January 27, 1852.

JAMES MEADOWS RENDEL, President, in the Chair.

No. 865.—Description of an Iron Viaduct, erected at Manchester, on the joint station of the London and North Western, and the Manchester, Sheffield, and Lincolnshire Railways. By ALFRED STANISTREET JEE, M. Inst. C. E.¹

THIS Viaduct was designed, by the Author, for the purpose of extending the accommodation of the goods station of the London and North Western, and the Manchester, Sheffield, and Lincolnshire Railways. The Act of Parliament, giving the necessary powers, was passed in 1846, but owing to want of funds, the work was not commenced till the beginning of 1849, when the increased traffic rendered additional space indispensable.

The viaduct forms an addition of 36 feet to the breadth of the station, throughout nearly its entire length, of about 700 feet; and gives three additional lines of rails on the upper level, without interfering with those below, on the level of the street. The station is formed on brick arches, at a height of about 30 feet above the streets. These arches are used as warehouses for goods, and the rails below communicate with those above, by means of hoists worked by stationary engines.

It was essentially necessary, in widening the station, that there should be no interference with the lines, either on the top, or the bottom level, and an extra width was, therefore, extended over the whole length of the goods station. The system of construction was by placing cast-iron pillars at intervals of 20 feet from each other, along the outside of the space to be enclosed. Cast-iron transverse girders of 31 feet 7½ inches clear span were then inserted at the proper level, with one end of each girder resting upon the brickwork of the existing arches, and the other end upon a pillar.

To these transverse girders were attached smaller longitudinal girders, also of cast iron, in such positions that one girder should be under each rail, and in order to give stability to the structure, in the direction of its length, brick abutments were erected at each end.

The longitudinal girders and outside cornices, being built into the abutments, afforded an effectual stay to the pillars, and kept the whole structure steady; and in order to prevent the transverse girders and pillars from moving laterally, they were fastened to the brickwork of the existing arches by wrought-iron tie-rods. The foundations of the pillars were composed of brickwork, and were

¹ The discussion upon this Paper extended over a portion of two evenings, but an abstract of the whole is given consecutively.

laid upon the red sandstone rock, which is at a depth of about 30 feet from the surface, at the west end, and about 10 feet from the surface, at the east end.

Upon the top of the longitudinal girders half-balk Memel timbers were bolted, and the whole space was planked with Memel deals, 3 inches thick, laid with a slight fall towards the outside gutters; well caulked and covered with a layer of tar and sand. The chairs were spiked to the planking, and where necessary, on account of its slope, oak packings were used, to bring them up to the proper level. In every case, care was taken that the spikes should have a good hold on the longitudinal timbers. In order to accommodate the traffic, it was necessary to have twenty-one turn-tables, which were fixed between the girders, and were of the simplest construction; moving round a hardened-steel pivot in the centre, and upon six rollers of 12 inches diameter on the outside. It was necessary, in order to communicate with the Sheffield Company's warehouses, to carry two lines of rails over Sheffield Street, at right angles to the main station. This was done by means of cast-iron girders, each 42 feet 5 inches span, resting on iron columns. It being more convenient to the contractors to cast each girder in two parts, a very ingenious plan was adopted for joining them. The girders were increased in depth, at the joint, by adding to their upper portion; and the joints, being planed true, were bolted together. At the bottom side of the lower web, a recess, of an elliptic form, was cast, into which a wrought-iron strap was put, whilst at a red heat, and the contraction, on cooling, made a very perfect joint, the wrought-iron strap being just in the proper place to resist the tension of the girder. This crossing of Sheffield Street also forms a transverse stay to the whole structure.

At the western end of the station is situated a large warehouse, belonging to the Sheffield Company, and in order to communicate with this, it was necessary to carry the three lines of rails across Store Street. The space to be spanned was 65 feet, and it was accomplished by means of wrought-iron girders, of a novel construction (Wood-cuts, Figs. 13, 14, and 15, Table V., page 232). The top part of each girder is a cylindrical tube, of 2 feet diameter, composed of boiler-plates half an inch in thickness. To the underside of this tube the middle web is riveted; it is formed of plates five-sixteenths of an inch thick, and 3 feet 6 inches deep. The bottom flange, 20 inches wide, is riveted to these plates; it consists, at the middle portion, of three thicknesses of plates three-eighths of an inch thick, diminishing to one thickness at the ends. The whole is put together with angle-iron, and the cylindrical form of the tube is preserved, by riveting the ends of the plates to internal angle-iron hoops.

The several parts of these girders are so arranged, that the whole is very accessible, and both the top and the bottom are well adapted to resist the strains they are respectively required to bear. The girders rest on large wall-plates, bolted down to the brickwork. Each of them was tested with a weight of 60 tons on the centre, and the deflection was not greater than one inch. The lines of railway are carried by timber cross-pieces, supported by angle-iron brackets, riveted to the middle web of the girders.

The whole of the cast-iron work is of 'Stirling's toughened iron,' and the contract was well executed by Messrs. Robinson and Russell, every part being fitted with the greatest accuracy, and each girder was tested to at least twice the load that can ever be brought upon it, the breaking weight being six times the greatest load it is calculated to carry. The total cost of the structure, including the foundations and laying the rails, was £13,868 13s. 4d., or nearly £20 per foot lineal.

The quantity of cast-iron, shown in the original design, was 1157 tons, but the contractors being permitted to use 'Stirling's toughened iron,' a considerable saving in the weight was effected, the actual quantity used being only 859 tons; whilst the strength of the girders was not diminished by the change, as was proved by the testing, which showed that they were fully capable of supporting the required weight.

The following is a detail of the quantities, and of the cost of each part of the structure:—

DESCRIPTION.	Quantity.	Price.	Amount.
		£. s. d.	£. s. d.
Excavating foundations . .	2,782 cub. yds.	0 2 6	360 5 0
Brickwork	1,650 ,,	0 15 0	1,237 10 0
Footings	321 ,,	1 0 0	321 0 0
Ashlar	513 cub. feet	0 1 4	34 4 0
Cast-iron ('Stirling's tough- ened iron')	859 tons 1 cwt.	8 7 7½	7,199 18 4
Wrought-iron, in bolts, tie- rods, &c.	19,040 lbs. . .	0 0 4	317 6 8
Wrought-iron girders over Store-street.	44 tons 15 cwt.	22 0 0	984 10 0
Memel timber	4,642 cub. feet	0 2 10	657 12 4
,, planking, 3 in. thick	25,449 sup. feet	0 1 0	1,272 9 0
Laying three lines of rails .	250 linl. yards	0 3 0	37 10 0
Turntables, fixed.	21 ,,	45 0 0	945 0 0
Iron staircase, complete . .	..	..	75 8 0
,, fence railing and gates.	..	..	426 0 0
Total	..	.. £	13,868 13 4

The Paper is accompanied by an Appendix, containing the details of the testing of the girders, and is illustrated by diagrams of the forms and sections of the girders, whence the woodcuts (Figs. 1 to 15) are compiled.

APPENDIX.

TABLES showing the RESULT of the TESTS applied to each GIRDER.

TABLE I.

TRANSVERSE CAST-IRON GIRDERS.

Fig. 1 shows Elevation and Plan.

,, 2 ,, Section at centre.

,, 3 ,, Ditto at neck.

Fig. 1.

Figs. 2, 3.

	Feet.	Inches.
Total length of girder	37	3
Span	31	8
Depth at centre	3	3
Thickness of vertical web	0	2
,, top flange	0	2 1/4
Breadth of ditto	0	8
Thickness of bottom flange	0	2 1/2
Breadth of ditto at centre	2	0
,, ,, at ends	1	6

Weight of each girder 7 tons 10 cwt.

Each girder was tested, first with 28·80 tons, and then with 67·88 tons, applied at the centre, and the deflection and set recorded in inches and decimals; the results are given in the following Table:—

No.	Deflection.	Set.	No.	Deflection.	Set.	No.	Deflection.	Set.	No.	Deflection.	Set.
1	0·26	0·00	9	0·32	0·00	17	0·30	0·00	25	0·22	0·00
„	0·60	0·10	„	0·68	0·10	„	0·65	0·10	„	0·52	0·05
2	0·20	0·00	10	0·30	0·00	18	0·27	0·00	26	0·25	0·00
„	0·55	0·00	„	0·70	0·12	„	0·60	0·08	„	0·58	0·08
3	0·15	0·00	11	0·28	0·00	19	0·52	0·00	27	0·30	0·00
„	0·50	0·05	„	0·52	0·05	„	0·68	0·12	„	0·62	0·15
4	0·12	0·00	12	0·28	0·00	20	0·50	0·00	28	0·30	0·00
„	0·48	0·08	„	0·52	0·10	„	0·65	0·08	„	0·62	0·10
5	0·20	0·00	13	0·28	0·00	21	0·35	0·00	29	0·22	0·00
„	0·42	0·08	„	0·65	0·08	„	0·62	0·08	„	0·52	0·10
6	0·20	0·00	14	0·32	0·00	22	0·38	0·00	30	0·26	0·00
„	0·48	0·10	„	0·70	0·12	„	0·65	0·10	„	0·55	0·10
7	0·25	0·00	15	0·28	0·00	23	0·25	0·00	31	0·26	0·00
„	0·60	0·08	„	0·62	0·12	„	0·55	0·05	„	0·55	0·10
8	0·22	0·00	16	0·25	0·00	24	0·32	0·00	„	„	„
„	0·58	0·00	„	0·60	0·10	„	0·65	0·10	„	„	„

TABLE II.
LONGITUDINAL CAST-IRON GIRDERS.

Fig. 4 shows Elevation and Plan.

„ 5 „ Section at centre.

„ 6 „ „ at end.

Fig. 4.

Figs. 5, 6.

	Feet.	Inches.
Total length	19	2 1/4
„ between supports	18	1 1/4
Depth at centre	2	2
„ at ends	1	5
Thickness of vertical web	0	1
„ top flanch	0	1
Breadth of „	0	9
Thickness of bottom flanch	0	1 1/4
Breadth „ „	0	9

Weight of each girder 1 ton 4 cwt.

These girders were tested with a weight of 28·80 tons, applied to the centre, and the deflection recorded in inches and decimals; the results are given in the following Table:—

No.	Deflection.	No.	Deflection.	No.	Deflection.	No.	Deflection.	No.	Deflection.	No.	Deflection.	No.	Deflection.
1	0·27	24	0·30	47	0·32	70	0·25	93	0·30	116	0·25	139	0·30
2	0·22	25	0·25	48	0·20	71	0·30	94	0·26	117	0·30	140	0·38
3	0·23	26	0·30	49	0·25	72	0·30	95	0·26	118	}	141	0·35
4	0·25	27	0·26	50	0·35	73	0·25	96	0·28	119		142	0·35
5	0·30	28	0·39	51	0·28	74	0·30	97	0·28	120	}	143	0·30
6	0·30	29	0·30	52	0·22	75	0·28	98	0·18	121		144	0·28
7	0·30	30	0·30	53	0·18	76	0·30	99	0·18	122	}	145	0·30
8	0·32	31	0·28	54	0·20	77	0·32	100	0·30	123		146	0·30
9	0·30	32	0·35	55	0·28	78	0·30	101	0·28	124	}	147	0·30
10	0·25	33	0·32	56	0·25	79	0·28	102	0·28	125		148	0·28
11	0·30	34	0·32	57	0·18	80	0·25	103	0·25	126	}	149	0·28
12	0·25	35	0·30	58	0·28	81	0·28	104	0·28	127		150	0·30
13	0·20	36	0·32	59	0·30	82	0·30	105	0·28	128	}	151	0·28
14	0·30	37	0·28	60	0·30	83	0·28	106	0·30	129		152	0·30
15	0·22	38	0·28	61	0·25	84	0·30	107	0·28	130	}	153	0·28
16	0·25	39	0·28	62	0·20	85	0·25	108	0·30	131		154	0·30
17	0·20	40	0·25	63	0·22	86	0·18	109	0·28	132	}	155	0·32
18	0·22	41	0·32	64	0·30	87	0·20	110	0·30	133		156	0·28
19	0·21	42	0·25	65	0·30	88	0·28	111	0·28	134	}	157	0·28
20	0·22	43	0·28	66	0·25	89	0·28	112	0·30	135		158	0·28
21	0·28	44	0·35	67	0·22	90	0·22	113	0·28	136	}	159	0·30
22	0·20	45	0·28	68	0·25	91	0·26	114	0·20	137		160	0·30
23	0·22	46	0·28	69	0·25	92	0·30	115	0·25	138	0·30	161	0·30

There was no permanent set observable in any of these girders.

TABLE III.

SHORT CAST-IRON GIRDER,
carrying the end of the centre Girder of the Sheffield-street Bridge.
Span, 16 feet 4 inches.

Fig. 7 shows Elevation and Plan.

„ 8 „ Section at centre.

„ 9 „ „ at end.

Fig. 7.

Figs. 8, 9.

* These girders were tested, after their erection, with the specified weight of 10 tons, and the deflection in no case exceeded 0·10.

IRON VIADUCT.

	Feet.	Inches.
Total length	19	3
„ between supports	16	3½
Depth at centre	2	0¼
„ at ends	1	6
Thickness of vertical web.	0	1¼
„ of top flanch	0	1½
Breadth of ditto	0	3
Thickness of bottom flanch	0	1½
Breadth of ditto	1	0

Weight of girder, 1 ton 5 cwt.

This girder was tested, after the completion of the bridge, by weights varying from 10 to 20 tons applied at its centre, in addition to what it already supported (about 6 tons 10 cwt.). The deflection was recorded in inches and decimals, and is given in the following Table:—

Weight.	Deflection.	Set.
10	0·05	..
12	0·06	..
14	0·07	..
16	0·09	..
18	0·10	..
20	0·11	0·00

TABLE IV.

CAST-IRON GIRDERS—Sheffield-street Bridge.

Fig. 10 shows Elevation and Plan.

„ 11 „ Section at centre.

„ 12 „ „ at ends.

Fig. 10.

Figs. 11, 12.

	Feet.	Inches.
Total length	47	6
,, between supports	42	5
Depth at centre	3	6
,, at ends	2	4
Thickness of vertical web	0	1½
,, of top flanch	0	1½
Breadth of ditto	0	9
Thickness of bottom flanch	0	2
Breadth of ditto	1	6

Weight of each girder, 7 tons 10 cwt.

Each girder was tested with a weight of 18·83 tons, applied at the centre, and the deflection was recorded in inches and decimals. The following Table gives the results :—

No.	Weight.	Deflection.	Set.
1	18 83	0·75	0·06
2	18·83	0·93	0·13
3	18·83	0·93	0·13

TABLE V.

WROUGHT-IRON TUBULAR GIRDERS—Store-street Bridge.

Fig. 13 shows Section of the Girder.

,, 14 ,, Elevation.

,, 15 ,, arrangement of Plates of Bottom Flanch.

	Feet.	Inches.
Total length of girder	71	0
,, span	65	0
Depth from centre of tube to bottom flanch	4	6
Diameter of tube (outside)	2	0
Thickness of tube, 3 plates at each end	0	0⅞
,, ,, other 7 plates	0	0½
Depth of vertical web	3	6
Thickness of web, 2 plates at each end	0	0⅝
,, ,, other 5 plates	0	0¼
Width of bottom flanch	1	8
Thickness of ditto at centre	0	1½
,, ,, at ends	0	0¾

Weight of each girder, 11 tons 4 cwt.

Fig. 13.

Two of these girders, B and C, were tested in London, with weights of 33 tons and 60 tons on the centre of each. Subsequently, the whole of the girders were tested, with weights equally distributed. The weights in the latter case have been halved, so as to bring them more nearly to correspond with the former, and the results of the whole are given in the following Table. The deflections are given in inches and decimals.

No.	Weight.	Deflection.	Set.
A	10·75	0·1550	0·000
B	19·25	0·3250	..
„	33·00	0·5000	..
„	35 50	0·6250	..
„	60·00	0·9500	0·000
C	16·25	0·2875	..
„	33·00	0·6200	..
„	38·75	0·7000	..
„	60·00	1·0100	0·000
D	12·50	0·2250	0·000

Fig. 14.
Elevation of Wrought-Iron Girder. Fig. 15.
Arrangement of Bottom Plates.