aug. 13	0 1 1 24	
			280 „ „ 3½ „		„	July 1	0 1 3 24	
			630 „ ⅝ in. by 2¼ „		„			
			3,140 „ „ 2½ „		„	June 27	0 18 0 3*	
			340 „ „ 2⅝ „		„	„ 29	0 0 2 15	
						July 3	0 0 3 24	
			230 „ ⅞ in. by 1⅞ in. C.'s R.		0 15 6	June 29	0 0 2 23	
			270 „ „ 1⅞ in. cup.		„	„ 20	0 1 3 12	
						Aug. 18	0 0 1 11	
			2,950 „ „ 2½ „		„			
			120 „ „ 2¼ in. C.'s R.		„	June 20	1 2 3 20	
			660 „ „ 2⅜ in. cup.					
			2,650 „ „ 2½ „		„	„ 22	0 1 3 8	
						Aug. 13	0 0 1 22	
					„	June 19	1 10 0 16	
			130 „ „ 2¾ „		„			
			180 „ ¾ in. by 1⅝ in. C.'s R.		„			
			2,130 „ „ 2 in. cup.		„	„ 17	0 9 0 20	
		1,004	50 „ „ 2½ „		„			
			2,610 „ „ 2¼ „		„	„ 18	0 10 2 14*	
			50 „ „ 2⅝ „		per cwt. delivered.			
28	July 1874. 439	1,212	1,000 „ ½ in. by 2⅜ in.		1 2 0	July 31	0 0 2 10	Wanted immediately.
						Aug. 6	0 0 1 12	
R. 92			200 „ „ 3¼ „		„			
2,911			Counter-sunk heads same as before.					
B. 212			3¼ in. by 8½ in. draw bolts.	0 5 0 0	„	Aug. 7	0 5 0 10	
2,921			¾ „ 4⅛ in. „		„			
			Sq. rd. sq. - - -	0 2 0 0	„	„ „	0 2 1 10	
N. 75			¾ in. hex. nuts tapped -	0 5 0 0	„	Sept. 14	0 3 3 7	
						„ 30	0 2 0 0	
1	August 1874. 474	1,283	2,000 ¾ in. by 1⅜ in. cuphead rivets.		13 10 0	Aug. 6	0 0 3 2	The rivets are to be of same quality as those we have recently been supplying, and any inferior quality will be rejected by the inspector.
R. 99						„ 7	0 1 1 25	
						„ 10	0 1 0 14	
						„ 13	0 1 1 19	
						Sept. 3	0 5 2 12	
			16,000 „ 1¼ „		„	Aug. 17	0 6 1 20	
						„ 18	0 2 3 16	
						„ 25	0 5 0 4	
						„ 26	0 2 2 17	
						„ 27	0 7 1 20	
						„ 28	1 5 2 26	
			970 „ 1¼ „		„	Dec. 11	0 2 1 7	
			850 „ 2⅛ „		„	Aug. 6	0 3 3 3	
						„ 7	0 3 2 27	
			25,950 „ 2¼ „			„ 8	0 13 3 25	
						„ 12	0 11 1 2	
						„ 13	1 7 0 3	
						„ 14	0 19 3 18	
			450 „ 2⅝ „			„ 12	0 2 0 27	
						„ 17	0 1 3 17	
			4,000 ⅞ „ 2½ „		„	„ 6	1 1 1 7	
						Sept. 16	0 1 0 2	
						„ 17	0 2 3 24	
			2,000 „ 2⅝ „		„	Aug. 6	0 4 2 18	
						„ 7	0 6 0 15	
						Sept. 17	0 3 0 7	
			1,500 ⅝ „ 1½ in. panhead		„	Dec. 21	0 3 1 11	1,800
			2,100 „ 1⅜ „		„	Aug. 13	0 0 2 27	
					per ton delivered.			

Copies of Hopkins, Gilkes, and Co.'s Orders, &c.—*cont.*

Order No.	Name.	Customer's Order No.	Description.	Weight.	Price.	Date of delivery.	Weight.	Remarks.
				ts. cwt. qr. lb.	£ s. d.		ts. cwt. qr. lb.	
28	617							
R. 126		1,333	1,700 ¾ in. by 2 in. cuphead rivets.		0 13 6	Sept. 17	0 7 0 15	1,700
						„ 24	0 6 0 16	
			350 „ 2½ „		„	„ 23	0 1 0 24	350
						Dec. 4	0 1 1 1	350
			100 „ 2¾ „		„	Sept. 1	0 0 1 24	100
			100 „ 3 „		„	„ „	0 0 2 0	100
			4,100 „ 1⅝ „		„	„ „	0 12 3 6	
						„ 11	0 1 2 0	
					„	„ 16	0 1 1 18	
			*1,600 „ 1¼ „		„	„ 23	0 4 0 20	
			*100 „ „ „		„			
			*2,000 ⅝ in. by 1½ in. panhead		„	Dec. 15	0 3 3 2	
						„ 16	0 2 3 24	
			9,800 „ 1¼ in. panhead rivets.		„	„ 21	0 2 1 26	1,000
			(Not required now.)					
			*2,000 ⅝ in. by 1⅜ in. panhead rivets.		„	„ 16	0 3 0 0	
			300 „ 3 „		„	Sept. 11	0 0 3 12	300
			1,000 „ 1¼ „					
			*300 „ 1⅜ „		„			
	Sept. 1874.							
	635							
B 329		1,366	Screw 48 bolt end - -		0 4 0	„ 9	0 2 1 15	12
3,172					per cwt.	„ 10	0 0 3 4	4
						„ 11	0 6 1 8	32

Nut will be sent with bolt ends.

16	721							
B. 375		11,440	9,800 bolts and nuts 1⅛ in. -		1 1 0	Oct. 30	1 10 1 7	1,150
						„ 31	0 10 2 0	400
			To tracing - - -		per cwt.	Nov. 7	1 14 0 24	1,350
						„ 11	0 11 1 24	450
	To be oiled and packed in double bags and labelled "Tay Bridge."				delivered	„ 13	0 10 1 4	405
						Dec. 3	1 0 1 7	800
					at their	„ 4	0 3 3 6	150
						„ 11	0 11 1 16	450
					works.	Feb. 5	3 3 2 7	3,380
						April 26	0 10 2 4	420
						May 11	0 14 2 8	580
						„ 22	0 3 3 24	160
						June 11	0 5 3 14	240
						„ 16	0 8 3 12	380
						„ 17	0 4 2 23	200
						„ 18	0 4 1 4	156
						„ 25	0 1 1 26	59
26	783							
R. 150		1,513	1,250 cup. rivets 3 in. by 1¼ in.			Sept. 29	0 5 2 24	1,250
			850 „ „ 1¼ „			Dec. 2	0 4 1 4	
			1,350 „ „ 2 „			Sept. 28	0 1 2 3	
						„ 29	0 0 3 18	
			1,200 „ „ 2⅛ „			„ 30	0 1 3 4	
						„ 28	0 1 3 3	
			100 „ „ 3⅜ „			„ 29	0 5 3 20	
						Nov. 28	0 0 2 4	100
28	797							
R. 155		1,523	5,300 „ ⅞ in. by 2 „		0 13 6	Oct. 7	0 8 0 20	
						Nov. 14	0 10 0 3	791
			540 „ „ 1⅞ „			Dec. 2	0 8 0 17	
			8,880 „ „ 2⅛ „		„	„ 3	0 10 1 24	
						„ 4	1 15 1 24	
					„	„ 23	1 17 0 12	
			300 „ „ 2¼ „		„	„ 2	0 10 3 20	
						„ 3	0 3 1 15	
			3,000 „ „ 2⅜ „		„			
			4,000 „ „ 2½ „		„	Nov. 17	0 14 0 20	2,544
						Dec. 17	0 2 3 8	617

Copies of Hopkins, Gilkes, and Co.'s Orders, &c.—*cont.*

Order No.	Name.	Customer's Order No.	Description.	Weight.	Price.	Date of delivery.	Weight.	Remarks.
				ta. cwt. qr. lb.	£ s. d.		ts. cwt. qr. lb.	
			12,700 cup. rivets $\frac{7}{8}$ in. by $2\frac{5}{8}$ in.		0 13 6	Oct. 2	0 4 3 8	3,161
			"			" 5	0 9 0 21	1,618
			"			" 20	0 13 1 0	2,294
						Nov. 28	0 12 2 19	2,300
						Dec. 1	0 19 2 12	2,624
						" 2	0 2 3 1	
						" 4	0 15 1 8	
			3,000 " " $2\frac{3}{4}$ "		"	Nov. 10	0 18 2 9	3,000
			9,400 " " $2\frac{1}{2}$ "		"	Oct. 2	0 16 0 24	3,023
						" 5	0 7 3 2	1,200
			"			" 7	0 2 0 0	
						" 17	0 10 2 12	1,680
						" 19	0 11 2 26	1,780
						" 20	0 14 0 14	1,794
			1,700 " " 3 "		"	" 2	0 10 0 14	1,748
						" 5	0 7 3 22	1,334
			200 " " $3\frac{1}{8}$ "		"	Nov. 13	0 1 1 1	200
						" "	0 6 0 20	850
			950 " " $3\frac{3}{4}$ "		"	" "	0 7 0 16	950
			170 " " $3\frac{5}{8}$ "		"	Oct. 19	0 1 0 24	170
			250 " " $3\frac{7}{8}$ "		"	" "	0 1 3 22	250
28	798							
R. 156		1,524	850 " " $3\frac{1}{4}$ "		"	" 20	0 6 2 2	
			850 " " 4 "		"	" "	0 6 3 0	
			1,350 " " $4\frac{1}{8}$ "		"	" 5	0 2 2 26	340
						" 17	0 3 2 4	436
						" 21	0 4 3 21	626
			450 " " $4\frac{1}{4}$ "		"	" 5	0 3 3 18	460
			200 " " 5 "		"	" "	0 2 0 5	215
			10,000 " $\frac{1}{4}$ in. by $1\frac{1}{4}$ "		"	" 27	0 2 2 27	
						" 28	0 14 1 19	
						" 29	0 9 1 2	
						" 30	0 15 2 10	
						" 31	0 6 1 3	
						Nov. 20	0 6 0 27	
			3,100 " " $1\frac{7}{8}$ "		"	Oct. 22	0 2 3 26	
						Nov. 10	0 7 1 10	
						" "	0 7 2 23	
			1,200 " " 2 "		"	Oct. 22	0 1 2 20	
						Nov. 17	0 2 0 15	
			3,700 " " $2\frac{1}{8}$ "		"	Oct. 21	0 17 0 26	
						Nov. 4	0 8 3 27	
			150 " " $2\frac{1}{4}$ "		"	Oct. 9	0 0 3 23	150
		1,525	2,850 pan. rivets $\frac{5}{8}$ in. by $1\frac{1}{2}$ in.			" 7	0 0 2 12	
						" 8	0 0 3 20	
						" 13	0 0 1 0	
						" 14	0 1 3 16	
			1,650 " " $1\frac{5}{8}$ "		"	" 7	0 1 0 16	
						" 8	0 1 1 10	
						" 9	0 3 3 12	
						" 10	0 1 3 13	
			23,700 " " $1\frac{1}{2}$ "			" 15	0 3 3 17	
						" 16	0 1 2 8	
						" 17	0 5 0 18	
						" 19	0 2 2 24	
						" 27	0 0 2 3	
						" 28	0 2 1 2	
						" 29	0 1 1 10	
						" 30	0 0 3 18	
						" 31	0 1 2 6	
						Nov. 2	0 2 0 21	
						" 3	0 1 3 14	
						" 5	0 2 3 22	
						" 7	0 2 3 12	
						" 13	0 5 3 6	
			2,900 " $\frac{7}{8}$ in. by $1\frac{3}{8}$ in.			" 17	0 3 2 18	
						" 21	0 2 2 4	
			4,500 " " $1\frac{3}{8}$ "		"	Oct. 10	0 2 3 6	
						" "	0 4 1 8	
						" 31	0 2 0 12	
						Nov. 7	0 0 2 10	
						" 9	0 1 1 23	
						" 10	0 2 0 19	
						" 23	0 1 0 8	
30	806							
B. 416		1,529	736 bolts $1\frac{3}{8}$ in. by $5\frac{1}{4}$ in.		1 1 6	" 18	0 2 3 25	134
						" 21	0 9 2 5	420
3,428	To be labelled "Tay Bridge."		Sq. rd. hex.			Dec. 3	0 1 2 12	71
						" 11	0 0 2 4	24
						Jan. 28	0 2 3 4	91
					"	Cancelled.		

Copies of Hopkins, Gilkes, and Co.'s Orders, &c.—*cont.*

Order No.	Name.	Customer's Order No.	Description.	Weight.	Price.	Date of delivery.	Weight.	Remarks.
				ts. cwt. qr. lb.	£ s. d.		ts. cwt. qr. lb.	
			768 bolts 1⅛ in. by 4⅝ in. Sq. rd. hex.		1 1 0	Dec. 3	0 14 1 5	660
						„ 11	0 8 2 14	400
W. 64			384 washers 3 in. diam. by ⅛ in. thick for 1⅛ in. bolts.		„	Nov. 4	0 2 3 15	384
					„	Oct. 22	0 3 2 24	2,300
			4,608 washers 2½ in. diam. by $\frac{5}{16}$ in. thick for 1⅛ in. bolts.			Nov. 28	0 4 0 16	
T.A. 832			352 washers 2½ in. diam. by ¼ in. thick for 1 in. bolts.		„ per cwt.	Oct. 26	0 1 3 14	352
3	Oct. 1874. 825							
W. 66								
T.A. 832	To be labelled "Tay Bridge."	1,556	270 washers 3½ in. diam. by ¼ in. thick for 1⅛ in. bolts.			Oct. 26		
12	863							
B. 165	To be addressed Hopkins, Gilkes, and Co., for "Tay Bridge."	1,579	3,600 cup. rivets ⅞ in. by 2½ in.		0 13 6	Oct. 24	0 4 3 23	1,391
						Nov. 21	0 5 2 24	
			3,800 „ „ 1⅞ „			„ 7	0 10 0 6	
					„	„ 10		
						„ „		
			1,800 „ „ 2⅝ „		„	„ 21	0 5 1 27	
			1,800 „ „ 2¼ „		„	„ 11	0 1 3 10	
						„ 23	0 5 2 20	1,581
						„ 24	0 2 0 20	
						„ 28	0 10 0 1	2,676
			2,200 „ „ 2 „		„	Oct. 20	0 8 2 0	2,200
			1,000 „ „ 3½ „		„	„ 21	0 4 3 20	1,000
			300 „ ⅞ in. by 2½ „		„	Dec. 16	0 1 0 24	300
			300 „ 1 „ „ „		(Not wanted.) (per cwt.)			
15	885							
B. 167		1,600	⅞ in. by 1⅛ in. rivets to sample.	1 18 0 0	1 7 0	Oct. 16	0 2 3 0	
						„ 17	0 8 2 13	
						„ 19	0 3 1 5	
						Dec. 5	0 2 3 18	
						„ 7	0 4 3 1	
						„ 8	0 6 0 8	
						„ 10	0 6 0 15	
			⅞ in. by 2½ „ „	0 2 0 0	„ per cwt.	„	0 2 0 16	
			To be made of Low Moor iron, which will be supplied by Hopkins, Gilkes, and Co. at 22*s.* per cwt.					
B. 599 4	Dec. 1874. 1,181	1,762	2,200 bolts 1¼ in. by 5½ in.		1 1 0	„ 24	0 6 2 1	200
3,971						Jan. 2	0 10 0 15	300
						„ 13	0 1 0 1	80
						„ 14	0 2 1 1	66
					per cwt. delivered.	„ 26	0 6 2 16	200*
						„ 27	0 10 1 1	300
						„ 28	0 5 0 9	150
						„ 29	0 6 1 7	187
						„ 30	0 1 1 0	37
						Feb. 2	0 2 2 9	76
						„ 3	0 2 1 1	67
						„ 4	0 7 3 25	238
						„ 6	0 10 0 8	300
						„ 8	0 4 2 23	141
			1,250 „ „ 5 „			Jan. 13	0 2 3 13	87
						„ 14	0 1 2 25	53
			Screwed, 2½ in.			„ 15	0 5 2 21	174
						„ 16	0 4 3 14	130

* Must be delivered during first week in January.

Copies of Hopkins, Gilkes, and Co.'s Orders, &c.—*cont.*

Order No.	Name.	Customer's Order No.	Description.	Weight.	Price.	Date of delivery.	Weight.	Remarks.
				ts. cwt. qr. lb.	£ s. d.		ts. cwt. qr. lb.	
			Hexheads and nuts, round necks and washers to each, $\frac{1}{16}$ in. thick. As per tracing.			Jan. 19	0 4 3 26	150
						,, 21	0 6 2 13	200
						,, 22	0 5 3 14	176
						,, 28	0 9 1 15	281
11	JAN. 1875. 1,293							
N. 197		2,005	1⅛ in. hex. nuts tapped (1,914.)	0 10 1 0	1 5 0	,, 26	0 1 0 2	All invoices for goods supplied against this order must be made out on separate forms, and have inserted on each, for "Tay Bridge Works."
						,, 28	0 1 0 18	
						,, 30	0 0 3 14	
						Feb. 3	0 1 2 4	
						,, 4	0 2 0 23	
						,, 6	0 2 3 14	
						,, 8	0 0 2 13	
W. 91			cwt. qr. lb. 1 in. "(584)" 2 1 10 -		1 5 0	Jan. 19	0 2 0 10	
TA. 1,142			364 washers, 3 in. dia. by ⅛ in. thick by 1⅛ in.		,,	Feb. 16		
			184 washers, 2⅛ in. dia. by ⅛ in. thick by 1 in.		,,		0 6 0 13	
			876 washers, 2⅛ in. dia. by ⅛ in. thick by 1 in.		,,			
					per cwt.			
May 3	MAY 1875. 1,971	2,777	46,000 cup. rivets, ⅞ in. by 1⅞ in.			May 6	0 14 3 4	4,500 *
						,, 11	0 3 3 3	1,100
						,, 19	0 4 3 28	1,600
						,, 20	0 0 1 10	100
						,, 25	0 18 2 23	6,000
						June 4	1 0 0 22	6,500
						,, 7	0 16 2 14	5,500
						,, 11	1 17 1 11	12,000
						,, 15	0 12 0 21	3,900
						July 7	0 15 0 6	4,800
			3,550 ,, ⅞ in. by 1⅝ in.			May 7	0 12 1 26	3,550
					12 15 0 per ton.			
			3,900 ,, ⅞ in. by 2½ in.			,, 7	0 1 0 14	290
						,, 19	0 15 1 21	3,610
			2,700 ,, ⅞ in. by 2½ in.			,, 7	0 4 2 12	1,200
						,, 19	0 5 3 20	1,500
			2,150 ,, ⅞ in. by 2⅝ in.			June 9	0 12 0 22	2,150
	1,972	2,776	3,800 ,, ⅞ in. by 1⅞ in.			May 11	0 13 1 0	Special attention to be given to the counting of the above rivets, and each bag to be labelled, Hopkins, Gilkes & Co., "Tay Bridge."
May 3			1,300 ,, ⅞ in. by 2⅝ in.			,, 7	0 1 1 26	
						,, 29	0 4 3 11	
			1,800 ,, ⅞ in. by 2½ in.			,, 20	0 3 1 3	
						,, 25	0 2 2 5	
						,, 29	0 1 0 3	
			2,200 ,, ⅞ in. by 2 in.			,, 20	0 6 1 21	
R. 378						,, 29	0 1 1 14	
					12 15 0			
			1,000 ,, ⅞ in. by 3½ in.			,, 20	0 0 3 2	150
						,, 25	0 0 2 7	100
						June 12	0 3 2 23	750
			300 ,, ⅞ in. by 2⅛ in.			,, 11	0 1 2 12	300
			300 ,, 1 in. by 2½ in.			May 29	0 1 2 7	220
May 3	1,973	2,778	340 ,, ⅞ in. by 1⅛ in.			,, 25	0 0 1 19	80
						June 14	0 1 0 20	260
						,, 14	0 1 0 21	260
						Aug. 10	0 8 3 2	1,790
			850 ,, ⅞ in. by 2 in.		12 15 0	May 20	0 2 2 21	550
						,, 31		90
						June 9	0 0 3 23	210
			380 ,, ⅞ in. by 2⅛ in.			,, 7	0 1 3 12	380
R. 379			2,200 ,, ⅞ in. by 2¼ in.			May 20	0 0 3 7	150
						June 4	0 10 1 1	2,050
			850 ,, ⅞ in. by 2⅛ in.			May 20	0 0 1 6	50
						June 11	0 5 2 10	800
			620 ,, ⅞ in. by 2⅜ in.			May 20	0 0 1 6	50
						,, 31	0 2 0 0	860
						June 9	0 1 0 18	210
			380 ,, ⅞ in. by 3⅛ in.			,, 11	0 5 2 18	880
			900 ,, ⅞ in. by 3½ in.			May 20	0 0 3 0	70
						,, 31	0 0 1 20	60
						June 24	0 5 2 12	870
			2,050 ,, ⅞ in. by 1⅞ in.					
			970 ,, ⅞ in. by 2⅛ in.			May 20	0 3 3 8	970
			300 ,, ⅞ in. by 1½ in.			June 24	0 0 2 4	30
			700 ,, ⅞ in. by 1⅝ in.			Sept. 8	0 1 1 4	
May 3	1,974	2,779	1,260 ,, ⅞ in. by 2 in.			June 9	0 3 1 27	750
						,, 29	0 2 3 4	600

Copies of Hopkins, Gilkes, and Co.'s Orders—*cont.*

Order Number.	Name.	Customer's Order Number.	Description.	Weight.	Price.	Date of Delivery.	Weight.	Remarks.
				ts. cwt. qr. lb.	£ s. d.		ts. cwt. qr. lb.	
			1,100 cup. rivets, $\frac{7}{8}$ in. by $2\frac{1}{2}$ in.			June 7	0 5 0 20	1,100
			2,150 „ $\frac{7}{8}$ in. by $2\frac{1}{4}$ in.			„ 4	0 10 3 4	1,150
			3,100 „ $\frac{7}{8}$ in. by $2\frac{3}{4}$ in.			„ 9	0 11 3 10	3,000
			300 „ $\frac{7}{8}$ in. by $2\frac{1}{2}$ in.			May 31	0 0 1 19	60
						June 24	0 2 0 9	240
R. 380			1,100 „ $\frac{7}{8}$ in. by $3\frac{1}{2}$ in.			„ 11	0 7 2 2	1,100
			1,300 „ $\frac{3}{4}$ in. by $2\frac{1}{2}$ in.			May 20	0 0 2 14	300
						„ 25	0 2 3 5	800
			650 „ $\frac{3}{4}$ in. by $2\frac{3}{4}$ in.			„ 20	0 1 1 13	320
						„ 23	0 1 0 27	330
			400 „ $\frac{5}{8}$ in. by $1\frac{1}{4}$ in.			June 24	0 0 2 26	400
			850 „ $\frac{5}{8}$ in. by $1\frac{3}{8}$ in.			Sept. 8	0 2 0 10	
			170 „ $\frac{5}{8}$ in. by $1\frac{1}{2}$ in.			Aug. 24	0 1 0. 6	176
	June, 1875. 2,203							
B. 1,128 4,582 22 R. 40		2,931	170 $\frac{1}{2}$ in. by 5 in. couch screws.			June 29	0 0 2 6*	
			3,000 $\frac{7}{8}$ in. by 2 in. cup rivets.			„ 24	0 7 3 6	2,100
			3,000 $\frac{7}{8}$ „ $2\frac{1}{2}$ in. „			„ 24	0 10 0 11	2,750
	July, 1875. 2,274							
5		2,981	7,200 „ $2\frac{1}{2}$ in. rivets, cupheads.		0 12 6	July 7	0 11 2 0	3,000
						„ 7	0 2 1 8	600
						„ 13	0 11 0 5	2,700
						„ 27	0 3 3 11	900
R. 418	To be addressed:— H., G. & Co., "Tay Bridge."		3,600 „ $2\frac{1}{4}$ in. „		„	„ 7	0 16 2 22	3,600
			4,400 „ 2 in. „		„	„ 7	0 14 2 20	4,400
			2,000 „ $3\frac{1}{2}$ in. „		„	„ 13	0 10 0 21	2,000
	August, 1875.							
B. 1,251 4	2,435	3,111	482 bolts, $1\frac{1}{8}$ in. by $6\frac{1}{2}$ in. Sq. rd. hex.		0 19 0	Oct. 14	0 6 3 9	260
			1,996 bolts, $1\frac{1}{8}$ in. by $4\frac{3}{4}$ in.		„	„ 22	0 5 3 21	250
						Nov. 2	0 7 3 5	350
						„ 11	0 4 3 7	210†
						„ 25	0 14 1 27	630
						„ 29	0 6 0 15	250
						Dec. 1	0 6 3 2	400
			228 „ by $5\frac{1}{2}$ in. Sq. rd. hex.		„	„	0 7 3 3	Completes.
1,449						Oct. 9	0 5 2 5	214
			1,176 bolts, $1\frac{1}{8}$ in by $4\frac{3}{4}$ in.		„	„ 2	0 4 3 9	391
						„ 4	0 2 3 3	
			90 „ by $5\frac{1}{2}$ in. Sq. rd. hex.		„	„ 27	0 8 1 2	600
	September, 1875.							
1,487 7	2,622	3,226	2,000 3 in. by $\frac{1}{2}$ in. snap-head rivets.			Sept. 20	0 8 3 8	2,000‡
			2,500 $2\frac{3}{4}$ „ „			„ 14	0 3 3 1	900
						„ 16	0 8 0 4	1,600
			14,000 $2\frac{1}{2}$ „ „			„ 16	0 8 1 0	200
						„ 23	0 7 1 16	1,800
						Oct. 9	1 11 1 0	3,000
						„ 16	0 3 0 8	
						„ 21	0 13 1 0	
			21,000 $2\frac{1}{2}$ „ „		12 0 0 per ton.	Sept. 14	0 7 0 2	1,900
						„ 16	1 14 3 6	1,000
						„ 20	0 9 1 11	2,500
						„ 22	0 15 1 20	1,500
						„ 23	0 3 2 2	1,000
						Oct. 4	1 0 2 10	5,500
						„ 16	0 17 3 23	
			5,000 $1\frac{7}{8}$ „ „			Sept. 14	0 16 0 7	5,000
						„ 22	0 5 0 0	1,800
						Oct. 21	0 18 2 11	
			1,700 $3\frac{1}{8}$ $\frac{7}{8}$ „			Sept. 20	0 12 0 18	1,700
			1,000 $3\frac{1}{8}$ „ „			„ 22	0 7 3 14	1,000
			1,600 3 „ „			„ 20	0 6 1 14	
						„ 22	0 3 2 20	600
			2,000 $2\frac{1}{2}$ „ „			„ 20	0 7 1 8	1,500
						„ 22	0 2 2 14	500
			500 $2\frac{1}{2}$ „ „			„ 22	0 2 2 3	500
25	2,725	3,308	22,000 $\frac{7}{8}$ in. by $1\frac{7}{8}$ in. cup rivets.		11 15 0	Sept. 20	0 3 3 26	1,200
						Oct. 2	1 14 0 11	10,000
						„ 4	0 11 0 7	3,500
						„ 9	0 10 1 16	2,700
						„ 12	0 14 2 21	4,600
			11,000 „ $2\frac{1}{2}$ „			Sept. 30	0 6 3 7	1,900
						Oct. 2	0 9 2 7	9,000
						„ 13	0 16 3 26	4,500
						„ 20	1 5 0 14	6,625

* Most urgently wanted to be sent to "Tay Bridge" to-morrow.

† To be packed in [illegible]

Copies of Hopkins, Gilkes, and Co.'s Orders, &c.—*cont.*

Order No.	Name.	Customer's Order Number.	Description.	Weight.	Price.	Date of Delivery.	Weight.	Remarks.
				ts. cwt. qr. lb.	£ s. d.		ts. cwt. qr. lb.	
			700 ¾ in. by 1½ in. cup rivets		11 15 0	Sept. 30	0 2 0 21	700
	Oct. 1875.							
18	2,805	3,360	¾ in. by 2⅜ in. cup rivets -	1 0 0 0	„	Oct. 22	0 18 1 9	
2,584			⅞ „ 1⅞ „ -	1 0 0 0	„	„ 15	0 3 0 3	
			1 „ 2⅛ „ -	0 10 0 0	„			
			1 „ 2 „ -	0 10 0 0	„	„ „	0 11 3 24	
			1 „ 2⅛ „ -	0 10 0 0	„	„ „	0 12 3 15	
			1 „ 1⅝ „ -	2 10 0 0	„	„ 29	1 0 0 0	
						„ 22	0 12 0 15	
						„ 26	0 11 1 4	
						Nov. 24	0 12 1 0	
						„ 29	0 12 2 23	
	2,847	3,390						
26			1,000 ⅞ in. by 2½ in. rivets, countersunk.		„	„ 3	0 1 3 6	
			1,100 ¾ in. by 3 in. rivets, countersunk.		„	„ 10	0 1 2 0	
						Oct. 27	0 2 0 24	
	Nov. 1875.							
5	2,912	3,448	20,000 ¼ in. by ⅞ in. rivets, cupheads.		„ per ton	Nov. 23	2 4 0 4	} 20,000
			12,000 ¾ in. by 2½ in. rivets, cupheads.				1 6 2 20	
26	3,010							
		3,533	⅞ in. by 4½ in. rivets, cuphead	0 3 0 0				
			1 in. by 3 in. „ -	0 5 0 0				
			¾ in. by 2 in. „ -	0 10 0 0				
						Dec. 3	0 4 0 20	
			„ 2½ in. „ -	0 10 0 0		„ 21	0 15 3 12	
			„ 2¾ in. „ -	0 10 0 0	11 15 0 all round			
						„ 1	0 3 0 10	
			„ 3 in. „ -	0 5 0 0		„ 8	0 8 0 24	
						„ 1	0 12 2 24	3,000
			3,000 ¾ in. by 2½ in. „ -					
			1,600 „ 2¾ in. „ -					
			1,800 „ 2⅞ in. „ -					
			1,100 „ 2⅞ in. „ -					
			1,200 „ 2⅞ in. „ -			Nov. 3	0 5 1 0	
			1,400 „ 3 in. „ -			„ 30	0 7 0 16	
						Dec. 1	0 7 0 16	
			800 „ 3½ in. „ -			Nov. 30	0 4 0 24	
			4,100 „ 1⅛ in. „ -					
			4,200 „ 1⅜ in. „ -					
			4,400 „ 2 in. „ -			Dec. 1	0 18 1 16	
30	3,085							
	Urgent—Carriage paid.	3,554	440 bolts 1½ in. by 6 in. long. Sq. heads, rd. necks. ½ in. hex. lock nuts.		0 17 6			
			400 bolts 1⅝ in. by 6½ in. „		„			
			400 „ „ 4½ in. „		„			
			400 „ „ 4¾ in. „			„ 15	0 10 0 12	402
						„ 21	0 4 3 2	
			1,640 washers for above ⅛ in. thick, wanted immediately.		„	„ 28	0 4 2 4	
		3,544	6,470 1½ in. by 4¼ in. bolts, sq. heads.		„	„ 15	0 7 2 12	343 single nuts.
			Hex. nuts, rd. necks.			„ „	0 12 1 15	445 „
			2,860 1⅝ in. by 5¼ „		„	„ 8	0 11 1 25	
			700 „ 5½ „		„			This does not appear to be properly marked off, although the order was made.
			1,570 „ 6½ „		„			
			1,120 by 1 in. 2½ in. sq. heads, hex. nuts, and rd. necks.		„	„ 9	0 15 3 0	1,125
			1,180 1 in. by 3¼ in. sq. heads, hex. nuts, and rd. necks.		„	„ 8	0 19 2 24	
			250 1 in. by 3⅝ in. sq. heads, hex. nuts, and rd. necks.		„	„ „	0 4 0 24	
			350 1 in. by 5 in., with hex. lock nuts 1 in. thick, and the other ½ in. thick rd. necks.		„			
			375 1 in. by 5 in. T heads, hex. nuts, rd. necks.		„	„ 9	0 6 2 0	350
			240 1 in. by 6 in. sq. heads, hex. nuts, and rd. necks.		„	„ „	0 4 3 20	183

Copies of Hopkins, Gilkes, and Co.'s Orders, &c.—*cont.*

Order No.	Name.	Customer's Order Number.	Description.	Weight.	Price.	Date of Delivery.	Weight.	Remarks.
				ts. cwt. qr. lb.	£ s. d.		ts. cwt. qr. lb.	
			15,400 washers, 2½ in. dia., $\frac{5}{16}$ in. for 1½ in. bolts.		0 17 6	Dec. 15	1 12 1 0	
			3,600 $\frac{5}{16}$ in. by 2½ in. for 1 in. bolts.		,,	,, 22	0 4 2 4	
			360 ½ in. by 3¼ in. for 1¼ in. bolts.					
		3,553	500 1½ in. by 4¾ in. sq. heads, hex. nuts, and rd. necks.		,,			
			200 1½ in. by 6¼ ,,		,,			
			100 ,, 5¼ ,,		,,			
			40 1 in. by 8½ hex. lock nuts and rd. heads.		,,	,, 16	0 1 0 11	42
			100 washers, ½ in. by 3 in. for 1½ bolts.		,, ct.			
			1,200 washers, $\frac{5}{16}$ in. by 2½ in. for 1½ bolts.					
	Dec. 1875.							
3	3,055	3,566	500 couch screws, ½ in. by 3½ in. sq. heads and rd. necks.		1 5 0	Oct. ,, 15	0 1 0 23	500
	3,060	3,573	1,260 ¾ in. by 1½ in. cup rivets	0 10 0 0				
			,, 1¾ ,,	0 10 0 0				
			,, 2¼ ,,	0 10 0 0		,, 8	0 11 0 24	
			,, 2¾ ,,	0 6 0 0		,, 18	0 6 1 20	
			,, 3¼ ,,	0 6 0 0		,, 8	0 6 3 12	
			,, 3¾ ,,	0 6 0 0		,, 18	0 7 0 18	
			⅞ in. by 3¼ in. cupheads	0 6 0 0		,, ,,	0 5 0 0	
			,, 4 ,,	0 6 0 0		,, ,,	0 7 0 24	
			⅞ ,, 2 ,,	0 10 0 0		,, ,,	0 15 0 6	
			,, 2¼ ,,	0 10 0 0		,, 14	0 12 2 16	
			,, 2½ ,,	0 10 0 0				
			,, 3 ,,	0 5 0 0				
			,, 3¼ ,,	0 10 0 0				
			,, 3½ ,,	0 5 0 0				
	3,063							
6		3,571	1,300 1 ,, 2¾ ,,	Mason.		,, 15	0 8 2 26	
			1,800 ,, 2¾ ,,			,, ,,	0 7 2 4	
			850 ,, 1¾ ,,	,,				
			1,000 ,, 2⅞ ,,	,,				
	Jan. 1876.							
13	5	3,680	1¼ in. hex. nuts, untapped -	0 10 0 0	1 1 0	Jan.	0 10 0 0	
			1⅛ ,, ,, -	0 10 0 0	1 0 0	,,	0 10 0 0	
14	6	3,689	⅞ in. sq. nuts, tapped -	0 2 0 0		,,	0 1 0 0	
						,,	0 1 0 19	

Copies of Letters from Cleveland Bolt Company to Hopkins, Gilkes & Co., complaining of Quality of Iron. Sent to Solicitor, Board of Trade, by Mr. Hadland, by Letter dated 8th April 1880.

Letter to H., G. & Co., Ld.

Gentlemen, September 26th, 1873.

Please name your lowest price for the following:—

152 bars 1¼ in. by 12 ft.
128 ,, 2 in. by ,,
128 ,, 1¾ in. by ,,
128 ,, 1½ in. by ,,
128 ,, 1⅛ in. by ,,
} About 30 tons.

Crown quality; also for *best quality*, and state how soon you can deliver.

A reply by bearer will oblige.

Yours, &c.
Signed for C. B. & N. Co.,
Joseph Preston.

Order to H., G. & Co., Ld.

September 26th, 1873.

152 bars 1¼ in. by 12 ft. best quality
128 ,, 2 in. by ,, ,,
128 ,, 1¾ in. by ,, ,,
128 ,, 1½ in. by ,, ,,
128 ,, 1⅛ in. by ,, ,,
} Well rolled and exact to size.

at 12*l.* 16*s.* per ton d/d. here.

Tough and fibrous.

Delivery in two or three days from above date.

Signed for C. B. & N. Co.,
Jos. Preston.

Letter to H., G. & Co.

September 30th, 1873.

Respecting the parcel of 2 in. round iron which we have to hand, we beg to say that a number of the bars are ½ in. too short, and are consequently useless to us. When we have got through the bulk, we will inform you what amount of short bars there are.

We remain, &c.
Signed for C. B. & N. Co.
Jos. Preston.

P.S.—Since writing the above we have tested the iron, and we regret to say that the result has been the reverse to satisfactory, so far from being best, it is most inferior.

Letter to H., G. & Co., Ld.

Dear Sirs, October 1st, 1873.

We are duly in receipt of your favour of to-day, and regret that we cannot accept the bars referred to at "common" price, as we have a large quantity at present in stock, which is superior to yours in quality. You will please, therefore, replace the defective bars with "Best" as per our contract. When you contracted, the stipulation was delivery in two or three days, and on your engagement to us we are apprehensive of very serious difficulties if you do not relieve us at once. We have only had the 2 in. round as yet, which is useless to us.

Be careful about the lengths, please.

Be good enough to see that the bars are well rolled and of fibrous quality, or they will be refused by the engineer.

Yours, &c.
Signed for C. B. & N. Co.,
Joseph Preston.

LETTER to H., G. & Co.

October 2nd, 1873.

THE 1¼ in. and 1½ in. round iron sent from your works last night, as per your invoice to hand this morning, has not reached here, nor can we tract it between Newport and Bottle House Point.

We are really pushed to the utmost extremity for this iron, and must urge you to ascertain its whereabouts without delay, failing which the parcel must be replaced immediately.

Our contract is very binding, being based on the time named for delivery by you, and we fear most serious consequences.

We trust you will realize the importance of this matter to us, and take steps accordingly with promptitude.

Yours, &c.

Signed for C. B. & N. Co.,
JOSEPH PRESTON.

LETTER to H., G. & Co., Ld.

GENTLEMEN, October 3rd, 1873.

IN reply to yours of yesterday's date, we will keep a portion of the 2 in. round at "common" price, but, having a good supply of this quality, we cannot accept the whole.

We have been compelled to purchase at a higher rate suitable 2 in. for the contract, and, therefore, must request you to cancel this size.

We fear our clients will cancel the whole of the order on account of the delay which has attended its execution, and we must impress upon you the necessity of sending us the balance of the iron immediately.

Yours, &c.

Signed for C. B. & N. Co.,
G. N.

LETTER to H., G. & Co. Ld.

GENTLEMEN, October 3rd, 1873.

WE have your favour of to-day, and beg to say that the information conveyed to you by the Railway Co., to the effect that the trucks containing the 1¼ in. and 1½ in. round were put back into our siding yesterday morning is totally untrue.

Yours, &c.

Signed for C. B. &N. Co.,
G. N.

LETTER to H., G. & Co., Ld.

DEAR SIRS, October 7th, 1873.

REFERRING to the 1¼ and 1½ round iron which you have sent us, we regret to find, on testing, that it is of very inferior quality, and totally unfit for the purpose for which it was ordered.

Our order was for "Best" iron, and in your letter of the 2nd inst., you state you are preparing iron of suitable quality expressly for us.

Please understand that we reject the iron, and must request you to replace it by another parcel of proper quality.

We send you samples of bars, which we have tested, for your inspection.

As we are already behind in our contract, in consequence of your delay, you will see the necessity of at once letting us have another supply without a moment's delay.

Relying on your attention,

We are, &c.

Signed for C. B. & N. Co.,
JOS. PRESTON.

COPIES OF ORDERS sent by Hopkins, Gilkes, & Co. to Cleveland Nut and Bolt Company, Limited. (Originals at Middlesboro'.) Sent to Solicitor, Board of Trade, by Mr. Hadland, by Letter dated 8th April 1880.

H., G. & Co.'s No. 851 — C. B. & N. Co.'s No. 52

May 11th, 1874.

8	cwt. of	¼ in.	by 1½ in.	rivets, snapheads.
6	,,	,,	by 2½ in.	,,
9	,,	,,	by 2¾ in.	,,
1½	,,	,,	by 3½ in.	,,
6	,,	½ in.	by 2½ in.	,,
9	,,	,,	by 2½ in.	,,
22	,,	,,	by 2¾ in.	,,
4	,,	,,	by 2¾ in.	,,
11	,,	,,	by 2¾ in.	,,
9	,,	,,	by 3½ in.	,,
25	,,	,,	by 3¾ in.	,,
2	,,	,,	by 4½ in.	,,

112½ cwt. at 15l. 10s. per ton as per your quotation and to sample iron received to-day.

Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

H., G. & Co.'s No. 905 — C. B. & N. Co.'s No. 91

May 19th, 1879.

500	¼ in.	by 2½ in.	rivets, snapheads, good quality.	
4,300	,,	by 2¼ in.	,,	,,
2,400	,,	by 2⅜ in.	,,	,,
2,000	,,	by 2½ in.	,,	,,
2,300	,,	by 2¾ in.	,,	,,
6,000	,,	by 3½ in.	,,	,,
2,000	,,	by 3¾ in.	,,	,,
150	,,	by 4½ in.	,,	,,
3,200	⅜ in.	by 1½ in.	,,	,,
5,800	,,	by 1⅝ in.	,,	,,
1,300	,,	by 2½ in.	,,	,,
1,000	,,	by 2¾ in.	,,	,,
4,000	,,	by 2¾ in.	,,	,,

Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

1,002 — June 15th, 1874. — 209

170	rivets, ¼ in.	by 1½ in.	snap.	
380	,, ,,	by 2 in.	,,	
250	,, ,,	by 2⅛ in.	,,	
2,150	,, ,,	by 2¼ in.	,,	
900	,, ,,	by 2⅜ in.	,,	
6,400	,, ,,	by 1½ in.	,,	
600	,, ½ in.	by 1½ in.	,,	
200	,, ,,	by 2¼ in.	,,	
120	,, ⅝ in.	by 1⅝ in.	countersunk	
250	,, ,,	by 2 in.	snap.	
720	,, ,,	by 2⅛ in.	,,	
970	,, ,,	by 2¼ in	,,	
120	,, ,,	by 2¼ in.	countersunk.	
1,360	,, ,,	by 2½ in.	snap.	
1,170	,, ,,	by 2⅝ in.	,,	

Signed for H., G. & Co., Ld.
HENRY LEWIS.

1,003 — 209

400	⅜ in.	by 2¾ in.	rivets, snap.	
240	,,	by 3¼ in.	,,	,,
280	,,	by 3½ in.	,,	,,
630	⅝ in.	by 2⅛ in.	,,	,,
3,140	,,	by 2¼ in.	,,	,,
340	,,	by 2⅜ in.	,,	,,
230	⅝ in.	by 1¾ in.	,,	countersunk.
270	,,	by 1¾ in.	,,	snap.
2,950	,,	by 2¼ in.	,,	,,
120	,,	by 2¼ in.	,,	countersunk.
660	,,	by 2⅜ in.	,,	snap.
2,650	,,	by 2⅜ in.	,,	,,
130	,,	by 2¾ in.	,,	,,
180	⅝ in.	by 1⅞ in.	,,	countersunk.
2,130	,,	by 2 in.	,,	snap.

Signed for H., G. & Co., Ld.,
HENRY LEWIS.

1,004 — June 15th, 1874. — 209

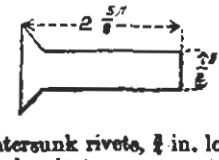
50	¼ in.	by 2⅛ in.	rivets, snap.	
2,610	,,	by 2¼ in.	,,	,,
50	,,	by 2⅜ in.	,,	,,

¾ in. and ⅞ in. rivets, at 15s. 6d.
½ in. rivets, at 19s. 6d. as per your quotation of the 13th inst.

Signed for H., G. & Co., Ld.
HENRY LEWIS.

1,212 — July 28th, 1874. — 439

Original order, 1,500, altered to 1,000 countersunk rivets.



200 countersunk rivets, ⅝ in. long. Same tool as last.
5 cwts. of ¾ in. by 3½ in. bolts and nuts, common draw bolts.
2 cwts. of ¾ in. by 4½ in. bolts and nuts, common draw bolts.
5 cwts. of 3 in. cantled nuts, tapd.

Signed for H., G. & Co., Ld.,
R. T.

H., G. & Co.'s No. C. B. & N. Co.'s No.

1,233 August 1st, 1874. 474

2.000 ⅞ in. rivets by 1¼ in. long, snapheads.
16.000 „ „ by 1⅜ in. „ „
970 „ „ by 1½ in. „ „
350 „ „ by 2⅛ in. „ „
25,950 „ „ by 2¼ in. „ „
450 „ „ by 2⅜ in. „ „
4,000 ¾ in. „ by 2½ in. „ „
2,000 „ „ by 2⅝ in. „ „
1,800 ⅝ in. „ by 1¼ in. panheads.
2,100 „ „ by 1⅜ in. „

Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

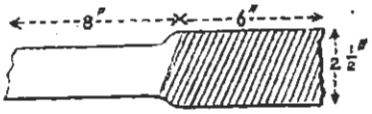
1,353 August 28th, 1874. 617

1,700 ⅞ in. by 2 in. rivets, snapheads.
350 „ by 2⅛ in. „ „
100 „ by 2⅜ in. „ „
100 „ by 3 in. „ „
4,100 „ by 1⅛ in. „ „
1,600 „ by 1⅜ in. „ „
100 „ by 1½ in. „ „
5,600 ⅝ in. by 1½ in. panheads.
9,800 „ by 1¼ in. „
13,400 „ by 1⅜ in. „
300 „ by 3 in. „
1,000 „ by 1½ in. „
300 „ by 1⅝ in. „
300 „ by 1¾ in. „

Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

1,366 August 31st, 1874. 635

48 Screw bolt ends.



Nut will be sent with bolt ends at 4*s.* per cwt.

Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

1,440 September 15th, 1874. 721

9,800 1¼ inch bolts to our tracing sent August 11.
Bags to be extra strong.
Price 21*s.* per cwt. delivered at our works.
To be oiled and packed in bags ready for sending off.

Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

Copy of letters attached to above order.
September 15th, 1874.

With this we beg to enclose your order for 9,800 1¼ inch bolts to our tracing at 21*s.* per cwt., delivered here in accordance with your offer of the 12th August.

Of course you will oil the bolts before sending them, and pack them in bags, *sufficiently strong for their transit with other goods which we shall have to send to the "Tay Bridge," if this* should not be within the scope of your offer, you must please advise us at the earliest possible to-morrow.

Yours, &c.
Signed H., G. & Co., Ld.,
EDGAR GILKES.

September 16th, 1874.

Please note that the order for 9,800 bolts, 1¼ inch dia. should read 9,800 bolts 1¼ inch dia. to tracing.

Signed for H., G. & Co., Ld.,
R. TELFORD.

1,513 September 25th, 1874. 783

1,250 ⅞ in. by 1½ in. rivets, cupheads.
850 „ by 1¾ in. „
1,350 „ by 2 in. „
1,200 „ by 2¼ in. „
100 „ by 3¼ in. „

Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

H., G. & Co.'s No. C. B. & N. Co.'s No.

1,523 September 28th, 1874. 797

5,300 ⅞ in. diam. by 2 in. long rivets, cupheads.
540 „ by 1¾ in. „
8,830 „ by 2¼ in. „
800 „ by 2⅜ in. „
3,000 „ by 2½ in. „
4,000 „ by 2⅝ in. „
12,700 „ by 2¾ in. „
3,000 „ by 2⅞ in. „
9,400 „ by 2¾ in. „
1,700 „ by 3 in. „
200 „ by 3⅛ in. „
850 „ by 3¼ in. „
950 „ by 3⅜ in. „
170 „ by 3⅝ in. „
250 „ by 3¾ in. „

Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

1,524 September 28th, 1874. 798

850 ⅞ in. by 3¾ in. cuphead rivets.
850 „ by 4 in. „
1,350 „ by 4⅛ in. „
450 „ by 4¼ in. „
200 „ by 5 in. „
10,000 ¾ in. by 1¼ in. snapheads.
3,100 „ by 1⅜ in. „
1,200 „ by 2 in. „
3,700 „ by 2⅛ in. „
150 „ by 2¼ in. „

Signed for H., G. & Co. Ld.,
ROBERT TELFORD.

1,525 September 28th, 1874. 798

2,850 ⅝ in. by 1¼ in. panhead rivets.
1,650 „ by 1⅜ in. „
23,700 „ by 1½ in. „
2,900 „ by 1⅝ in. „
4,500 „ by 1¾ in. „

Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

1,529 September 29th, 1874. 806

736 bolts, 5½ in. by 1⅛ in. square heads, hex nuts, round necks.
176 bolts, 8⅛ in. by 1 in. square heads, hex lock nuts, round necks.
768 bolts, 4⅛ in. by 1⅛ in. square heads, hex nuts, round necks.
384 washers, 3 in. diameter by ⅛ in. thick, for 1⅛ in. bolts.
4,608 washers, 2⅛ in. diameter by $\frac{3}{16}$ in. thick, for 1⅛ in. bolts.
352 washers, 2⅛ in. diameter by ¼ in. thick for 1 in. bolts.
21*s.* cwt. all round.

Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

LETTER attached to the above order.
September 29th, 1874.

GENTLEMEN,

REFERRING to our order of September 15th, for 9,800 bolts and nuts, please suspend the making of these until we hear from the people at Tay Bridge, as we believe only a portion of the order is required at present, we will write you again when we receive definite instructions.

We beg to accept your offer of September 14th, for bolts, and herewith enclose formal order for same, with the exception of 1,568 bolts 1¼ in. by 4¼ in.; we make this exception because these bolts form part of the 9,800 which you have already contracted to supply.

We are, &c.
HOPKINS, GILKES & Co., Ld.,
(Signed) J. W. WILLIAMS.

H., G. & Co.'s No. C. B. & N. Co.'s No.

1,556 October 2nd, 1874. 825

270 washers for 1½ in. bolts, wanted at once.

T A 832. Signed for H., G. & Co.,
ROBERT TELFORD.

1,579 October 12th, 1874. 863

3,600 ¾ in. by 2½ in. snaphead rivets.
3,800 „ by 1¾ in. „
1,300 „ by 2¼ in. „
1,800 „ by 2¼ in. „
2,200 „ by 2 in. „
1,000 „ by 3½ in. „
300 ⅞ in. by 2½ in. „
300 1 in. by 2½ in. „

To be addressed H., G. & Co.,
for "Tay Bridge,"
At 13*l.* 10*s.* as per your quotation.
Signed for H., G. and Co., Ld.,
ROBERT TELFORD.

1,600 October 15th, 1874. 885

38 cwts. of 1¼ in. by ¾ in. rivets to sample sent.
2 cwts. of 2¼ in. by ¾ in. rivets to sample sent.
To be made from "Low Moor" iron supplied by us at 22*s.* per cwt., rivets to be charged at 27*s.*
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

(December 4th, 1874, Orders for Bolts No. 15).

2,005 January 9th, 1875. 1,293

Cwts. qrs. lbs. (1,914)
10 1 0 hex nuts, screwed for 1½ in. bolts.
(584)
2 0 10 „ „ 1 in. „
364 washers, 3 in. dia. by ½ in., tapped for 1½ in. bolts.
washers, 2½ in. dia. by ½ in., tapped for 1 in. bolts.
876 washers, 2½ in. dia. by ½ in., tapped for 1 in. bolts.
(99 rec.)
All invoices for goods supplied against this order must be made out on separate forms, and have inserted on each for "Tay Bridge Works."
Signed for H., G. & Co., Ld.,
H. HY. THOMAS.

COPY of LETTER.

January 9th, 1874.

DEAR SIRS,

WE beg to accept your offer of the 28th ulto. to supply nuts and washers at 25*s.* per cwt., d/d. at Tee's Engine Works, and we herewith enclose you the order. We place it with you on condition that you will give *prompt* delivery, as we are wanting them *at once*.

Yours, &c.,
H., G. & Co., Ld.,
(Signed) J. W. WILLIAMS.

2,777 May 3rd, 1875. 1,971

46,000 ¾ in. by 1¾ in. cuphead rivets.
3,550 „ by 1¼ in. „
3,900 „ by 2¼ in. „
2,700 „ by 2½ in. „
2,150 ¾ in. by 2¼ in. countersunk heads, at 12*l.* 15*s.*, as per quotation, half the above to be delivered at once, remainder in eight weeks.
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

H., G. & Co.'s No. C. B. & N. Co.'s No.

2,776 May 3rd, 1875. 1,972

3,800 ¾ in. by 1¾ in. cuphead rivets.*
1,300 „ by 2¼ in. „
1,800 „ by 2¼ in. „
2,200 „ by 2 in. „
1,000 „ by 3½ in. „
300 ⅞ in. by 2½ in. „
300 1 in. by 2½ in. „
At 12*l.* 15*s.*, as per quotation.
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

2,778 May 3rd, 1875. 1,973

340 ¾ in. by 1¾ in. cuphead rivets.
850 „ by 2 in. „
380 „ by 2¼ in. „
2,200 „ by 2¼ in. „
850 „ by 2½ in. „
620 „ by 2¾ in. „
830 „ by 3½ in. „
900 „ by 3¼ in. „
2,050 ¾ in. by 1¾ in. „
970 „ by 2½ in. „
300 ⅞ in. by 1¼ in. „
700 „ by 1½ in. „
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

2,779 May 3rd, 1875. 1,974

1,350 ¾ in. by 2 in. cuphead rivets.
1,100 „ by 2¼ in. „
2,150 „ by 2¼ in. „
3,100 „ by 2½ in. „
300 „ by 2⅝ in. „
1,100 „ by 3½ in. „
1,300 ¾ in. by 2¼ in. „
140 „ by 2½ in. „
650 „ by 2⅝ in. „
400 ⅞ in. by 1¼ in. „
850 „ by 1½ in. „
170 ⅞ in. by 1⅞ in. „
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

2,931 June 21st, 1875. 2,208

170 ½ in. by 5 in. couch screws.
3,000 „ by 2 in. „
3,000 „ by 2½ in. „
The above are most urgently wanted, kindly have them put in hand at once.
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

Memo.

June 22nd, 1875.

REFERRING to our Order No. 2,931, of June 21st, please cancel the 3,000 ¾ in. by 2½ in. rivets, we trust you will put the rest of the order in hand to-day, that the rivets may be forwarded to "Tay Bridge" *to-morrow without fail*.
Signed for H., G. & Co.,
ROBERT TELFORD.

2,981 July 5th, 1875. 2,274

7,200 ¾ in. by 2½ in. cuphead rivets.
3,600 „ by 2¼ in. „
4,400 „ by 2 in. „
2,000 „ by 3½ in. „
To be delivered here, addressed—
Hopkins, Gilkes, & Co.,
12*l.* 10*s.* per ton. "Tay Bridge."
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

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* Special attention to be given to counting of above rivets, and each bag to be labelled Hopkins, Gilkes, & Co., "Tay Bridge."

H., G. & Co.'s No. C. B. & N. Co.'s No.

3,111 August 4th, 1875. 2,435

482 bolts, 1⅛ in. by 6½ in. long, sq. heads, round necks, hex nuts.
1,996 „ „ by 4¾ in. „ „
228 „ „ by 5¼ in. „ „
1,176 „ „ by 4¼ in. „ „
90 „ „ by 5¼ in. „ „
2,400 washers, 2⅛ in. diam. by ⅛ in. thick for 1¼ in bolt.
5,000 washers, 2⅛ in diam. by $\frac{3}{16}$ in. thick for 1⅛ in. bolt.
At 19*s.* as agreed, to be packed in bags, addressed—"Tay Bridge."
Signed for H., G., & Co., Ld.,
ROBERT TELFORD.

3,226 September 7th, 1875. 2,622

2,000 ¼ in. by 3 in. snaphead rivets.
2,500 „ by 2¾ in. „
14,000 „ by 2½ in. „
21,000 „ by 2¼ in. „
1,000 „ by 2 in. „
5,000 „ by 1¾ in. „
1,700 ⅜ in. by 3¼ in. „
1,000 „ by 3¼ in. „
1,600 „ by 3 in. „
2,000 „ by 2¼ in. „
500 „ by 2¼ in. „
At 12*l.* 10*s.* per ton.
The whole of the ¼ in. rivets and *one-half of the* ¼ in. *rivets* at once, and the remaining half of the ¼ in. in six weeks' time.
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

3,308 September 25th, 1874. 2,725

22,000 ¾ in. by 1¼ in. cupbead rivets.
11,000 „ by 2¼ in. „
700 „ by 1½ in. „
Urgently wanted.
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

3,360 October 13th, 1875. 2,805

1 ton ¼ in. by 2¾ in. cuphead rivets.
1 „ „ by 1⅞ in. „
½ „ „ by 2⅛ in. „
½ „ ⅜ in. by 2 in. „
½ „ „ by 2⅜ in. „
2½ „ ⅜ in. by 1½ in. „
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

3,390 October 23rd, 1875. 2,847

1,000 ⅜ in. by 2¼ in. countersunk rivets.
1,100 ⅜ in. by 3 in. „
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

3,443 November 5th, 1875. 2,912

20,000 ¾ in. by 1¼ in. cuphead rivets.
12,000 „ by 2¼ in. „
Against contract at 11*l.* 15*s.* 0*d.* per ton.
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

3,533 November 25th, 1875. 3,010

3 cwts. ¼ in. by 4¾ in. cuphead rivets.
5 „ 1 „ by 3 in. „
10 „ ¾ „ by 2 in. „
10 „ „ by 2½ in. „
10 „ „ by 2¼ in. „
5 „ „ by 3 in. „
3,000 „ by 2¼ in. „
1,600 „ by 2¼ in. „
1,800 „ by 2¼ in. „
1,100 „ by 2½ in. „
1,200 „ by 2¾ in. „
1,400 „ by 3 in. „
800 „ by 3¼ in. „
4,100 „ by 1¼ in. „
4,200 „ by 1¼ in. „
4,400 „ by 2 in. „
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

H., G. & Co.'s No. C. B. & N. Co.'s No.

3,554 November 30th, 1875. 3,035

440 bolts, 1¼ in. by 5 in. long, sq. heads, rd. necks, ⅞ in. hex, lock nuts.
400 bolts, 1¼ in. by 6½ in. long, sq. heads, rd. necks, ⅞ in. hex, lock nuts.
400 bolts, 1¼ in. by 4¼ in. long, sq. heads, rd. necks, ⅞ in. hex, lock nuts.
400 bolts, 1¼ in. by 4½ in. long, sq. heads, rd. necks, ⅞ in. hex, lock nuts.
1,640 washers for do. $\frac{3}{16}$ thick.
At 17*s.* 6*d.* per cwt. as per agreement.
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

3,544 November 30th, 1875. 3,035

6,470 1¼ in. by 4¼ in. bolts, square heads, hex nuts, and round necks.
2,860 1¼ in. by 5¼ in. bolts, square heads, hex nuts, and round necks.
700 1¼ in. by 5½ in. bolts, square heads, hex nuts, and round necks.
1,570 1⅛ in. by 6¼ in. bolts, square heads, hex nuts, and round necks.
1,120 1 in. by 2¼ in. bolts, square heads, hex nuts, and round necks.
1,180 1 in. by 3⅛ in. bolts, square heads, hex nuts, and round necks.
250 1 in. by 3¾ in. bolts, square heads, hex nuts, and round necks.
350 1 in. by 5 in. with hex lock nuts, one 1 in. thick nut, other ⅞ in. thick usual.
375 1 in. by 5 in. tee heads, hex nuts, round necks.
240 1 in. by 6 in. square heads, hex nuts, round necks.
15,400 washers, 2⅛ in. dia. by $\frac{3}{16}$ in. thick for 1¼ in. bolts.
3,600 washers, 2¼ in. dia. by $\frac{3}{16}$ in. thick for 1 in. bolts.
360 washers, 3¾ in. dia. by ¼ in. thick for 1⅜ in. bolts.
At 17*s.* 6*d.* per cwt., as per agreement.
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

3,553 November 30th, 1875. 3,035

500 bolts, 1¼ in. by 4¾ in. long, square heads, hex nuts, round necks.
200 bolts, 1¼ in. by 6¼ in. long, square heads, hex nuts, round necks.
100 bolts, 1¼ in. by 5¼ in. long, square heads, hex nuts, round necks.
40 bolts, 1 in. by 8¼ in. long, hex lock nuts, round necks.
100 washers, 3 in. dia. by ⅜ in. thick for 1¼ in. bolts.
1,200 washers, 2⅛ in. dia. by $\frac{3}{16}$ in. thick for 1¼ in. bolts.
At 17*s.* 6*d.* per cwt. as per agreement.
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

3,566 December 3rd, 1875. 3,055

500 couch screws, 3½ in. by ⅝ in., square heads and round necks.
At 25*s.* per cwt. as per agreement.
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

3,573 December 6th, 1875. 3,060

1,260 ¾ in. by 1¼ in. cuphead rivets.
10 cwts. ¾ in. by 1¼ in. „
10 „ „ by 2¼ in. „
10 „ „ by 2¼ in. „
6 „ „ by 3¼ in. „
6 „ „ by 3¼ in. „
6 „ „ by 3¼ in. „
6 „ „ by 3¼ in. „
6 „ „ by 4 in. „
10 „ ¾ in. by 2 in. „
10 „ „ by 2¼ in. „
10 „ „ by 2¼ in. „
5 „ „ by 3 in. „
10 „ „ by 3¼ in. „
5 „ „ by 3¼ in. „
Signed for H., G. & Co., Ld.,
HENRY LEWIS.

H., G. & Co.'s No. C. B. & N. Co.'s No.

3,371 December 4th, 1875. 3,063

1,300 1 in. by 2¼ in. cuphead rivets.
1,800 „ by 2¼ in. „
850 „ by 1¼ in. „
1,000 „ by 2¼ in. „
Wanted at once.
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

3,680 January 13th, 1876. 5

10 cwts. 1¾ in. nuts, hex, untapped, 21*s.* (in pencil).
10 cwts. 1¾ in. nuts, hex, untapped, 21*s.* (in pencil).
At 20*s.*
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

3,689 January 14th, 1876. 6

2 cwts. ⅞ in. square nuts, tapped.
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

1,762 December 4th, 1874. 1,181

2,290 bolts, 1¼ in. diam., 5¼ in. long, screwed, 2¼ in.
1,250 bolts, 1¼ in. diam., 5 in. long, screwed, 2¼ in.
With hex heads and nuts, each supplied with one washer to tracing No. 5,766.
21*s.* per cwt. d/d. at works.
These bolts are all to be delivered during the first week in January next; if you cannot do this, please return the order to us.
Signed for H., G. & Co., Ld.,
ROBERT TELFORD.

COPIES OF SUCH QUOTATIONS as were made in writing to Hopkins, Gilkes, & Co. by Cleveland Nut and Bolt Company, Limited. Sent to Solicitor, Board of Trade, by Mr. Hadland, by letter dated 8th April 1880.

Quotations to Messrs. Hopkins, Gilkes, & Co., Limited, March 20th, 1874.

DEAR SIRS, March 21st, 1874.

CONFIRMING our verbal quotation to you this morning, we beg to say our price for 50 tons ¾ in. by ¾ in. bridge rivets is 15*l.* 10*s.* per ton. Delivered at your works. Usual terms.

Yours, &c.
Signed for C. B. & N. Co.,
J. P.

DEAR SIRS, May 16th, 1874.

REPLYING to your favour of to-day, we shall be happy to supply the ¾ in. sq. sq. sq. bolts at 27*s.* per cwt. We could let you have them in less than a week from receipt of order.

Yours, &c.
Signed for C. B. & N. Co.,
J. P.

DEAR SIRS, July 21st, 1874.

WE shall be glad to book your order for 500 ¾ in. double nutted bolts to your tracing at 25*s.* per cwt., delivered at your works. Usual terms.

Yours, &c.
Signed for C. B. & N. Co.,
J. P.

DEAR SIRS, August 12th, 1874.

WE have to thank you for your esteemed inquiry of 11th inst., and in reply beg to say we shall have pleasure in supplying 9,800 1⅛ in. bolts to your tracing at 21*s.* 6*d.* per cwt., delivered at Tayport Station, near Dundee.

If delivered here our price will be 21*s.* per cwt. Trusting to receive your commands,

We are, &c.
Signed for C. B. & N. Co.,
J. P.

DEAR SIRS, August 26th, 1874.

REPLYING to your esteemed inquiry of 25th inst., we shall be happy to supply the holding-down bolts to your sketch at 22*s.* 9*d.* per cwt., delivered at your works. Usual terms.

Yours, &c.
Signed for C. B. & N. Co.,
J. P.

DEAR SIRS, September 3rd, 1874.

REPLYING to your esteemed inquiry of to-day, we beg to say our present price for washers of the sizes you name will be 21*s.* per cwt., delivered at your works.

Terms of payment—cash on 10th of month following delivery, less 2½ per cent.

Awaiting the favour of your commands, which shall have our best attention,

We are, &c.
Signed for C. B. & N. Co.,
G. N.

DEAR SIRS, September 14th, 1874.

REPLYING to your esteemed inquiry of to-day, we shall be happy to supply the bolts and washers you require at 20*s.* per cwt. all round.

Trusting to receive your commands, and assuring you of our best attention.

Yours, &c.
Signed for C. B. & N. Co.,
G. N.

DEAR SIRS, September 29th, 1874.

WE shall be happy to supply you with one ton of 1½ in. washers, ¼ in. thick at 24*s.* per cwt.

Terms of payment — cash on 10th month following delivery, less 2½ per cent.

Soliciting the favour of your order,

We are, &c.,
(Signed) C. B. & N. Co.,
Per ROBERT LEVY.

DEAR SIRS, October 7th, 1874.

REPLYING to your valued communication of the 6th inst., we shall have much pleasure in booking your order for the rivets to specification, at 13*s.* 6*d.* per cwt. all round, delivered at your works.

Terms of payment—cash on 10th of month following delivery, less 2½ per cent. Awaiting the favour of your commands,

We are, &c.
(Signed) C. B. & N. Co.,
Per R. L.

DEAR SIRS, December 3rd, 1874.

REPLYING to your favour of to-day, we have now the pleasure to quote you our very lowest price for the bolts to your tracing, and hope the same will be satisfactory and enable you to send the order. Soliciting which,

We are, &c.
Signed for C. B. & N. Co.,
J. P.

1¼ in bolts, hex heads, round necks and hex nuts, 5 in. and 5¼ long, with washers ⅛ in. thick, to tracings, 21*s.* per cwt., delivered at your works. Terms of payment as usual.

GENTLEMEN, December 28th, 1874.

YOUR kind favour, dated the 21st inst., only came to hand this morning, in reply we beg to say that the price for the nuts and washers inquired about is 25*s.* per cwt., delivered at your Tees Engine Works. Terms as usual.

We wait the favour of your commands, and

We remain, &c.
(Signed) C. B. & N. Co.,
Per ROBERT LEVY.

March 25th, 1875.

REPLYING to your verbal inquiry of to-day, our prices will be as under:

Woodscrews, 5 in. and 4 in. by ¼ in. and ⅛ in., 27*s.* per cwt.

Washers, 3 in. dia. by ¼ and ⅛ in. thick, 19*s.* per cwt.

Usual terms, delivered at your works.

DEAR SIRS, April 21st, 1875.

WE shall be happy to supply you with 18 cwt. ¾ in. hex tapped nuts, 28*s.* 6*d.* per cwt., and 5 cwt. each ⅝ in., ¾ in., 1 in., 1¼ in., at 31*s.*, 28*s.*, 28*s.*, 29*s.* per cwt.

We shall also be glad to book your order for 13 tons of good guaranteed quality girder rivets at 12*l.* 15*s.* per ton.

Hoping to receive your commands,

We are, &c.

(Signed) C. B. & Co.,
per R. L.

DEAR SIRS, June 29th, 1875.

WE beg to hand you our revised quotation for 5 tons of ⅞ in. rivets, 1¼ in. to 3½ in. long, delivered at your works, being 12*l.* 10*s.* per ton. Usual terms.

We can deliver this quantity in a week or ten days. A sample of the iron accompanies the quotation.

Yours, &c.

C. B. & N. Co.,
Per R. L.

DEAR SIRS, September 23rd, 1875.

WE shall be happy to supply all the rivets referred to to-day, viz., 30 tons or upwards (⅞ dia. and up.) at 11*l.* 15*s.* per ton. Delivery to extend over the next three months. Usual terms.

Yours, &c.

(Signed) C. B. N. & Co.,
Jos. PRESTON.

DEAR SIRS, November 26th, 1875.

ANNEXED we have the pleasure to hand you our prices for the bolts named in your memo., and trust the same will enable you to place the order with us.

We are, &c.

Signed for C. B. & N. Co.,
J. P.

22*s.* for ⅝ in. bolts., sq. rd. hex.
18*s.* for ¾ in. „ „
⅝ in. couch screws, 25*s.* Delivered at your works. Terms of payment as usual.

April 16th, 1876.

½ in. by 1 in. cup rivets	-	18*s.* 6*d.* per cwt.
⅝ in. by 6 in. „	-	11*s.* 6*d.* „
⅝ in. by 1½ in. sq. rd. hex.	-	35*s.* 0*d.* „
¾ in. by 1½ in. „	-	27*s.* 0*d.* „
⅞ in. by 2½ in. „	-	26*s.* 0*d.* „
1 in. by 3½ in. „	-	24*s.* 0*d.* „
1¼ in. by 4½ in. „	-	23*s.* 0*d.* „
1½ in. by 4 in. „	-	23*s.* 0*d.* „

June 2nd, 1876.

REFERRING to our quotation of yesterday, we have reconsidered the matter, and shall be glad to supply you with the rivets at the following reduced prices:—

10 tons ⅞ in. girder rivets at 10*l.* 17*s.* 6*d.* per ton.
40 tons ¾ in. „ at 12*l.* 10*s.* 6*d.* „
40 tons ⅝ in. „ at 12*l.* 10*s.* 0*d.* „

Delivered at your works. Terms as usual.

DEAR SIRS, June 8th, 1876.

As arranged this morning we have entered for you 50 tons of ⅝ in., ¾ in., ⅞ in. rivets for delivery over about 3 months at 10*l.* 12*s.* 6*d.* per ton, delivered at your Tees Engine Works. Payment by your acceptance at 4 mm. from 10th month *following* delivery.

It is understood that you do not ask us to deliver more than 10 tons of ¾ in. against this contract.

Yours, &c.

C. B. & N. Co.,
Per ROBT. LEVY.

DEAR SIRS, July 17th, 1876.

WE shall have much pleasure in supplying you with 33,000 ½ in. by 7½ in. cuphead spikes, and 12,000 ½ in. by 5 in. pointed, at 13*s.* 6*d.* per cwt., delivered at your works. Terms of payment as usual.

Awaiting the favour of esteemed order.

We are, &c.

Signed for C. B. & N. Co.,
WILLIAM MOTHERWELL.

September 7th, 1876.

REFERRING to our quotation of date, we beg to hand an amended price, viz.:—

10 to 12 cwts. 1½ in. hex. tapped nuts, 22*s.* per cwt., packed in bags and delivered at your works, and trust to be favoured with your order.

Yours, &c.

(Signed) C. B. N. & Co.,
WM. MOTHERWELL.

ACKNOWLEDGMENTS of Hopkins, Gilkes, & Co.'s Orders. Sent to Solicitor, Board of Trade, by Mr. Hadland, by Letter dated 8th April 1880.

[Lithographed forms with copy of orders at foot.]

May 12th, 1874.

To Hopkins, Gilkes, & Co., Ld.,.
Tees Engine Works.

"Rivets as per specification. Price 15*l.* 10*s.* per ton."

July 28th, 1874.

1,500 rivets ⅝ in. by 2½ in. countersunk heads.
200 „ „ by 3½ in. „
5 cwts. bolts ¾ in. by 3½ in. sq. rd. sq.
2 „ „ „ by 4½ in. „ „ „
5 „ ¾ in. hex nuts tapped.

August 1st, 1874.

2,000	¾ in. by 1½ in.	cuphead rivets	13*l.* 10*s.* per ton, delivered.
16,000	„ by 1½ in.	„	
970	„ by „	„	
350	„ by 2½ in.	„	
25,950	„ by 2½ in.	„	
450	„ by 2½ in.	„	
4,000	⅞ in. by 2½ in.	„	
2,000	„ by 2½ in.	„	
1,800	¾ in. by 1½ in.	panhead	
2,100	„ by 1½ in.	„	

August 29th, 1874.

Rivets as per specification.

To screw 48 bolt ends as per sketch, price 4*s.* per cwt.
Tees Engine Works.

September 16th, 1874.

9,800 1½ in. bolts and nuts to tracings. Price 21*s.* per cwt. delivered at your works, to be oiled and packed in extra strong bags.

September 26th, 1874.

1,250	cupbead rivets ⅞ in. by	1½ in.	Terms of payment as usual.
850	„ „ by	1¾ in.	
1,350	„ „ by	2 in.	
1,200	„ „ by	2½ in.	
100	„ „ by	3½ in.	

September 28th, 1874.

Rivets as per specification. Price 13*l.* 10*s.* per ton, delivered. Terms of payment as usual.

September 29th, 1874.

736 bolts 1½ in. by 5½ in. sq. rd. hex 176 bolts 1 in. by 8½ in. sq. rd. hex, lock nuts - - - 768 bolts 1½ in. by 4½ in. sq. rd. hex 384 washers 3 in. dia. by ½ in. thick, for 1½ in. bolts - - - 4,608 washers 2½ in. dia. by $\frac{3}{16}$ in. thick, for 1½ in bolts - - 352 washers 2½ in. dia. by ¼ in thick, for 1 in. bolts - - -	At 21*s.* per cwt., delivered at your works. Terms as usual.

DEAR SIRS, September 30th, 1874.

WE are sorry we cannot comply with your request of the 29th instant, in reference to the 9,800 bolts, as we have now nearly completed the forging of the whole quantity. *Had it been otherwise, we should have had pleasure* in carrying out your wishes.*

Your esteemed Order, No. , is duly to hand, and we will give same our best attention.

Signed for C. B. & N. Co.,
G. N.

[*Lithographed forms with copy of orders at foot.*]

3,600	rivets ⅞ in. by	2½ in.	cupheads
3,800	„ by	1¾ in.	„
1,300	„ by	2½ in.	„
1,800	„ by	2¼ in.	„
2,200	„ by	2 in.	„
1,000	„ by	3½ in.	„
300	„ ⅞ in. by	2½ in.	„
300	„ 1 in. by	2½ in.	„

Price 13*l.* 10*s.* per ton. Terms as usual.

To be addressed—H., G. & Co., for "Tay Bridge."

* This letter is attached to the above Order.

October 15th, 1874.

38 cwt. ¾ in. by 1½ in. rivets, to sample
2 cwt. „ 2½ in. „
} Price 27*s.* per cwt.

To be made of Low Moor iron, which will be supplied by you at 22*s.* per cwt.

January 11th, 1875.

10 cwt. 1 qr. 0 lbs. 1½ in. hex nuts, tapped.
2 „ 0 „ 10 „ 1 in. „
364 washers 3 in. dia. by ⅛ in. thick by 1½ in. hole.
184 „ 2½ in. dia. by ¼ in. thick by 1 in. hole.
876 „ 2½ in. dia. by ¼ in. thick by 1 in. hole.
Price 25*s.* per cwt. delivered at your works.

All goods supplied against this order must be made out on separate forms, and have inserted on each—For "Tay Bridge Works."

January 9th, 1875.

We beg to accept your offer of the 28th ult., to supply nuts and washers, at 25*s.* per cwt., d/d. at Tees Engine Works, and we herewith enclose you the order.*

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* Letter attached to the above Order.

We place it with you, on condition that you will give *prompt* delivery, as we are wanting them *at once*.

Yours, &c.

Signed H., G. & Co., Ld.,
J. W. Williams.

[Lithographed forms, with copy of orders at foot.]

July 6th, 1875.

7,200 rivets ¾ in. by 2½ in. cupheads
3,600 „ „ by 2½ in. „
4,400 „ „ by 2 in. „
2,000 „ „ by 3½ in. „
} For "Tay Bridge" at 12*s.* 6*d.* per cwt. Delivered at your works.

Sept. 9th, 1875.

2,000 3 in. by ¾ in. snapbead rivets
3,500 2½ in. by „ „
14,000 2½ in. by „ „
21,000 2½ in. by „ „
1,000 2 in. by „ „
5,000 1½ in. by ½ in. „
1,000 ¾ in. by „ „
1,600 3 in. by „ „
2,000 2½ in. by „ „
500 2½ in. by „ „
} At 12*l.* per ton. The whole of the ½ in. rivets and one half of the ¾ in. rivets at once, and the remaining half of the ¾ in. in six weeks' time.

No. 16.

Results of Tests made by Mr. Kirkaldy upon Portions of the Tay Bridge.

Results of Experiments to ascertain the Ultimate Tensile Strength and Rates of Extension of Six Iron Bolts and Nuts, received per Henry Law, Esq., C.E.

Test. No.	Description.	Length between Head and Nut.	Dimensions over Thread.		Total Stress in Pounds—Extension Inch.															Ultimate.			Appearance of Fracture.
			Diam.	Area.	10,000	12,000	14,000	16,000	18,000	20,000	22,000	24,000	26,000	28,000	30,000	32,000	34,000	36,000	38,000	40,000	Extension Total.	Stress. Total.	Stress. Per sq. in.	
O		inches.	inch.	sq. in.																	inch.	lbs.	lbs.	per cent. per cent.
1435	Unmarked	3·60	1·18	1·003	·023	·027	·031	·040	·046	·051	·057	·062	·067	·071	·077	·082	·091	·106	·130	·170	·231	40,810	40,687	45 Fibrous, 55 Crystalline.
1436	„	4·20	„	„	·016	·020	·026	·032	·040	·046	·052	·058	·064	·071	·081	·100	·122	·151	·190	—	·262	39,720	39,601	97 „ 3 „
1433	„	3·80	„	„	·017	·021	·026	·031	·038	·042	·048	·052	·057	·061	·067	·072	·080	·090	·106	—	·186	39,610	39,491	0 „ 100 „
1434	„	3·80	„	„	·020	·025	·030	·037	·044	·050	·056	·061	·068	·074	·080	·088	·098	·118	—	—	·126	36,115	36,006	40 „ 60 „
1432	„	3·80	„	„	·015	·018	·021	·024	·028	·032	·038	·044	·050	·056	·060	·066	·071	—	—	—	·097	35,755	35,648	0 „ 100 „
1431	„	3·80	„	„	·014	·022	·031	·040	·046	·052	·060	·065	·071	·078	·088	·104	·125	—	—	—	·222	34,825	34,720	88 „ 12 „
	Mean	—	—	—	·018	·022	·028	·034	·040	·045	·052	·057	·063	·068	·075	·085	·098	—	—	—	·179	37,806 Tons. 16·9	37,692 Tons. 16·8	45 „ 55 „

H. C. Rothery, Esq., F.L.S., M.R.S.L., F.R.M.S.
President of the Court of Inquiry,
Somerset House.

David Kirkaldy,
99, Southwark Street, London, S.E.
21st April 1880.

RESULTS of EXPERIMENTS to ascertain the RESISTANCE to EXTENSION and RUPTURE, under a gradually increased PULLING STRESS of THREE IRON TIE-BARS having COUPLING-LINKS attached with COLLARS, received per HENRY LAW, Esq., C.E.

Test No.	Link Number.	Original Dimensions.	Sectional Area.	Length between Cotter and Bolt-hole.	Total Stress on Link in Pounds—Extension Inch.																									Ultimate Extension.	Ultimate Stress.		Position of Fracture.
					10,000.	12,000.	14,000.	16,000.	18,000.	20,000.	22,000.	24,000.	26,000.	28,000.	30,000.	32,000.	34,000.	36,000.	38,000.	40,000.	42,000.	44,000.	46,000.	48,000.	50,000.	52,000.	54,000.	56,000.	58,000.	60,000.		Total.	Per sq. in.	
O		inches.	sq. in.	in.																										inch.	lbs.	lbs.	
1415	Unmarked	4·47 × ·51	2·279	135·7	·070	·090	·109	·128	·150	·171	·190	·210	·230	·255	·280	·300	·326	·355	·378	·408	·430	·460	·486	·525	·570	·620	·680	·738	—	—	0·76	56,692	24,875	
1417	„	4·47 × ·51	2·279	125·3	·112	·148	·177	·188	·211	·229	·248	·260	·280	·300	·320	·338	·360	·380	·400	·420	·450	·485	·525	·570	·625	·688	·810	·900	·992	—	1·12	59,524	26,118	
1419	„	4·50 × ·49	2·205	125·2	·100	·149	·218	·246	·270	·290	·320	·342	·370	·396	·428	·460	·498	·525	·560	·598	·638	·680	·738	·788	·850	·911	·972	1·07	—	—	1·16	56,488	25,618	

SUMMARY of RESULTS of SECOND EXPERIMENTS to ASCERTAIN the QUALITY of the IRON.

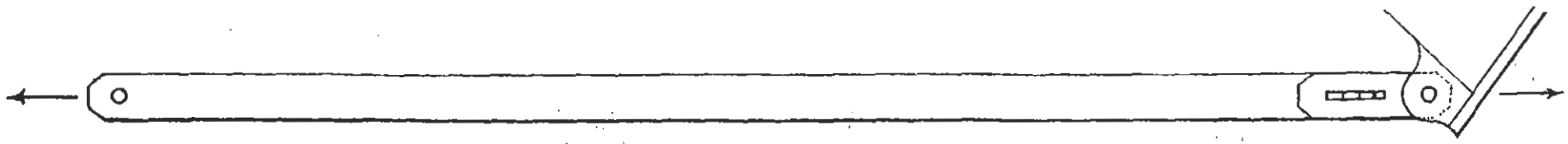
Test No. 1st Experiment.	Test No. 2nd Experiment.												
0·1415	0·1416	Bar broke with 99,810 lbs. = 43,795 lbs. or 19·55 tons per square inch,	contraction of area at fracture 10·53 per cent.,		extension	6·6 per cent.,	fracture 70 per cent. fibrous,	30 per cent. crystalline.				
0·1417	0·1418	„	107,680 lbs. = 47,249 lbs. or 21·09	„	„	17·87	„	12·8	„	75	„	25	„
0·1419	0·1420	„	95,420 lbs. = 48,274 lbs. or 19·81	„	„	15·55	„	7·2	„	85	„	15	„

H. C. ROTHERY, Esq., F.L.S., M.R.S.L., F.R.M.S.,
President of the Court of Inquiry,
Somerset House.

DAVID KIRKALDY,
99, Southwark Street, London, S.E.,
22nd April 1880.

RESULTS of EXPERIMENTS to ascertain the RESISTANCE to EXTENSION and RUPTURE, under a gradually-increased PULLING STRESS of COLUMN-LUGS attached with BOLT to TIE-BARS and COUPLING-LINKS and COLLARS, received per HENRY LAW, Esq., C.E.

Test No.	Description.	Total Stress on Lugs and Links in Pounds.—Extension Inch.																									Ultimate Extension.	Ultimate Stress. When Links broke.	Ultimate Stress. When Lugs broke.	Position of Fracture.
		10,000.	12,000.	14,000.	16,000.	18,000.	20,000.	22,000.	24,000.	26,000.	28,000.	30,000.	32,000.	34,000.	36,000.	38,000.	40,000.	42,000.	44,000.	46,000.	48,000.	50,000.	52,000.	54,000.	56,000.	58,000.	60,000.				
0																												inch.	lbs.	lbs.	
1365 1	No. 4 bottom lugs	·091	·112	·164	·191	·246	·292	·355	·422	·464	·512	·555	·624	·662	·723	·764	·802	·844	·891	·944	—	—	—	—	—	—	—	·976	—	46,888	Two lugs, unsound, and bolt broken.
1365 2	Do. do. (Third lugs broken when recd.)	·052	·075	·100	·133	·160	·180	·209	·229	·255	·288	·306	·338	·362	·398	·420	·452	·483	·520	·552	·586	·689	·684	·750	·834	—	—	·862	—	56,124	Two lugs, sound.
1372 1	No. 6 bottom lugs	·060	·080	·106	·135	·162	·186	·206	·231	·256	·276	·302	·329	·351	·375	·400	·431	·456	·490	·521	·558	—	—	—	—	—	—	·568	—	48,292	Do. do. unsound.
1372 2	Do. do. do. do.	·063	·085	·128	·154	·178	·204	·230	·258	·280	·305	·336	·360	·382	·415	·440	·471	·506	·545	—	—	—	—	—	—	—	—	·599	45,944	45,944	One do. do. and one link at hole.
1372 3	Do. do.	·057	·071	·107	·130	·156	·180	·206	·232	·256	·284	·310	·334	·368	·397	·425	·462	·500	·538	·570	·615	·655	—	—	—	—	—	·702	50,848	50,848	One lug, sound, and one link at hole.
1359 1	No. 2 top lugs	·110	·128	·141	·160	·184	·200	·224	·245	·254	·288	·312	·336	·366	·390	·425	·455	·482	·520	·550	·590	·628	·672	·728	·785	·833	—	·888	59,452	—	Two links at holes.
																														59,992	Two lugs, sound.
1359 2	Do. do.	·114	·143	·172	·194	·216	·260	·292	·306	·328	·361	·380	·404	·430	·460	·487	·516	·550	·578	·619	·652	·690	·728	·755	—	—	—	·796	—	55,912	Do. do.
1359 3	Do. do.	·092	·121	·138	·150	·162	·186	·210	·239	·251	·278	·291	·320	·344	·368	·391	·422	·455	·484	·516	·548	·581	·627	·660	·700	·742	·841	·844	60,044	—	Two links at holes.
																														62,480	Two lugs, sound.
1378 1	No. 7 top lugs	·064	·075	·094	·125	·144	·180	·198	·226	·258	·276	·314	·338	·366	·390	·414	·440	·472	·504	·533	·572	·612	·650	—	—	—	—	·690	—	58,728	Two lugs, sound.
1378 2	Do. do. do. do.	·060	·078	·106	·130	·160	·190	·217	·248	·266	·290	·320	·344	·370	·396	·416	·448	·488	·515	·554	·593	·644	·683	·735	·781	·826	·875	·912	—	60,715	Do. do.
1378 3	Do. do.	·060	·084	·122	·154	·178	·212	·246	·270	·298	·322	·360	·389	·420	·444	·487	·506	·538	·560	·608	·630	—	—	—	—	—	—	·665	—	42,184	Do. do.
1384 1	No. 8 top lugs	·065	·090	·114	·142	·170	·200	·235	·274	·310	·348	·375	·416	·426	·478	·508	·550	·588	·610	·647	·675	·704	—	—	—	—	—	·736	—	51,796	One lug, unsound.
1384 2	Do. do. do. do.	·068	·100	·127	·150	·176	·202	·230	·254	·280	·304	·330	·356	·379	·403	·425	·450	·476	·500	·532	·560	·590	·628	·651	·698	·730	—	·765	—	58,588	Two lugs, sound.
1384 3	Do. do.	·069	·098	·118	·148	·179	·205	·230	·260	·283	·315	·345	·378	·406	·432	·454	·472	·504	·534	·556	·588	·625	·650	·683	·720	—	—	·748	—	57,488	Do. do.

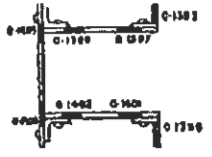


H. C. ROTHERY, Esq., F.L.S., M.R.S.L., F.R.M.S.,
President of the Court of Inquiry,
Somerset House.

DAVID KIRKALDY,
99, Southwark Street, London, S.E.,
30th April 1880.

RESULTS of EXPERIMENTS to ascertain the TENSILE STRENGTH and QUALITY of the IRON used in RIVETED GIRDER, marked No. 10, received per H. LAW, Esq., C.E.

Test No.	Description.		Original. Size.	Original. Area.	Ultimate Stress. Total.	Ultimate Stress. Per Square Inch of Original Area.	Fractured. Size.	Fractured. Area.	Difference. Area.	Difference. Per Cent.	Stress per Sq. Inch of Fractured Area.	Extension in 10 Inches. Inch.	Extension in 10 Inches. Per Cent.	Appearance of Fracture.
O			inches.	sq. in.	lbs.	lbs. lbs. tons.	inches.	sq. in.			lbs.			
1397	Side web plate	−	2·00 × ·89	·780	40,105	51,416 } 52,188 = 23·3	1·95 × ·84	·663	·117	15·0 } 15·0	61,898	0·98	9·8 } 10·0	Fibrous, 25 per cent. crystalline.
1398		−	do.	do.	41,810	52,961 }	1·95 × ·84	·663	·117	15·0 }		1·03	10·3 }	,, 15 ,, ,,
1399		+	do.	do.	32,865	42,134 } 42,675 = 19·1	1·99 × ·87	·786	·044	5·6 } 5·6	45,227	0·19	1·9 } 2·2	,, 15 ,, ,,
1400		+	do.	do.	33,710	43,217 }	1·99 × ·87	·736	·044	5·6 }		0·26	2·6 }	,, 15 ,, ,,
1401	Side web plate	−	2·00 × ·88	·760	42,180	55,486 } 55,812 = 24·6	1·95 × ·83	·643	·117	15·3 } 15·7	65,683	1·08	10·3 } 10·7	45 per cent. fibrous, 55 per cent. crystalline.
1402		−	do.	do.	41,905	55,138 }	1·93 × ·83	·637	·123	16·1 }		1·11	11·1 }	Fibrous, 30 per cent. crystalline.
1403		+	do.	do.	33,645	44,269 } 43,983 = 19·6	1·99 × ·87	·736	·024	3·1 } 3·1	45,417	0·16	1·6 } 1·5	,, 10 ,, ,,
1404		+	do.	do.	33,210	43,697 }	1·99 × ·87	·736	·024	3·1 }		0·14	1·4 }	,, 5 ,, ,,
1405	Long top plate	−	2·00 × ·41	·820	36,165	44,103 } 44,960 = 20·1	1·95 × ·38	·741	·079	8·4 } 10·9	50,816	0·61	6·1 } 7·4	Do.
1406		−	do.	do.	37,570	45,817 }	1·92 × ·37	·710	·110	13·4 }		0·88	8·8 }	Do.
1407		+	do.	do.	29,865	36,420 } 37,063 = 16·6	1·98 × ·40	·792	·028	3·4 } 3·4	38,374	0·22	2·2 } 2·5	Do.
1408		+	do.	do.	30,920	37,707 }	1·98 × ·40	·792	·028	3·4 }		0·29	2·9 }	Do.
1409	Fractured plates	−	2·00 × ·42	·840	44,890	58,440 } 51,044 = 22·7	1·96 × ·37	·725	·115	13·6 } 9·6	56,529	0·74	7·4 } 4·8	50 per cent. fibrous, 50 per cent. crystalline.
1410		−	do.	do.	40,865	48,648 }	1·98 × ·40	·792	·048	5·7 }		0·23	2·3 }	75 ,, ,, 25 ,, ,, Deficient welding.
1411		+	do.	do.	39,180	46,630 } 47,864 = 21·3	1·99 × ·41	·816	·024	2·8 } 2·9	49,288	0·14	1·4 } 1·5	70 per cent. fibrous, 80 per cent. crystalline.
1414		+	2·00 × ·38	·760	37,315	49,098 }	1·99 × ·37	·736	·024	3·1 }		0·17	1·7 }	65 ,, ,, 35 ,, ,,
1412		−	2·00 × ·37	·740	38,090	51,472 } 51,729 = 23·1	1·98 × ·35	·698	·047	6·3 } 6·2	55,192	0·22	2·2 } 2·4	65 ,, ,, 35 ,, ,,
1413		−	2·00 × ·38	·760	39,510	51,986 }	1·98 × ·36	·713	·047	6·1 }		0·27	2·7 }	60 ,, ,, 40 ,, ,,
1443	Diagonal plate, N. 2 A.	−	2·00 × ·55	1·100	56,420	51,290 } 51,920 = 23·2	1·97 × ·51	1·004	·096	8·7 } 11·1	58,427	0·58	5·8 } 7·7	10 ,, ,, 90 ,, ,,
1444		−	do.	do.	57,805	52,550 }	1·94 × ·49	·951	·149	13·5 }		0·96	9·6 }	70 ,, ,, 30 ,, ,,
1445		+	do.	do.	49,855	45,322 } 44,347 = 19·8	1·99 × ·54	1·075	·025	2·3 } 1·3	44,981	0·12	1·2 } 1·0	92 ,, ,, 8 ,, ,,
1446		+	do.	do.	47,710	43,372 }	1·99 × ·55	1·094	·006	0·5 }		0·09	0·9 }	95 ,, ,, 5 ,, ,,
1395	Angles	−	2·00 × ·84	·680	36,885	54,242 } 53,260 = 23·7	1·85 × ·27	·499	·181	26·6 } 20·0	66,557	1·68	16·8 } 14·0	80 ,, ,, 20 ,, ,,
1396		−	2·00 × ·85	·700	36,595	52,278 }	1·89 × ·32	·605	·095	13·5 }		1·12	11·2 }	95 ,, ,, 5 ,, ,,



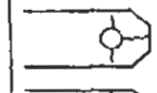
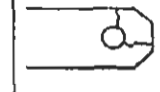
AVERAGES.

—	Strength per Sq. Inch. lbs. tons.	Contraction. per cent.	Extension. per cent.	Fracture.
Plates, lengthway -	51,192 = 22·84	11·4	7·1	67 per cent. fibrous, 33 per cent. crystalline.
,, crossway -	43,186 = 19·28	3·2	1·7	88 ,, ,, 12 ,, ,,
Angles, lengthway	53,260 = 23·77	20·0	14·0	88 ,, ,, 12 ,, ,,

H. C. ROTHERY, Esq., F.L.S., M.R.S.L., F.R.M.S.,
President of the Court of Inquiry,
Somerset House.

DAVID KIRKALDY,
99, Southwark Street, London, S.E.,
3rd May 1880.

RESULTS of EXPERIMENTS to ascertain the RESISTANCE to EXTENSION and RUPTURE, under a GRADUALLY INCREASED PULLING STRESS of THREE IRON TIE-BARS having COUPLING-LINKS attached with COTTERS, received per HENRY LAW, Esq., C.E.

Test No.	Link Number.	Original Dimensions.	Sectional Area.	Length between Cotter and Bolt-holes.	Total Stress on Link in pounds.—Extension inch. 10,000	12,000	14,000	16,000	18,000	20,000	22,000	24,000	26,000	28,000	30,000	32,000	34,000	36,000	38,000	40,000	42,000	44,000	46,000	48,000	50,000	52,000	54,000	56,000	58,000	60,000	Ultimate Extension.	Ultimate Stress. Total.	Per sq. in.	Position of Fracture.
O		inches.	sq. ins.	inches.																											inch.	lbs.	lbs.	
1425	Unmarked	4·47 × ·51	2·279	136·1	·091	·115	·140	·168	·192	·206	·232	·261	·284	·300	·326	·358	·389	·414	·455	481	·516	·543	·575	·594	·627	·662	·710	·778	·846	·972	1·21	60,056	26,351	
1427	do.	4·47 × ·51	2·279	153·7	·072	·098	·112	·129	·150	·167	·188	·217	·239	·268	·300	·333	·365	·400	·446	·482	·542	·588	·644	·711	·777	·870	—	—	—	—	1·02	53,924	23,661	
1429	do.	4·47 × ·50	2·235	153·7	·060	·090	·111	·135	·160	·176	·200	·230	·250	·280	·311	·354	·390	·428	·460	·501	·544	·580	·621	·672	·740	·808	·877	·980	—	—	1·14	57,688	25,811	

Continued from Report dated 22nd April 1880.

SUMMARY of RESULTS of SECOND EXPERIMENTS to ascertain the QUALITY of the IRON.

Test No. 1st Experiment.	Test No. 2nd Experiment.															
O. 1425	O. 1426	-	Bar broke with 105,330 lbs. = 46,217 lbs. or 20·63 tons per square inch,	Contraction of area at Fracture	Per cent. 15·70	Extension	Per cent. 11·7	Fracture	Per cent. 100	Fibrous,	Per cent. 0	Crystalline.
O. 1427	O. 1428	-	do.	do.	91,820 lbs. = 40,239 lbs. or 17·98 tons	do.	do.	do.	13·42	do.	6·6	do.	98	do.	2	do.
O. 1429	O. 1430	-	do.	do.	102,130 lbs. = 45,695 lbs. or 20·39 tons	do.	do.	do.	13·02	do.	9·4	do.	70	do.	30	do.
O. 1431 used in testing column lugs.	O. 1432	-	do.	do.	100,170 lbs. = 43,102 lbs. or 19·24 tons	do.	do.	do.	10·15	do.	7·8	do.	85	do.	15	do.
O. 1433 Report 30th April	O. 1434	-	do.	do.	111,410 lbs. = 47,028 lbs. or 20·99 tons	do.	do.	do.	8·16	do.	7·6	do.	5	do.	95	do.
Half tie-bar labelled No. 7	O. 1448	-	do.	do.	112,520 lbs. = 48,416 lbs. or 21·61 tons	do.	do.	do.	12·43	do.	10·1	do.	75	do.	25	do.
		Mean	-		103,897 lbs. = 45,194 lbs. or 20·14 tons	do.	do.	do.	12·15	do.	8·9	do.	72	do.	28	do.
Brought from Report dated 22nd April.		Mean	-		100,970 lbs. = 44,772 lbs. or 19·98 tons	do.	do.	do.	14·48	do.	8·7	do.	77	do.	23	do.
		Total Mean	-		102,433 lbs. = 44,948 lbs. or 20·06 tons	do.	do.	do.	13·31	do.	8·8	do.	74	do.	26	do.

H. C. ROTHERY, Esq., F.L.S., M.R.S.L., F.R.M.S.,
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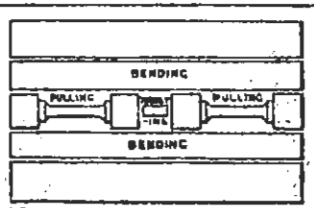
Somerset House.

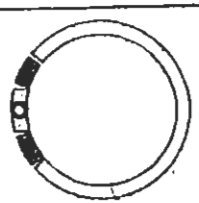
DAVID KIRKALDY,
99, Southwark Street, London, S.E.,
4th May 1880.

Summary of Results of Experiments, under Pulling, Thrusting, and Bending Stresses, of Specimens cut out of Broken Cast-Iron Columns, received per Henry Law, Esq., C.E.

Cut out of Column.	Pulling Stress.					Thrusting Stress.						Bending Stress.								
	Test No.	Diameter.	Area.	Ultimate Stress per sq. in.	Fracture.	Test No.	Diameter.	Area.	Length.	Ultimate Stress per sq. in.	Fracture.	Test No.	Dimensions. Breadth.	Dimensions. Depth.	BD^2	Span.	Ultimate Stress. Total.	Ultimate Stress. Per BD^2	Ultimate Deflection.	Fracture.
	O	inch.	sq. in.	lbs.		O	inch.	sq. in.	inches.	lbs.		O	inch.	inches.		inches.	lbs.	lbs.	inch.	
No. 1, 18″ diameter	1354	1·128	1·000	19,445	Sound.	1356	1·128	1·000	2·00	77,620	Sound.	1357	1·00	2·00	4·00	20	4,621	1,155	·134	Sound.
	1355	do.	do.	19,255	do.							1358	do.	do.	do.	do.	4,531	1,147	·128	do.
No. 2, do.	1360	do.	do.	22,065	do.	1363	do.	do.	do.	77,590	do.	1363	do.	do.	do.	do.	5,059	1,264	·127	do.
	1361	do.	do.	22,105	do							1364	do.	do.	do.	do.	5,189	1,297	·138	do.
No. 4, do.	1366	do.	do.	19,655	do.	1368	do.	do.	do.	76,840	do.	1369	do.	do.	do.	do.	4,556	1,139	·136	Slightly unsound.
	1367	do.	do.	19,810	do.							1370	do.	do.	do.	do.	4,738	1,184	·142	Sound.
No. 6, do.	1372	do.	do.	20,820	do.	1374	do.	do.	do.	74,720	do.	1376	do.	do.	do.	do.	4,631	1,158	·128	do.
	1373	do.	do.	20,708	do.							1377	do.	do.	do.	do.	4,638	1,159	·128	do.
No. 7, do.	1379	do.	do.	20,110	do.	1381	do.	do.	do.	77,380	do.	1382	do.	do.	do.	do.	4,621	1,155	·139	do.
	1380	do	do.	20,040	do.							1383	do.	do.	do.	do.	3,817	954	·111	Unsound.
No. 8, do.	1385	do.	do.	22,040	do.	1387	do.	do.	do.	79,970	do.	1388	do.	do.	do.	do.	3,296	824	·082	do.
	1386	do.	do.	22,185	do.							1389	do.	do.	do.	do.	4,708	1,177	·128	Sound.
18″ diameter	1390	do.	do.	20,205	do.	1392	do.	do.	do.	78,550	do.	1393	do.	do.	do.	do.	3,189	797	·074	Unsound.
	1391	do.	do.	18,185	Unsound.							1394	do.	do.	do.	do.	4,982	1,245	·132	Sound.
Mean -				20,473						77,524							4,474	1,118	·123	

H. C. Rothery, Esq., F.L.S., M.R.S.L., F.R.M.S.,
President of the Court of Inquiry,
Somerset House.





David Kirkaldy,
99, Southwark, Street, London, S.E.
5th May 1880.

North British Railway Company, St. Fort Station,
January 2nd, 1880.

List of Tickets collected off the 4.15 p.m. train ex Edinburgh last Sunday night.

Stations from	1st Single.	2nd Single.	3rd Single.	1st Return.	2nd Return.	3rd Return.	Gross Total.
King's Cross, London - - -	—	—	2	—	—	—	—
Edinburgh, Privilege - - -	—	—	—	—	1	—	—
,, Ordinary - - -	—	—	3	—	2	9	—
Glasgow, Privilege - - - -	—	—	—	—	1	—	—
Burntisland, Ordinary - - -	—	—	—	—	—	1	—
Dysart ,, - -	—	—	1	—	—	—	—
Kirkcaldy ,, - - -	—	—	—	—	—	1	—
Leslie ,, - - -	—	—	—	—	—	1	—
Ladybank ,, - - -	—	—	2	—	—	—	—
Newburgh ,, - - -	—	—	—	—	—	5	—
Abernethy ,, - - -	—	—	—	—	—	2	—
Perth ,, - -	—	—	3	—	2	2	—
Cupar ,, - - -	—	—	7		—	1	—
Dairsie ,, - - -	—	—	—	—	—	1	—
St. Andrews ,, - - -	—	—	—	—	—	1	—
Leuchars ,, - - -	—	—	7	—	—	1	—
St. Fort ,, - - -	—	—	—	—	—	1	—
	—	—	25	—	6	26	57

Besides the tickets collected, I issued five 3rd class tickets to Newport, which were not collected. The collector states that he examined a few Broughty tickets, five or six, and two season tickets.

(Signed) Robt. Morris;
Agent.

LONDON:
Printed by George E. Eyre and William Spottiswoode,
Printers to the Queen's most Excellent Majesty.
For Her Majesty's Stationery Office.