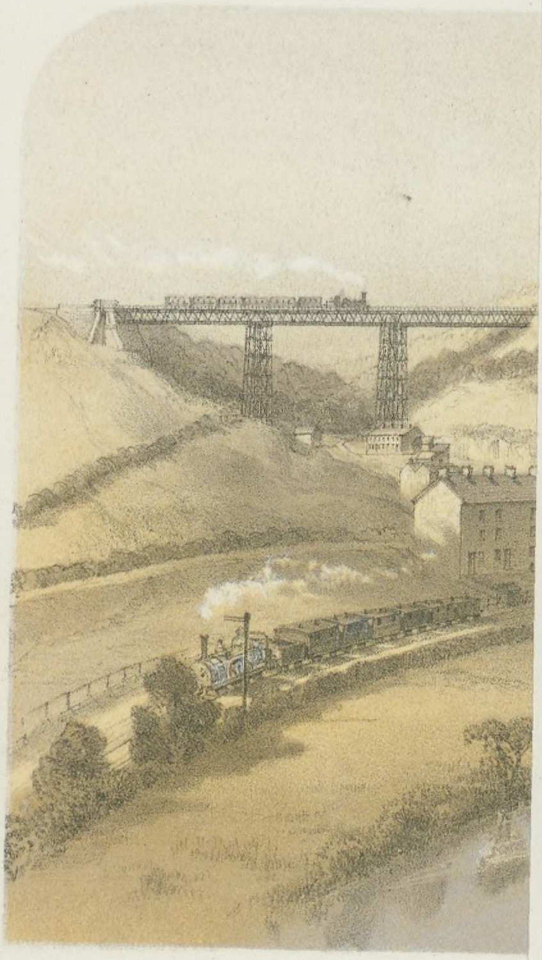
BRIDGES, ROOFS &c.

BY

HENRY N. MAYNARD.

John A. Irvin



Sketched by H.J.Cooke.

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John A Prior

THE VIADUCT WORKS' HANDBOOK;

BEING

A COLLECTION OF EXAMPLES FROM ACTUAL PRACTICE

OF

VIADUCTS, BRIDGES, ROOFS, AND OTHER STRUCTURES IN IRON;

TOGETHER WITH

TABLES OF PRICES, WEIGHTS, AND OTHER INFORMATION USEFUL TO ENGINEERS IN DESIGNING AND ESTIMATING WROUGHT AND CAST-IRON WORK.

BY

HENRY N. MAYNARD,

(MANAGER OF THE VIADUCT WORKS, CRUMLIN, MON.)

LONDON:
E. AND F. N. SPON, 48, CHARING CROSS.

1868.

Sketched by H.J. Cooke.

Maclure Macdonald & Macgregor Lith.rs 37, Walbrook

CRUMLIN VIADUCT,

ON THE TAFF VALE EXTENSION OF THE WEST MIDLAND RAILWAY,

CONSTRUCTED EXCLUSIVELY OF IRON. _ LENGTH 1658 FEET._ HEIGHT 200 FEET.

Designed and Erected by T. W. Kennard Esq. C.E.

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LONDON:
PRINTED BY GEORGE PHIPPS, 13 & 14, TOTHILL STREET,
WESTMINSTER.

PREFACE.

The want of a handy book, containing reliable data upon which approximate estimates for bridges, roofs, buildings, railway machinery, &c., may be formed, has long been felt, more especially by persons at a distance from home, and having charge of engineering work in foreign countries. Information on these subjects will accumulate in the hands of any one who is called upon to superintend extensive engineering works, and who will be at the pains to make notes of all that appears to deserve attention. The materials forming the following pages have been collected chiefly from work actually carried out at the Viaduct Works, which has passed through the author's hands during a period of about fourteen years while employed there. In order to make the book more generally useful, such tables have been added as are likely to be required in estimating work of the nature described, with a catalogue of articles manufactured at the Works.

The prices mentioned are to be understood as merely approximate; they will, of course, be modified according to the variations in the price of iron,* the quantity, mode of payment, &c. It is,

* The price of manufactured iron has varied in the last fourteen years as much as £3 to £4 per ton, and is continually varying.

therefore, necessary at all times to consider each work upon its own merits.

The Viaduct Works are situated immediately beneath the Crumlin Viaduct, the position of which is described herein under a brief description of that work. For a more complete account of the viaduct the reader is referred to a work published by the author, called a "Handbook to the Crumlin Viaduct." The works were erected, in the first instance, for the purpose of manufacturing that much-admired bridge, which hangs over them like a huge sign, and as a fitting memorial of their capabilities. Since the completion of that work many others of equal, and some of greater, magnitude have been manufactured upon the same spot, as will be found on examining the tabulated statements herein given of some of the bridges, &c., made there.

THE VIADUCT WORKS' HANDBOOK.

IRON BRIDGES.

Parallel iron girder bridges of the class shown in woodcuts, Figs. 1, 2, 3, for ordinary cases, are the most convenient in form for moderate spans, whether of triangular, as Fig. 1, latticed, as Fig. 2, or plain plate, as Fig. 3, and are either with floor on top of the main girders, and surmounted by parapet railing, or with floor at bottom as in Fig. 4, or at any convenient height wherein the main girders may serve as parapets.

FIG. 1

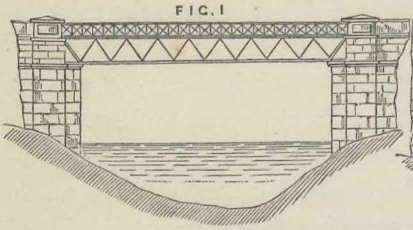


FIG. 2

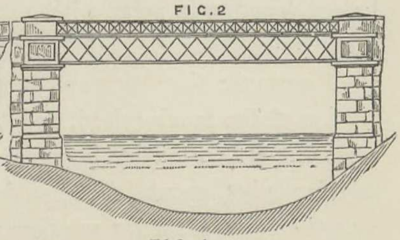


FIG. 3

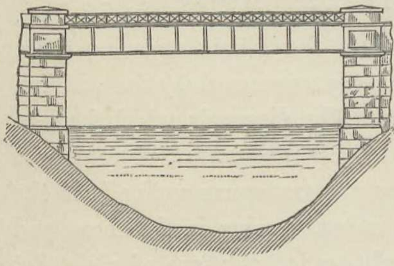
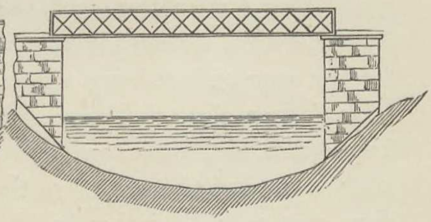


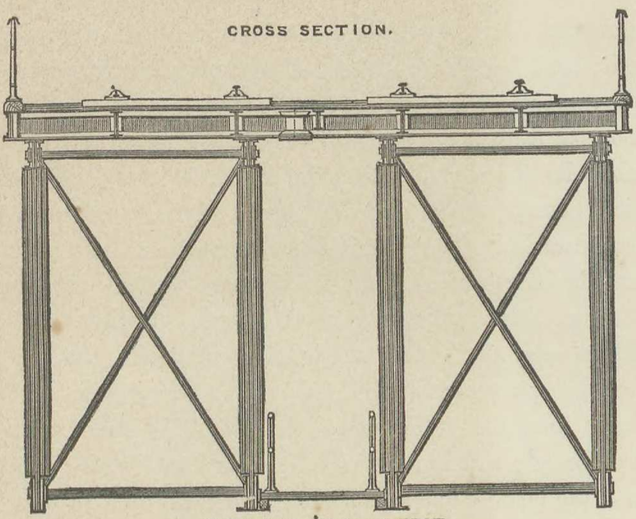
FIG. 4



It is generally found that the most economical depth of which girders may be constructed, as regards the quantity of material used in them, is about a twelfth of their span, although special circumstances make it necessary to deviate slightly from this. When height beneath a bridge is an object desired, with the minimum depth from bottom of girders to surface of the road carried by them, the arrangement shown by Fig. 4 is used; in other cases it is most economical to place the floor on top of the main girders.

Crumlin Viaduct, situated in one of the most picturesque spots in the county of Monmouth, and in what is geologically termed the South Wales coal basin, is distant from Pontypool four and a half, and from Newport, twelve miles; carries the West Midland section of the Great Western Railway across the charming valley of the river Ebbw, about seven miles from the great ironworks of Ebbw Vale, Nantyglow, &c. Is an example of the class, Fig. 1, known as Kennard and Warren's patent girders, consists of ten spans of 150 feet each, measured from centre to centre of supports, total length, including abutments, 1,658 feet, and is constructed to carry a double line of railway upon iron piers of great height, the particulars of which are given under that head.

The main girders spanning the opening between supports, four in each opening, are 15 feet 6 inches deep, and placed 9 feet apart, and braced together in pairs, with a space of 6 feet between the pairs, in the manner shown by sketch. The two inner girders are made somewhat stronger than the outer ones, because they carry a greater portion of the moving load, and the rails are nearer to them. The compression bars, or top flanges of these girders, are composed of rectangular tubes, about 14 inches deep and 18 inches wide, the width and thickness of plates varying according to the strain they bear; whilst their tension bars, or bottom flanges, are of plain flat bars, 16 inches deep, arranged in two flitches, the thickness varying, those for the inner girders being somewhat strengthened by the addition of angle iron along the lower edge. The diagonals, which have to bear compressive strain, and called struts, are formed of angle and plate iron, rivetted together so that the transverse section is of the form of a cross, 10 inches by 10 inches, varying in thickness, and those which only bear tensile strain, called ties, are of plain flat bars, 9 inches wide. The floor is 26 feet wide between parapets, composed of wrought-iron cross girders, 12 inches deep, placed about 5 feet apart, at right angles to and on top of the main girders, and bolted to them at each intersection; lighter longitudinal girders are placed under each rail between these cross girders, and attached to them, so that they are even on the top; the whole surface is covered with sheet iron, $\frac{1}{4}$ of an inch thick, well rivetted to them,—this forms an even surface, which is made waterproof by the application of a thick coating of hot tar and asphalte.



The weight of ironwork per span for the double way is as follows:—

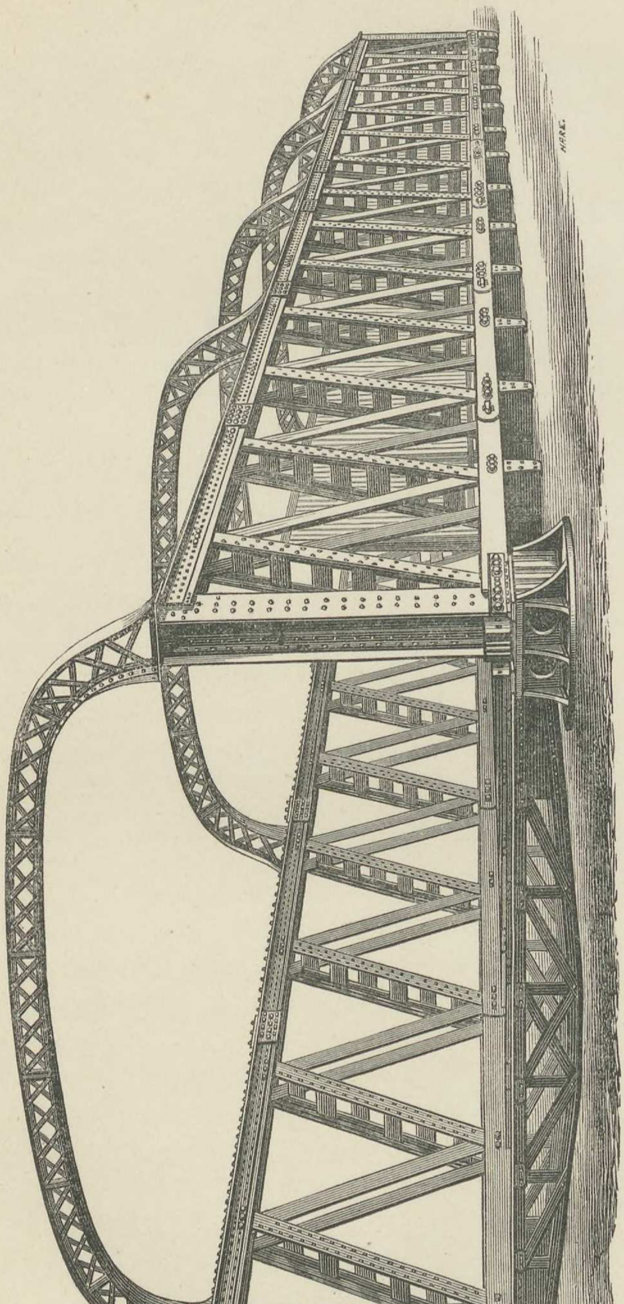
	Tons	cwts.	qrs.	lbs.		Tons	cwts.	qrs.	lbs.
Tension bars	14	7	2	2					
Compression bars . . .	17	0	2	21					
Diagonal struts . . .	9	13	0	22					
,, ties	6	19	1	18					
Gusset bracing . . .	4	11	3	20					
Pins, bolts, nuts, &c. . .	3	17	2	27					
Bearing blocks, &c. . .	0	2	1	12					
For one pair main girders	56	13	3	10	× 2 =	113	7	2	20
Flooring of wrought-iron plates and cross girders						50	5	0	0
						163	12	2	20 per span,

or 1·09 tons per foot run, including flooring; and taking the value of the ironwork, delivered f. o. b. in an English port, at £16 per ton, it brings the price to about £17 9*s.* per foot run.

The whole of the wrought-iron used in the above was manufactured at Blaenavon Works, which are situated within a few miles of the spot. The handrailing is formed of light ornamental cast-iron, bolted to the platform. The gross cost of this bridge, piers and abutments included, was £68,800, or about £41 10*s.* per foot run. It was erected immediately on the site of the Viaduct Works of Messrs. Kennard Brothers, by whom it was designed and carried out, and the cost of erection is included. Many other bridges of this class have been made since the Crumlin Viaduct; amongst others made at the same works may be mentioned Barrakur Bridge.

Barrakur Bridge.—This bridge consists of ten spans, of 155 feet each; total length, 1650 feet, situated over the Barrakur River, in India; made on Kennard and Warren's patent principle. Its chief novelty consists in being so constructed as to be entirely put up with bolts, thereby obviating the labour of rivetting, which, in a tropical climate, where skilled labour is scarce, is almost a necessary consideration. The joints of the compression bars are formed without side flanges of angle iron, which are planed and accurately fitted, so as to be put together with great facility. It is constructed to carry an 18-feet width of macadamized road over the top, there being three main girders in each opening; the centre one is stronger than the outer ones. The floor is of wood, which was provided abroad; cast-iron parapet, like that for Crumlin Viaduct, is used, and the piers or supports are of stone; the iron used is about 89 tons in each span or opening; and, taking the price as before, gives the cost £1,424 per span, or about £9 5*s.* per foot run.

Murray River Bridge, designed by W. Dempsey, Esq., C.E., of 26, Great George Street, Westminster, London, for Australia, another example of the same class of bridges recently made at Crumlin, is arranged for carrying the floor for road at the bottom. It is for a macadamized road 22 feet wide, and a footway supported outside the girders 3 feet wide on each side, with overhead arched stays. It has five spans of 121 feet centre to centre of supports, and is supported upon iron piers of the *cylindrical form* 8 feet diameter, more particularly described under that heading. This, like the last example, is arranged so that all the parts which have to be put together abroad are bolted, and no rivetting is necessary, and can therefore be erected by unskilled workmen. The top flanges or compression bars of main girders are of the semi-rectangular tube section, with thickening plates 24 inches wide, varying in number according to the strain, and are put together at the joints with turned bolts in drilled holes. The bottom flanges or tension bars consist of flat bars, and are jointed by steel pins turned oval and fitted in corresponding bored holes. Diagonal struts are of the H form of section, and ties of flat bars. The roadway is suspended by suitable connexions from the main girders upon light transverse girders of the open lattice description, at about 9 feet apart, pro-


HARE.

jecting on each side far enough to give support to the footways on each side, and to the extremities of these a light wrought-iron latticed parapet is fastened. The whole floor is covered with sheet-iron $\frac{3}{16}$ths of an inch thick, buckled to give it additional stiffness, and supported by longitudinal and transverse light angle iron to which the sheeting is rivetted, forming panels, which are sent from this country completely rivetted, and are attached to the cross girders with bolts when erected. On top of this sheeting is laid a coating of tar and asphalte, which makes the floor waterproof, and over which the metalling is laid. The weight of ironwork in one span is 111 tons exclusive of flooring, which, at £16, gives the cost per span £1,776, the weight per foot run, say, 18 cwt. 1 qr. 4 lbs., and price, at the above rate, £14 12*s*. 6*d*. The flooring is about 28 tons per span, or about £3 14*s*. per foot run in addition to the above.

TABLE *of particulars of some of the Bridges manufactured at Crumlin Viaduct Works, of the class Fig.* 1.

Where for, &c.	No. of Spans.	Length of Spans in Feet.	Gross Weight in Tons.	Remarks.
Llanelly and Llandilo Railway	1	150	60	Single Road at bottom, arched overhead stays, wood floor, no cross girders
India	3	$\frac{1}{100}$ $\frac{2}{50}$	—	Road on top; wood floor
East Indian Railway	14	89	623	Single-line, road at bottom, with cross girders
Pernambuco Railway	17	60	364	Road on top, single line, without cross girders
Bombay and Baroda Railway	10	60	227	Road at bottom, single line, with cross girders
Kidderpore and Balliaghatta	2	$\frac{1}{102}$ $\frac{1}{132}$	180	Road at bottom, macadamized road, iron floor
Lelajun, India	10	56	254	Road on top, macadamized road, iron floor
Rindh, India	1	100	95	Road on top, macadamized road, iron floor
Halifax Railway	4	79	150	Road at bottom, single line, wood floor, with cross girders
Crumlin Viaduct	10	150	1636	Road at top, for double-line railway
Murray River, Australia	5	121	555	Road at bottom, macadamized road, iron floor

Tagus Bridge.—This bridge, erected at Villa Nova da Constancia, on second section Badajoz line, is an example of the class Fig. 2, selected from many others of the same. It consists of 16 spans of 101 feet 10 inches each from centre to centre of piers, and the superstructure, that is to say, the girders and floor without piers, is constructed for a single line of railway, so that an additional line can be added by the addition of more girders.

The main girders, of which there are two for each span for a single line of railway, are 8 feet 10½ inches deep, placed about 10 feet apart, centre to centre, and connected together in pairs by light horizontal bracing. Their compression bars are of the semi-rectangular tube section, 18 inches wide on top, and 7 inches deep, giving a sectional area of 24·75 square inches at centre, and the greatest strain is 4 tons per sectional inch. This area is gradually diminished from the centre to the ends, where it is but 9 square inches. The tension bars consist of four bars 9 inches by ⅝ths of an inch, and, at the end, two bars 9 inches by ½ an inch. Those of the diagonals acting as struts are made of bar and angle iron, those acting as ties of flat bars. The end strut consists of one flat bar 6 inches by ⅜ths of an inch, and two angle bars 4 inches by 3 inches by ⅜ths of an inch, and the end tie of two bars 6 inches by ⅝ths of an inch; the centre struts and ties are of lighter sections. The floor is supported by transverse girders 19 in each span, placed about 5 feet 6 inches apart, resting on top of the main girders and attached thereto by bolts. These girders are composed of ¼-inch plate 9 inches deep, and four angle irons 3 inches by 3 inches, and are made long enough to give clear 14-feet width of roadway when the handrail standards are fixed upon them. The ends of the main girders, to allow for expansion, rest upon iron rollers moving on bed plates attached to tops of the piers. The weight of ironwork per span for a single line of way is as follows:—

	Tons.	cwts.	qrs.	lbs.
Two compression bars	8	4	2	3
Two tension bars	5	19	3	0
Two sets of struts and ties	6	10	3	13
Four vertical ends	1	13	1	6
Total for two main girders . . .	22	8	1	22


HARE

	Tons.	cwt.	qrs.	lbs.
Vertical and horizontal bracing between girders .	3	13	0	26
Nineteen cross girders and their bolts . . .	3	2	1	2
Rollers and bed plates	1	10	3	0
Two rows handrailing	2	13	3	24
Total . .	33	8	2	18

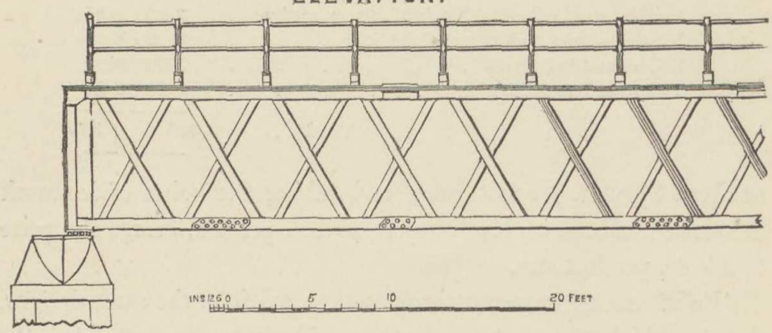
or about 6½ cwts. per foot run; and, taking the value of ironwork delivered f. o. b. in an English port at £16 per ton, brings the price to £5 4*s.* per foot run.

From among numerous bridges executed from the same designs, and to which the same particulars will apply, are extracted the following:—

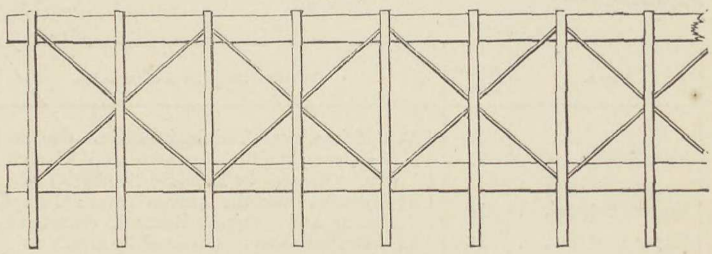
Name.	No of Spans.	Where situated, and other notes.
Ebro Bridge. . .	21	At Cadrieta, near Tudela, in Spain, over the river Ebro, carrying the Saragossa and Alsasua Railway. (Erected by Kennard Brothers.)
Aragon Bridge . .	18	At Marsilla, over the Aragon River: Pampeluna, Alsasua, and Saragossa Railway. (Erected by do.)
Tagus Bridge . .	16	As described above. (Erected by ditto.)
Asseca Bridge . .	5	On the Badajoz Line; piers 40 feet in blue clay. (Erected by ditto.)
Mondego Bridge .	9	Over the Mondego River, in Portugal.
Valle deEsquieras Viaduct . .	3	Situate on the Second Part of Fourth Section of Oporto Line of Railway.
Seisse Bridge . .	6	On the First Section of Oporto Line.

In designing these bridges, the Messrs. Kennard have taken, as the basis of their calculations, 1 ton per foot run as the test load, which, until recently, was considered ample for such bridges; but since there has been a great increase in the weight of locomotive engines, and a still further tendency to increase their weight, they have thought it desirable, wherever convenient, that the test load should be calculated at 1½ tons per foot run, exclusive of the weights of the girders, platforms, rails, &c., and that the strain should not exceed 4 tons per square inch in section in compression, and 5 tons in tension; and, accordingly, their bridges of class Fig. 2 and Fig. 4 are manufactured at the following approximate weights, exclusive of handrail:—

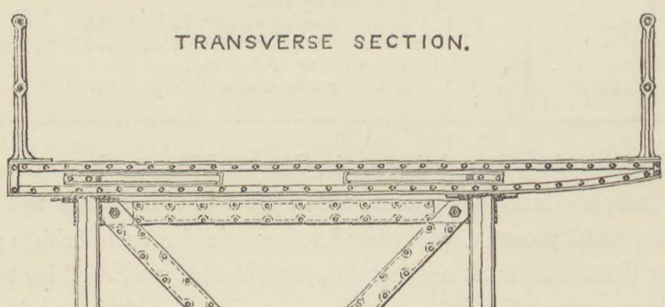
ELEVATION.



PLAN.



TRANSVERSE SECTION.

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Road on Top, as Fig. 2.

Spans. Feet.	Remarks.		T.	C.
10	Plate Girders	*Under Rails.*	1	2
15	” ”		1	15
20	” ”		2	7
25	” ”		3	2
30	” ”		4	7
35	” ”		7	0
40	Lattice Girders		10	0
50	” ”		12	10
60	” ”		18	0
70	” ”	*With Cross Girders.*	24	10
80	” ”		30	5
90	” ”		35	15
100	” ”	*With Cross Girders & Rail Bearers.*	42	0
110	” ”		51	0
120	” ”		61	10
130	” ”		73	0
140	” ”		84	10
150	” ”		99	0
175	” ”		130	0
200	” ”		160	0

Road through, as Fig. 4.

Spans. Feet.	Remarks.		T.	C.
20	Plate Girders	*With Cross Girders.*	5	0
25	” ”		6	5
30	” ”		7	15
35	” ”		9	15
40	Lattice Girders		15	0
50	” ”		18	0
60	” ”		25	0
70	” ”		31	15
80	” ”		36	10
90	” ”	*With Cross Girders & Longitudinal Rail Bearers.*	42	0
100	” ”		48	0
110	” ”		57	0
120	” ”		67	15
130	” ”		80	10
140	” ”		92	0
150	” ”		107	0
175	” ”		138	0
200	” ”		164	0

Another example of this class of bridge, worthy of notice, is the Velletri Viaduct, represented by the accompanying engraving, selected as an example of a cheap bridge, and one executed in a short space of time.

This bridge is situated at Velletri, near Rome, and is constructed to carry the railway over a deep valley. It consists of three spans of 152 feet of wrought-iron, 12 feet 3 inches deep; the total length of the bridge, including masonry abutments, 600 feet. It is supported on two cast-iron piers; each pier is formed of six cast-iron columns, 90 feet high, 3 feet diameter at base, tapering to 2 feet at top, bound together with arched cast-iron girders at each 20 feet, which are covered with ornamental cast-iron fascias. The thickness of columns 1 inch; the extreme height of the bridge is 135 feet. The superstructure is for a double line of railway, which is carried on top of the girders. This bridge was erected in the short space of two months—a work unprecedented in the history of bridge making.

Setting aside the piers, the superstructure weighs about 130 tons for a span, or about 390 tons in all; or, say, 17½ cwt. per foot, which, at the price of £16 per ton, is £14 per foot.

The following table of particulars of some of the bridges of this class, from designs of Messrs. Kennard, which have been manufactured by them at the Viaduct Works, may be found useful for reference in forming approximate estimates of the cost, in England, of iron superstructure of bridges of the kind illustrated; amongst these may be mentioned one which is noted (*a*) in the margin, it being remarkable as having been made in an exceedingly short space of time. The order was received at Crumlin Viaduct Works on 12th July, and the bridge was designed, made, and on its way to the shipping port on the 1st August, that is to say, in eighteen working days. It is about 230 feet long, and the weight, including piers, is about 300 tons; it contains 2500 bars and plates, 530 castings, 30,000 rivets, 8500 bolts, &c.

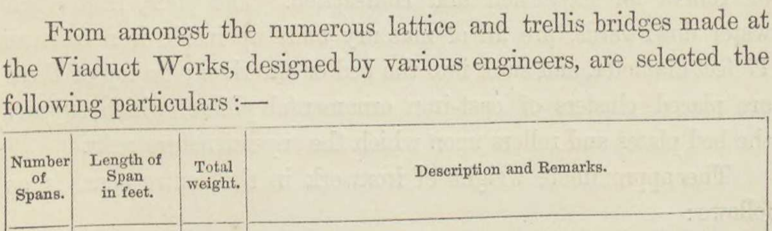
TABLE *of Particulars of some of the Bridges manufactured at Viaduct Works, of the class Fig.* 2 *and Fig.* 4.

Number of Spans.	Length of Span.	Total weight of the superstructure in tons.	Where for.	Remarks.
1	165	261	America	For a double line of railway, road at bottom
2	164 each	265	Italy	Ditto single ditto ditto bottom
3	150 „	384	ditto	Ditto double ditto ditto top; for wood floor, no cross girders
1	150	124	Ireland	For a single line of railway, road at middle
1	132	125	England	Ditto double ditto ditto bottom
5	131 each	422	Italy	Ditto single ditto ditto top
10	131 „	972	ditto	Ditto ditto ditto ditto bottom
1	115	66	ditto	Ditto ditto ditto ditto ditto
2	102 each	68	Portugal	Ditto ditto ditto ditto top
78	101 „	2652	Spain & Portugal	Ditto ditto ditto ditto ditto
2	100 „	84	England	Ditto ditto ditto ditto ditto
3	98 „	159	Italy	Ditto ditto ditto ditto bottom
1	98	51	ditto	Ditto ditto ditto ditto top
1	97	45	Portugal	Ditto ditto ditto ditto bottom
3	95 each	94	ditto	Ditto ditto ditto ditto top
1	86	38	Italy	Ditto ditto ditto ditto bottom
1	85	27	Granada	Ditto ditto ditto ditto ditto
2	82 each	84	Italy	Ditto ditto ditto ditto ditto
4	82 „	136	ditto	Ditto ditto ditto ditto top
(*a*) 3	78 „	115	Portugal	Ditto ditto ditto ditto ditto
1	75	32	England	Ditto ditto ditto ditto ditto
1	75	36	ditto	Ditto ditto ditto ditto bottom
3	70 each	90	Italy	Ditto ditto ditto ditto ditto
4	65 „	69	Portugal	Ditto ditto ditto ditto top
4	65 „	118	Italy	Ditto ditto ditto ditto ditto
15	60 „	328	America	Ditto ditto ditto ditto ditto
11	60 „	165	Portugal	Ditto ditto ditto ditto ditto

It will be noticed, in comparing the weights, that the bridges for Italy are much heavier than for some other countries. This is chiefly in consequence of the Government regulation of that country for iron bridges requiring that the metal should not be strained over 4 tons per square inch either in tension or compression; and hence they are made stronger than those for Spain and Portugal.

In all the foregoing examples of lattice bridges it will be seen that the lattices formed by the struts and ties, between the compression and tension bars, are placed at an angle of 60°. Many engineers adopt other forms of lattice girders; whilst some prefer placing the lattices at an angle of 45°: others, of various angles, making them also of lighter section, and placed nearer together, forming trellis-work more approaching the principle of a plate girder. From a careful comparison of the numerous examples which have come under the notice of the writer, it appears to show that, as regards economy, there is no great difference; for where a saving of iron is effected, it is generally attended with the employment of more expensive sections of material and labour in making.

Light trellis girders are sometimes economical and convenient for small foot bridges, &c., where they are employed to form a parapet, as well as to carry the weight, as in the accompanying sketch.



From amongst the numerous lattice and trellis bridges made at the Viaduct Works, designed by various engineers, are selected the following particulars:—

Number of Spans.	Length of Span in feet.	Total weight.	Description and Remarks.
5	120	275	Lattice 45°; no cross girders; 8 in. wood floor, road top. (Tees.)
12	70	240	Trellis bars about 1 foot apart, angle 45°; no cross girders; the road supported on wood cross bearers. (Spain.)
21	74	450	Ditto ditto.
4	98	120	Road top; no cross girders; single line.
180	30	1500	Solway—Single line railway, latticed at angle 45°.
5	176 to 202	2700	Thames, at Blackfriars—For 4 lines railway; trellis.

The Blackfriars Bridge, for carrying the London, Chatham, and Dover Railway over the Thames in London, may be selected from the foregoing list, as an example of trellis girder bridge top, a perspective view of a portion of which is given on the opposite page; was designed by Joseph Cubitt, Esq., C.E., and manufactured and erected by Messrs. Kennard; consists of five spans for a quadruple line of way carried on the bottom; each span contains three main girders, namely, one centre and one each side, these latter forming the parapets; all three are braced together by light overhead arches. The floor is composed of ¼-inch plain sheet iron, which rests upon transverse girders placed about 4 feet apart, and attached to the lower portion of the main girders; between these transverse girders, under each rail, is placed a light longitudinal girder, the top being even with them; the whole surface is protected from weather by a thin coat of asphalte, upon which the sleepers and rails are laid.

The main girders are, for uniformity, all of one depth, namely, 14 feet; the centre girder of middle span is built with plates and angle-iron, forming tension and compression bars of the semi-tubular section 4 feet 6 inches in width, and about 2 feet deep, the top plates varying in number and thickness, but having three feathers for attachment of the struts and ties forming the trellis bars; these bars are made of trough-iron where they form struts, and their section varied to suit the strain they bear; they are used in pairs, and are also stiffened by lattice bars and distance pieces attached to them, so as to connect the pairs. The ties are of plain bars, varying in section according to the strain they bear. Each main girder is attached to a fixed bearing at one end, the other being free to move on rollers for expansion and contraction. The piers, from high water downwards, are all of masonry built up inside iron caissons 17 feet diameter, and sunk into the bed of the river; on top of these are placed clusters of cast-iron ornamental pillars, which support the bed plates and rollers upon which the superstructure rests.

The approximate weight of ironwork in the centre span is as follows:—

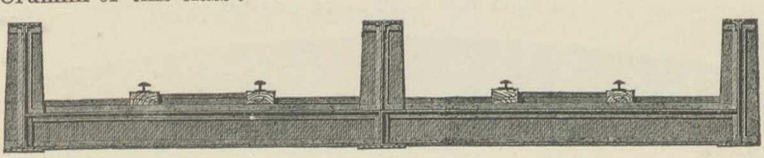

HARE

	Tons.	cwts.	qrs.	lbs.
Plates in compression and tension bars	285	10	3	8
Angle iron in " "	63	5	0	5
Struts	77	19	3	14
Ties	44	14	2	24
Arches	7	19	0	14
Transverse girders	93	9	3	14
Longitudinal girders	43	0	0	14
	615	19	2	9 the side and end spans being lighter.

The total weight of the superstructure is about 2700 tons, as the girders are all of excessive thickness in the centre flanges, there being six thicknesses of $\frac{3}{4}$-inch plate for the rivets to pass through. All the holes of the main girders were therefore drilled by special machinery, which is described in another part of this book.

Plate Girder Bridges, theoretically regarded as trellis girders, in which the lattices are placed so close as to touch each other, are, in some cases, found to offer advantages over the foregoing, but for spans from 50 to 150 feet they are not generally found economical.

The following are a few examples selected from bridges made at Crumlin of this class :—



1 span, 61 feet clear of the section given above, girders 5 feet deep.

	Tons	cwts.
Centre girder	10	18
Two side girders	17	12
Thirty-four cross girders . . .	13	12
Bracing	1	2
Bearing blocks	1	15
	45	0 for double line railway, rolling load $1\frac{1}{4}$ tons per foot run.

1 ditto, 47 feet span.

	Tons	cwts.
One centre girder	7	12
Two side girders	11	4
Twenty-eight cross girders . . .	11	4
Bracing	0	16
Bearing blocks	1	15
	32	11 for double line of railway, ditto.

The cost may be reckoned at £16 10*s.* per ton, delivered f. o. b. in England.

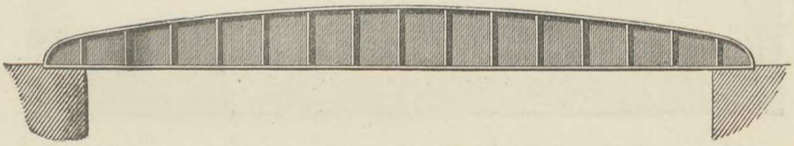
A bridge of the same class was made at Crumlin, and erected over a part of the Thames, consisting of 3 spans, the centre one 88 feet 6 inches, and two side spans 85 feet 3 inches clear, three continuous girders 279 feet long, 7 feet 6 inches deep, the centre one 2 feet 6 inches wide, and side girders each 2 feet.

	Tons	cwts.
The weight of 2 side girders	81	13
„ 1 double girder	57	10
„ 56 cross girders	25	0
„ 4 longitudinal girders . .	28	8
Total . . .	192	11

This bridge was erected on cast-iron cylinder piers sunk deeply into the bed of the river, and filled in with masonry; the cost of the bridge, complete, was somewhat less than £40 per foot run.

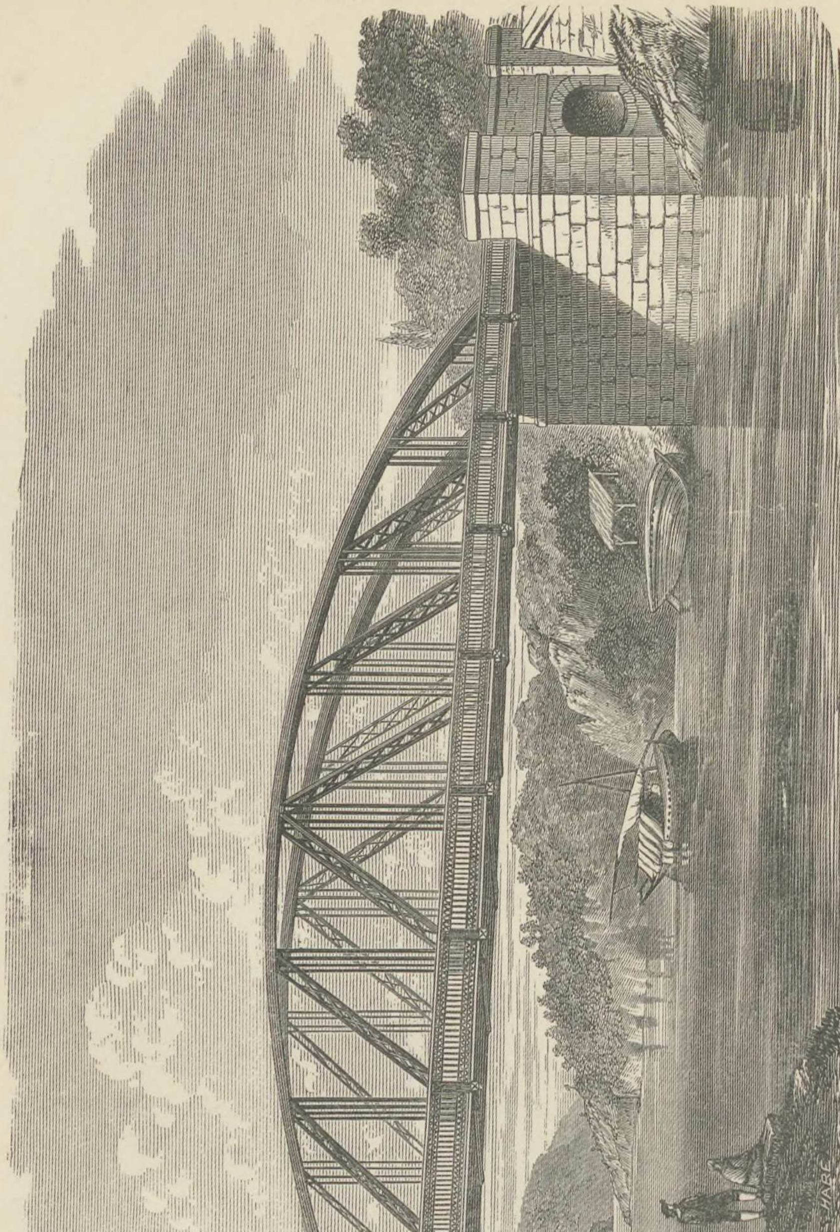
Arched Girder Bridges are sometimes used with economy, and they are selected for their more pleasing effect upon the eye than those of parallel girders.

CURVED TOP PLATE GIRDER BRIDGE



Girders of the above form have been constructed at Crumlin, upon the designs of various engineers, and from these we select a bridge of 100 feet span for double line of railway carried on three girders, the centre girder being stronger than the side girders, and about 11 feet deep, 2 feet 6 inches wide on top, the floor composed of wood 8 inches thick, bolted to under side of girders; weight of

Ironwork for 100	feet span, about	83 tons.
„ 90	„	67 „
„ 80	„	54 „
„ 70	„	43 „
„ 60	„	32 „
„ 50	„	25 „



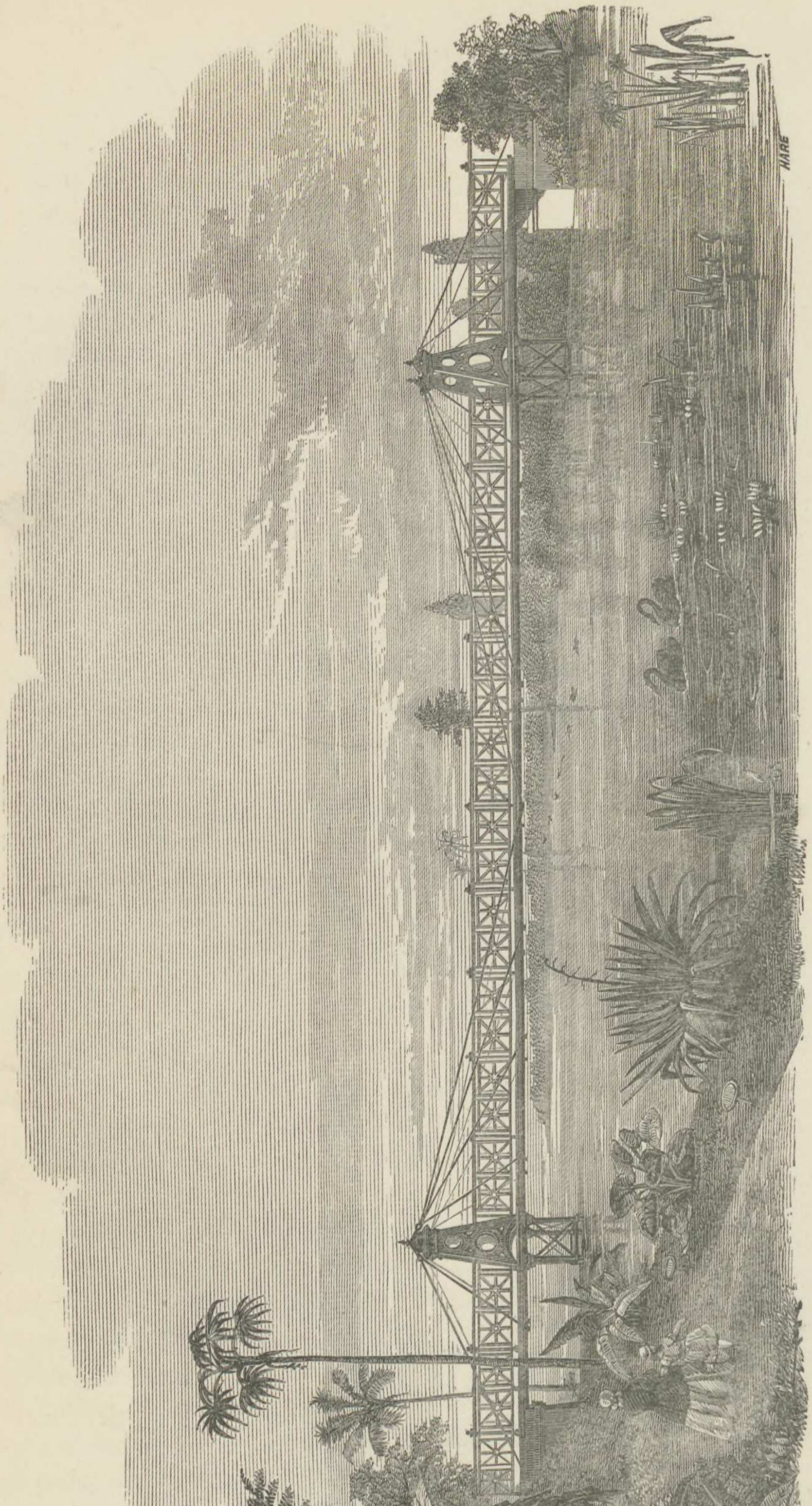
The cost of these girders is generally a trifle more per ton than of parallel girders, in consequence of the iron cutting to waste, and the extra expense of forging and bending the iron; there are obvious objections to the kind of floor here used, although often adopted.

A very elegant form of arched girder bridge is one recently made at Crumlin upon the design of E. Woods, Esq., C.E., an engraving of which is given on the accompanying page; the form of arch, when loaded, being a parabolic curve; it is to carry a public carriage road 19 feet 6 inches wide, and two footpaths each 4 feet wide, over a river. The span is 105 feet. There are two main girders, and their depth at centre is sufficient to allow of a horizontal brace or stay between them, at such height above the floor of the bridge as to admit of the passage under it of loaded vehicles. The main girders are of what is called the bow and string truss principle, and are placed 22 feet apart, centre to centre. The roadway is between, and the footways outside, the main trusses; the floor is carried upon transverse girders, which are sufficiently long to project on each side the main girders in the form of cantilevers, and are attached to the main girders at the points of intersection of struts and ties at tension bar, which are arranged at intervals of 10 feet 6 inches apart; upon these transverse girders is laid a floor for the roadway, consisting of joists of wood 12 inches deep, 6 inches thick, placed 3 feet apart, and covered close with 2½-inch diagonal planking in two layers, which is again covered with 3 inches of asphaltum, and upon this the road metalling, from 4 inches to 5 inches thick; the floor for footway is composed of 5-inch planking. The footways are protected on each side by ornamental cast-iron parapets, the base and top of which are finished off with moulded polished teakwood of massive section. The total weight of ironwork in this structure is about 60 tons. All the holes for rivets were most accurately drilled, and the workmanship throughout of a superior class.

The cost of ironwork, taking the iron at £18 per ton, f. o. b. an English port, for such a bridge, is about £10 5*s.* per foot run.

Suspension Bridges are not much used, chiefly because a moving load produces more or less undulation and vibration, resulting in injury to the roadway and other parts of the structure, and this, in large spans, becomes so serious as to involve the necessity of limiting the amount of traffic and speed of passing vehicles to an inconvenient degree; and, as compared with girder bridges, there is no economy in cost, taking all the chains and anchorage into consideration. The suspension principle, however, as regards appearance, can be made to give a much more pleasing effect than the rigid girder, and, moreover, presents means of passing moderate loads at reduced speeds across spaces it might be impracticable to span with any other kind of bridge, and it is possible some means may yet be devised to make such a system more rigid. Wires laid up together in straight lines, and bound together into ropes or cables, have been employed, as is well known, in lieu of chains of bars commonly adopted. Wires thus laid up have this advantage over cables of twisted wire, that they will elongate only, under a given strain, to the extent common to iron so strained, while the twisted wire cable will stretch, yielding and contracting more or less according to the tightness or slackness with which the wires may have been originally twisted together. This yielding or stretching presents a difficulty in the way of securing the proper level of the roadway of a suspension bridge.

From amongst the suspension bridges made at Crumlin, we select one of which we give an engraving. It is a small foot-bridge, and has some points worthy of notice. The suspending chains radiate from the top of the tower, intersecting the platform at various points at which they are attached, instead of forming a continuous curve as in the ordinary way, thus adding greatly to the stiffness of the platform. This has been found to answer tolerably well for small spans. Other means are now engaging the attention of engineers, in which the girder and suspension bridge are combined, and some bold examples have recently been brought to notice, and upon their success may depend future progress of the suspension principle; and now that the production of steel of reliable quality, and double the tenacity of iron, manufactured by the Bessemer process, has become so well known, it is difficult to say how far it may affect the future of suspension bridges, particularly those of very large spans, where the weight of the chains alone is so important an element in the calculation of the strains they have to sustain. Similar reasoning may, of course, apply to bridges of other kinds, but, perhaps, not with the same force, for in none is the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diminution in size of the parts so acceptable as in the chain or cable, subject only to tension.

The following is an estimate of a suspension bridge of the most improved kind, consisting of three spans, 400 feet, width of road 20 feet, and two footpaths equal to 10 feet, ratio of depth to span 1 to 10; strain allowed on iron with bridge loaded 84 pounds per foot, or 400 tons on each span in addition to the weight of the bridge, is on charcoal iron wire in cables 8 tons per inch, best wrought-iron, 5 tons tension and 4 tons compression. The platform of the bridge is of ¼-inch plate iron strengthened by angle iron with cross girders of wrought-iron; the parapet is of wrought-iron rivetted to the wrought platform, forming with it and the longitudinal beams a horizontal girder of great lateral stiffness to prevent oscillation; at the same time considerable vertical stiffness is given to the platform by attachment of the longitudinal girders and bracing. The floor plates, previously asphalted, are intended to be covered with wood paving; the footpaths of stone paving laid on the plates in a similar way.

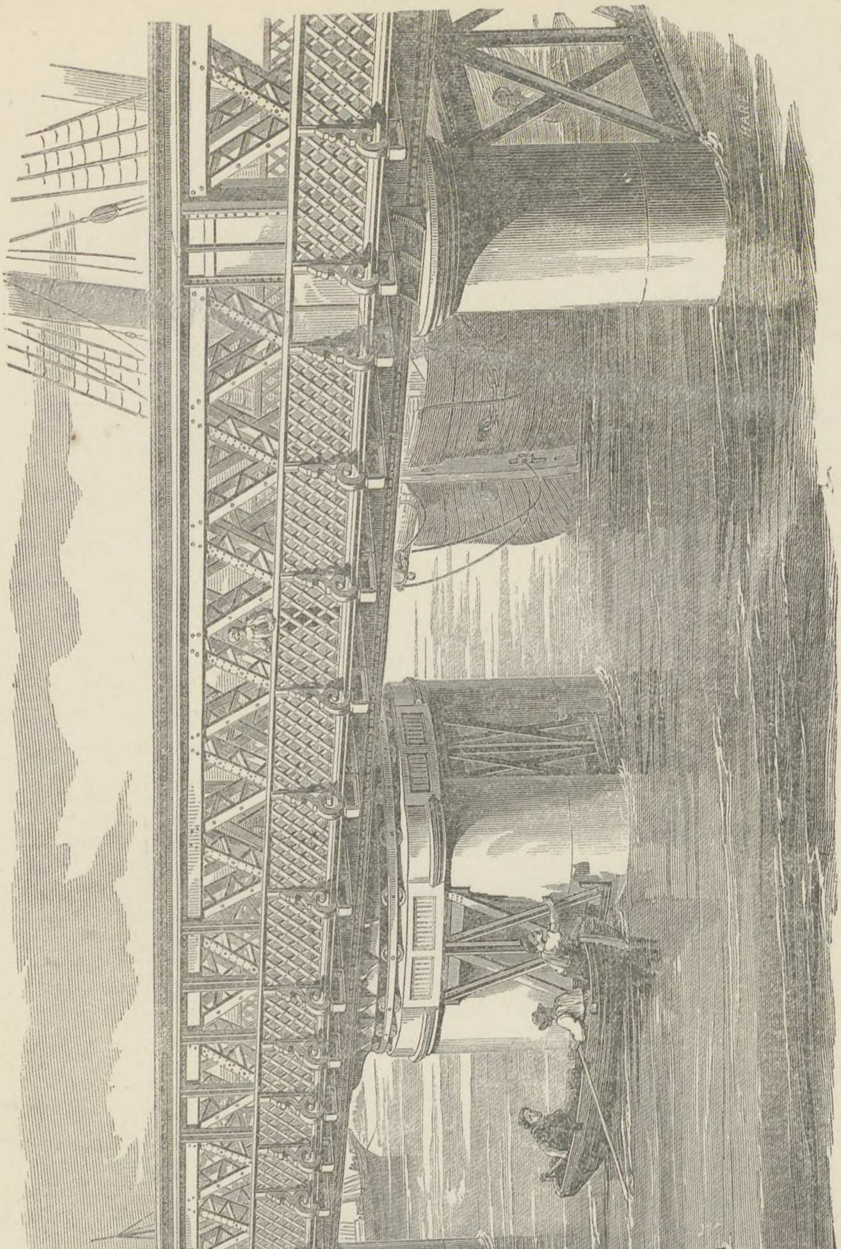
The quantities of iron are as follows:—

	Tons.	
Best charcoal cable	250	
Beams and flooring plates of the platforms .	387	
Cast saddles to attach to cable . . .	40	
Parapet, including angle iron and sundries .	272	
Cast-iron towers	110	
	1059	@ £25 = £26,475

or about £22 per foot run.

If plain wire is used instead of cables the cost of manufacture is greatly reduced, and the material is made up in small bundles, and therefore more convenient for transport in a foreign country.

Swing Bridges.—Under this heading we include such bridges as are required to cross navigable rivers, canals, &c., where it is necessary that they should open to allow of the passage of ships and other river traffic. There are several ways in practice of accomplishing this object, each having its own merit. The accompanying illustration represents one recently made at Crumlin to carry a public carriage road 18 feet wide, and one footpath 4 feet 6 inches wide, over a river, giving a clear way for the passage of vessels on the river of 90 feet, in two openings of 45 feet each, which may serve as approximate data for others of this class. The roadway is carried at the bottom of a pair of main girders 113 feet long of the lattice principle, placed 18 feet apart upon transverse girders placed 2 feet 6 inches apart, which project outside the main girders, forming cantilevers, and upon these transverse girders the floor, which is of wood planking, is laid, and covered with wood paving. The main girders are supported at the centre upon a revolving table or pivot, which revolves on top of a central pier composed of a cluster of four cylindrical iron piles, each of 7 feet diameter, sunk deeply into the bed of the river, and afterwards firmly braced together, and filled with masonry. They are so arranged in plan that their outer circumference lies exactly within a circle of 20 feet diameter, whilst they are equidistant from each other. The revolving table or pivot consists of a pair of massive cast-iron rings of 20 feet external diameter, one fixed and the other moveable, put together in segments, and of a section somewhat approaching that of a bridge-rail about 12 inches deep, and having a centre with radial arms, the under-side of the lower ring being formed to fit the top of the piles upon which it rests, and is attached, and has teeth cast round the outside, and the top surface is planed to suit conical turned rollers which are placed between it and the upper ring; the upper ring is similar to the lower ring, inverted, excepting it is formed to fit the under-side of the main and transverse girders to which it is attached, and it has no teeth. The rollers are 15 inches diameter, placed about 18 inches apart, the axles of which radiate from the centre of the circle upon which they roll, and pass through a wrought-iron ring which keeps them equidistant, and they terminate at the centre in a boss, forming a ring which revolves on a central pin. This pin is of wrought-iron, 10 inches diameter, and forms a vertical axis for the whole of the moving structure to turn upon. A pinion wheel is made to gear with the teeth cast on the outside of the lower ring, having a vertical axis, is attached by suitable bearings to the transverse girders of the bridge floor, with a large wheel fastened on its upper end, is made to revolve by a smaller pinion and vertical shaft, the end of which projects even with the surface of the floor, and is formed convenient for a horizontal tiller or removable handle, which is



turned by two men walking round upon the centre of the bridge, thereby setting in motion the pinion which acts upon the fixed teeth of the lower ring, and causing the bridge to revolve. This bridge was put together complete before leaving the works, and it was found that two men could quite easily turn it and cause it to revolve in a few minutes. It has obvious advantage over the old system of swing bridges, in which only one span is made to open, and where a large amount of counterpoise must be added to the weight required to move.

The total weight of ironwork in this bridge, exclusive of the cylindrical iron piles, is 87½ tons, and taking the price at £19 per ton f. o. b. an English port, brings the price to £1662 10*s.*, or about £14 14*s.* 6*d.* per foot run.

A swing bridge of single opening, on the counterpoise principle, to carry a single line of railway over a 30 feet opening, with two main girders, 51 feet long, placed 14 feet 6 inches apart, with cross girders and roadway at the bottom, weighs 34 tons, requires 46 tons of cast-iron balance weights, which have to be put in motion, in addition to the 34 tons of girders and platform, whenever the bridge is opened.

A bridge recently made at Crumlin, and erected in England, by Messrs. Kennard, on the telescopic principle, merits attention in point of economy of material. It carries a double line of railway over two spans of 45 feet each, and gives a clear opening of water-way, when open for river traffic, of 45 feet. The road is at bottom of the main girders, which are three in number, the centre girder being strongest, are continuous for 104 feet, and sufficiently long to reach over two spans; rest upon rollers, 3 feet diameter, fixed upon the central pier and upon the edge of the abutment. To open the bridge, it is drawn back upon the abutment by means of a chain and suitable crab gear, fixed on the central pier beneath the bridge; the chain is attached one end at each extremity of the girder, and takes one turn round the crab barrel, so that any motion in the crab causes the bridge to move in or out from the abutment corresponding. It will be seen that before the bridge can be drawn in upon the abutment, it is necessary to remove a portion of the rails, in order to allow the bridge to come in; this is done by the rails over the abutment, and for a distance corresponding to the opening of the bridge, being fixed upon suitable machinery, which enables them to be tilted into a horizontal position, and thereby to leave room for the bridge to move over them. The motion to the tilting machinery for the rails is given by a handle fixed on the abutment, and must be turned before the moving gear is set in motion. The whole is worked by two men. The total weight of ironwork in this bridge is 84 tons 19 cwts., and taking the value at £20 per ton, f. o. b. in England, brings the price to £1699.

Erecting and Fixing.—The cost of erecting and fixing (in England) wrought-iron girders and bridge tops, upon piers already built, under ordinary circumstances, may be estimated at about £4 per ton. This price will vary with circumstances peculiar to the country, or to the particular locality, height above ground or water, natural obstacles to be overcome, rate of wages, &c., and will be found to vary from £2 to £6 per ton.

Quality of Iron.—There are, probably, no structures in iron where the quality of the material employed deserves more careful attention than in bridge tops or girders. Notwithstanding this, competition in trade has had a great tendency of late to force down the prices to such a degree as to tempt some manufacturers, regardless of consequences, to *use* such iron as is totally unfit for the purpose. Iron should not be used of less ultimate tensile strength than 20 tons per square inch of section. As bearing upon this, the following results of testing plates of Blaenavon make, may be found interesting, showing it to possess those qualities so well adapted to bridge construction :—

	Breaking strain per square inch in tons.	
	With the grain.	Across the grain.
The average result of testing a number of Blaenavon "best best" plates; tested for the Government by Messrs. Laird Brothers, of Birkenhead	26.17	23.83
The Government test is	22	18

IRON PIERS, ABUTMENTS, AND FOUNDATIONS OF BRIDGES.

The employment of iron in the construction of piers, abutments, and foundations of bridges, presents so many advantages over wood, stone, or bricks, even where these materials can be obtained of good quality at moderate prices, as to have led to its almost general use. It is especially adapted to the piers of bridges manufactured in this country and exported to a colony; and, apart from its economy, and durability, it is easy of transport, and offers advantages over other materials in respect of the rapidity with which it can be erected, as all the parts being fitted together in this country, it requires comparatively little skilled labour abroad.

Cast-iron is chiefly employed, and in the form of hollow cylindrical piles, varying from 1 foot diameter up to about 10 feet diameter, and where light loads are to be carried sometimes solid wrought-iron piles, from 4 inches up to 8 inches diameter, with enlarged cast-iron screws attached to the lower end, and screwed into the ground, have been employed with advantage. The form and dimensions of the piles of any pier must at all times very much depend upon local circumstances, and the nature of the ground, the height they are required above ground, the depth of water, if any, where they are required, &c. It will, therefore, be advantageous at all times in sending any requisition from abroad for materials for iron bridge piers to be made in this country, to accompany such with as much information as to the nature of the ground, and, if possible, in the case of a work of considerable magnitude, borings of the site of intended piers, as the want of such information has occasionally led to sending from this country material for foundations altogether unsuitable for the intended purpose. It may be sufficient here to state that piles from 12 inches diameter up to 30 inches diameter are usually made to screw into the ground, unless this is impracticable in consequence of the hard nature of the ground, which, if it happens to be rock, the bottom of the pile may be cast with a base plate, as in the case of Crumlin Viaduct, and bolted directly upon it; and if compact gravel, it is generally sufficient to bed the iron upon a thick layer of concrete. Piles 3 feet diameter and upwards, are sunk by weighting, and dredging the soil from the inside; they are usually cast in short lengths, with inside flanges and bolts, and each length is also parted into about four segments, with vertical flanges and bolts, so that the whole are sent out from this country in the form of small segmental plates, that are of convenient size and form for stowing in a vessel, and for transport on arrival in the colony.

In designing a bridge of considerable length, in the most economical manner, it will be obvious that the length of its spans must, to a certain extent, be governed by the cost of the necessary piers to support them. It is found in practice that there is a certain proportion to be retained between the height of piers and the spans themselves, which is arrived at by roughly estimating the gross cost of the bridge at any assumed spans, and again estimating it at other spans, and comparing the results. As, for example, a bridge is to be erected over a ravine, 1600 feet wide, the bottom of which is, for the greatest part, nearly level, and composed of solid rock, and the depth at deepest part 200 feet from under-side of the intended level of girders; it will at once be seen that piers are requisite,—we may assume that spans similar to those of Tagus Bridge, already described, are used,—we should then have for the superstructure complete 16 spans, or

1600 feet at, for double line of way, £10 8*s*. per foot		= £16,640
And 15 piers, which if made of the Crumlin Viaduct class, each 200 feet high, will require 185 tons of cast-iron, at, say, £8 per ton	= £1480	
And 41 tons wrought-iron, at, say, £16 =	656	
	£2136 for 200 feet	
Or, at the rate of £10 14*s*. per foot, each will cost £2140 =		32,100
Total cost .		£48,740

Again estimating the cost, assuming that 60 feet spans of the same class are used, we should have for the superstructure 27 spans, which would require in each span, for double line, 28 tons of iron, at, say, £16 per ton, as before, or £448 for 60 feet, or £7 10*s*. per foot:—

CRUMLIN VIADUCT.

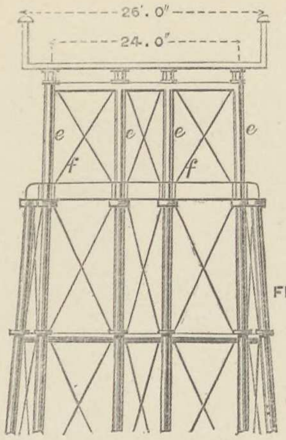
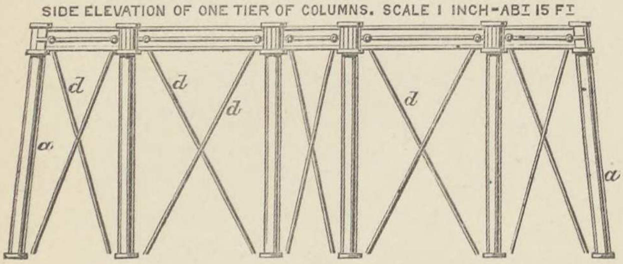


FIG. 7.

FIG. 2.

SIDE ELEVATION OF ONE TIER OF COLUMNS. SCALE 1 INCH=ABT 15 FT



PLAN OF COLUMNS

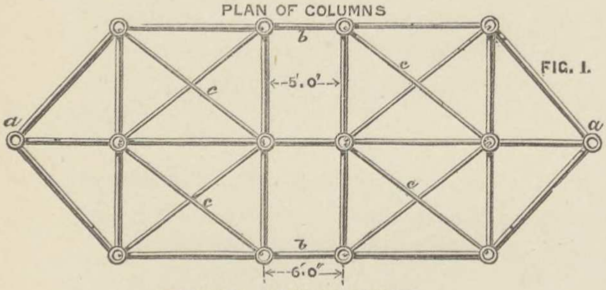


FIG. 1.

ENLARGED JOINT OF COLUMNS.

FIG. 4.

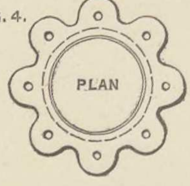
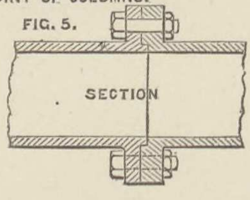
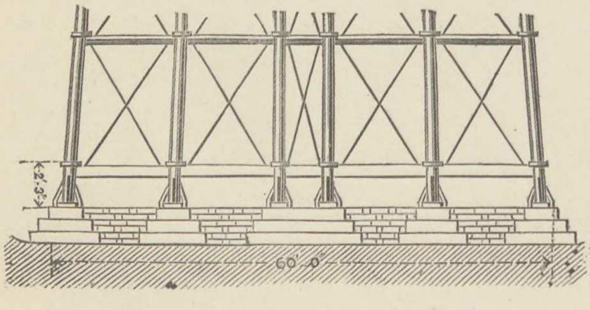


FIG. 5.





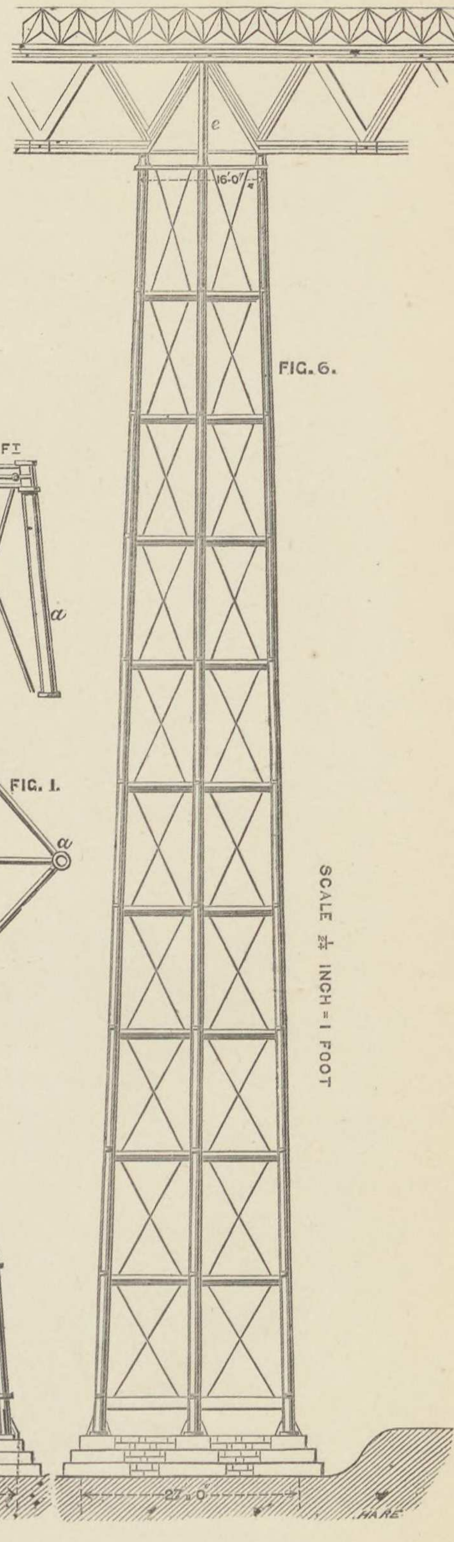


FIG. 6.

SCALE 1/24 INCH = 1 FOOT

Therefore 1600 feet, at £7 10*s*. per foot	= £12,000
This would necessitate the use of 26 piers as before, each 200 feet high, which, at the same price, would amount to	55,640
The total cost being .	£67,640

From the above it will be seen that where piers of great height are necessary, large spans are most economical. On the other hand, if their height is small, it will be found that small spans and numerous piers are more economical than large spans and few piers; because, in the latter case, the cost of the spans will be much greater in proportion to the space covered, and the quantity of material in the piers must also be increased in proportion to the greater weight to be carried by them.

The piers of Crumlin Viaduct combine, with lightness and strength, economy of material and facility for erection. A description of one of the highest will apply to all, as they only differ in height. It consist of fourteen hollow cast-iron columns, 12 inches external diameter, arranged in the form of an irregular hexagon, as shown in plan, Fig. 1. The two columns *a a* are of metal 1 inch thick, all the others are $\frac{3}{4}$-inch thick; each column is 170 feet long, consisting of ten lengths, each 17 feet, connected by bolts passing through lugs cast on outside, as shown at Figs. 4, 5; a projection of $\frac{1}{2}$ inch is formed on one end of each, which fits into a corresponding recess inside the adjoining length; all are accurately turned and fitted at the joints; the bottom rests on a short piece of column jointed in similar manner, and formed into a base-plate 3 feet square, and is 2 feet 3 inches high; strong 1-inch feathers cast outside to distribute the pressure of column upon the base-plate. The base-plate is fastened to the masonry or rock by ragbolts 12 inches long, let into the stone, and secured there by pouring in the interstices molten brimstone. The top or head of each column is formed into a cap 2 feet square, 1 inch thick.

The columns are all connected together by a system of horizontal bracing, which occurs near each joint, or at the top of each length, or tier, of columns, and consists of cast-iron distance pieces, of a girder form of section, with a flange running through its centre, called "distance girders;" they are 12 inches deep, 5 inches wide, and $\frac{3}{4}$-inch metal, arranged as shown in Fig. 2; the columns are formed octagonal at this part, so as to present a flat surface, to which the distance girders are secured by bolts passing through the columns. The distance girders are tied together diagonally by 1½-inch round wrought-iron bars, eight in each tier, and in the same horizontal plane, and are marked *c c c c* in Fig. 1; they are secured inside the columns with keys or cotters. The distance girders, connecting the bases of columns, are of larger dimensions,—namely, 18 inches deep, 6 inches wide, and of thicker metal.

Between each of the columns there are two vertical wrought-iron bracings, 4 inches wide, ½ inch thick, marked *d d*, Fig. 2, or seventy-two bars in a tier, each of which are fastened by a pin at each end, of 1⅜-inch diameter, which connects it to the distance girder, in which pockets of suitable form and dimensions are cast to receive the ends of bars. Each bracing bar is connected with the distance girders at one end by two short pieces of the same size bar,—namely, about 18 inches long, in which an elongated hole, 3 inches by 1 inch, is formed, corresponding to a similar hole in the bracing bar; the latter is secured between the two short pieces by a gib and cotter, which can be tightened so as to adjust the length of the bar to suit the work.

The triangles shown by Figs. 6, 7, at *e e*, surmount each of the piers, and rest upon the caps formed on top length of columns, to distribute the pressure of the superstructure evenly over the whole of the columns; each set consists of a strong cast-iron framing, composed of three longitudinal girders 2 feet deep, and eight transverse ditto binding the heads of the columns together, and forming a base, upon which are fixed cast-iron triangular framing pieces, 14 feet high, of suitable form and section to receive the main girders, which carry the floor, and take their bearing only at the apex of each triangle. Four triangles, forming a set, are united by wrought-iron vertical bracing bars, 4 inches by 1 inch, in the manner shown at *f f*, Fig. 7.

It will be seen that only two out of the fourteen columns of each pier are placed vertical; all the others are inclined inwards, the greatest inclination being about 1 in 12.

In constructing the piers it was necessary to make arrangement by which the main girders could be lifted at the centre; therefore the piers were built to the requisite height without the distance girders marked *b*, Fig. 1, leaving a parallel opening 5 feet in width throughout the height. Within this space, at the bottom of it, the main girders were built. They were of sufficient length to reach nearly from centre to centre of piers; and after they were lifted to top of piers, the distance girders *b b* were fixed with the bracing bars connected to them. The sectional area of acting metal in the columns of one pier is about 400 square inches, and the maximum strain on the iron under test load is less than 1½ tons per inch.

The advantages offered by iron piers over masonry are:—

1st. Simplicity in erection and construction, as all the materials can be prepared and fitted before they are brought to the spot, and no expensive scaffolding is required. They are so arranged that each length of columns can be completed, and a few planks laid upon them forms a good even floor, and convenient to proceed with the next length. The materials are drawn up by a common windlass, and, as the heaviest piece does not exceed one ton in weight, can be easily fixed by common sheer legs and pulleys.

2nd. The rapidity with which these iron piers can be built—a pier 200 feet high can be completed in ten or eleven weeks, while a masonry pier of the same dimensions about as many months.

3rd. The amount of pressure on the foundations in some situations is an important consideration. Mr. Kennard's iron pier is remarkable for its lightness, and consequently a small amount of pressure on the foundations. The following estimate shows the weight on the foundations of a pier of the Crumlin Viaduct, and what may be fairly calculated for a stone pier of suitable dimensions:—

WEIGHT ON FOUNDATION OF IRON PIER.	Tons.	WEIGHT ON FOUNDATION OF MASONRY PIER.	Tons.
Iron . . .	200	Masonry . .	2900
Superstructure .	100	Girders, &c.. .	100
Passing load . .	300	Passing load .	300
	600		3300

The base of the iron pier is about 40 feet by 30 feet, or 1,200 superficial feet, therefore the pressure on the foundation is about half a ton per superficial foot, while that of masonry pier must be at least five times as much.

4th. The saving in the cost of iron piers may be safely estimated at a third less than masonry, as may be seen from the following estimates:—

COST OF AN IRON PIER.

	£	s.
163 tons castings, at £13 .	2119	0
7 tons wrought-iron, at £16	112	0
1128 yards excavation, at 1*s.* 6*d.*	84	12
1400 cube feet Ashlar masonry, at 3*s.*	210	0
42 yards concrete, at 8*s.* .	16	6
	£2541	18

COST OF A MASONRY PIER.

	£	s.	d.
2197 yards excavation, at 1*s.* 6*d.*	164	15	6
1041 yards masonry footings, at £1 5*s.* .	1301	5	0
2120 yards, at £1 5*s.* .	2650	0	0
	£4116	0	6

The difference in favour of iron pier, £1574 2*s.* 6*d.*

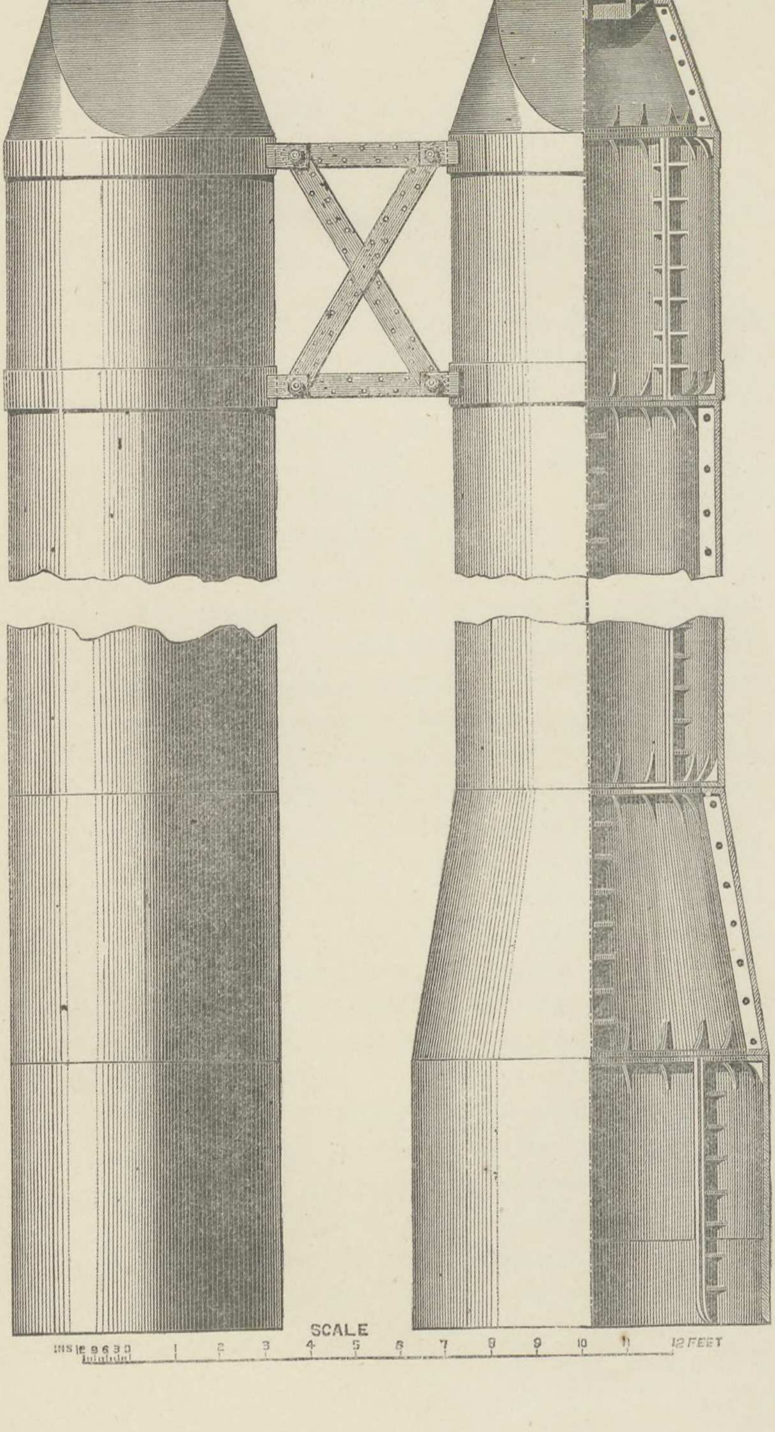
The cost of erecting, in England, structures of this kind varies from £2 to £4 per ton.

The piers of Tagus Bridge, the superstructure of which has been already described, at page 12, with illustrations, are an example of the larger cylindrical piles; in this bridge fifteen piers were required, the average height of each pier 50 feet above the bed of the river—a detail sketch is given at opposite page. Each pier is formed of three cast-iron cylinders, 6 feet in diameter, 1 inch thick, made in lengths of 6 feet, each length being built up of 4 plates or segments, planed and turned at their junctions, so that when bolted together with 1¼-in. diameter bolts, and caulked with a little red lead, the joints are made air-tight. The weight of these piers averages 25 cwt. per foot run. The weight of bracings and bolts about 2 cwt. per foot run. Estimating the price of the cast-iron at £8 per ton, and wrought-iron at £16 per ton, f. o. b. an English port, it gives the price of such a pier at £11 12*s.* per foot run.

The foundations of these piers, or that portion which is sunk below the bed of the river, to an average depth of 36 feet, are constructed by prolonging the outer piles 6 feet diameter to the requisite depth, while the central piles, which carry a greater weight, are increased to 8 feet diameter, to give the requisite area of bearing surface; they were sunk in the following manner:—

A sufficient number of 6-feet lengths, to reach a convenient distance through the water, are bolted together (with thick paint at the joints, to make them tight), and thus lowered from a raft or temporary stage into the position required; the earth is then removed from inside by scoops or spoons, furnished with long

CYLINDER PIER



handles, by which they may be worked from above the surface of the water. The centre part of the scoop is formed into a leather bag, into which the earth is scooped and brought to the surface.

The cylinder is weighted with a load, so that it may sink as the earth is excavated. If the bed of the river happens to consist of clay, when the cylinder reaches this stratum, the water is pumped out, leaving the bottom dry, as the clay will effectually exclude the water, and the operation is carried on by men going inside, as in well-sinking.

If a water-tight stratum is not found, and the depth is too great for the use of scoops, the operation is carried on by divers, or by the pneumatic process, which is known as Hughes' method, and may be briefly described as follows. A temporary air-tight cover is put upon the cylinder, in which is formed a box of sufficient dimensions to contain a man and a bucket of earth, with a door opening inwards from the box to the cylinder, and another outwards from the box to the atmosphere; the cylinder is thus formed into a diving-bell, with entrance from the air through the cover or box. The air is forced into the cylinder with such force as to drive all the water out under the edges of the cylinder below, and the workmen carry on the sinking inside in the dry, and can go in or out at any time. A man going in passes into the box described above, where he shuts himself in from the atmosphere, and opens an air-cock which communicates with the cylinder, and immediately produces equilibrium of pressure in the cylinder and box; he is then able to open the inner door and enter the cylinder. If he wishes to come out, the operation is simply reversed—he shuts himself in the box, and opens a cock which communicates with the atmosphere, when equilibrium of pressure in the box and atmosphere is immediately restored; he can then open the door and come out, bringing with him the earth excavated.

Many other processes of sinking have been tried from time to time, but none have been so successful as that described above, the just value of which may readily be appreciated when it is considered that, should a cylinder strike partially upon a large boulder stone or the trunk of a tree, as is sometimes the case, the process of sinking can be carried on when it might otherwise have become impossible.

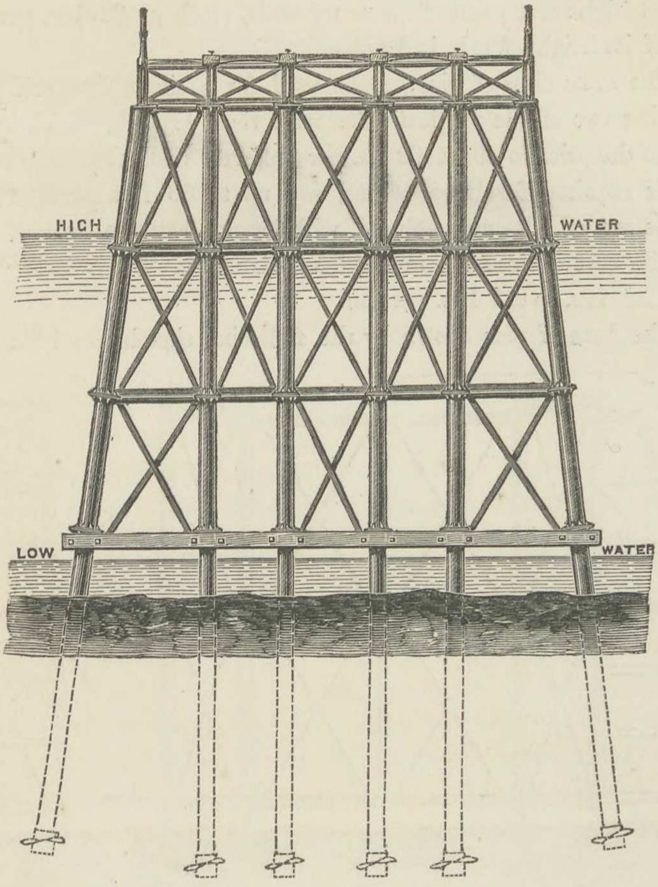
The cost of sinking and fixing cylinder bridge piers in England may be approximately reckoned as follows. These prices will of course vary with circumstances peculiar to the country or locality, or price of labour. Taking cylinders 6 feet diameter as the basis, a cylinder of this size may be sunk to a depth of 20 feet below water-line by the use of scoops alone for about 30*s.* per foot down; beyond this depth the scoops become inconveniently long for use, but the process of sinking may be continued, circumstances being favourable, by divers, from 20 to 60 feet, for about 60*s.* per foot down; and below that depth, from 60 to 90 feet, still by divers and scoops, for about 80*s.* per foot down.

Where the ground contains boulders or hard strata the compressed air apparatus is used, and the cost may be taken at £4 per foot down to 60 feet below water-line, and from 60 feet down to 90 feet at £6 per foot down.

If the strata is loose sand and gravel full of water, the sinking can be done by Kennard's patent sand pump, (particulars of this machine are given in another part of this book,) and the cost may be reckoned by this process to be 30*s.* per foot down, and may be carried to almost unlimited depth without increase of cost. The above prices include building up, and weighting and removing weights where necessary.

Upon the same principle, and with the same object (avoiding the construction of the ordinary coffer-dam), cylindrical and rectangular caissons are employed for foundations of abutments.

The opposite engraving represents an example of screw pile piers, used in a railway bridge lately made at these works, which is erected in this country over an arm of the sea, where the water is 23 feet at high water and 3 feet at low water. The bridge is nearly a mile in length, consisting of spans of 30 feet each. It is made sufficiently strong for a double line of railway. The piles are arranged in a single row, as shown in sketch, and are 12 inches diameter, and are of cast metal, in 10-feet lengths, $\frac{7}{8}$ of an inch thick, turned at ends, jointed with flanges containing 8 bolts, 1 inch diameter, in each joint. The lower lengths are made 17 feet each, and cast with screws 2 feet 10 inches diameter, and the metal at bottom is $1\frac{7}{8}$ inches thick; they are braced together with angle iron horizontally and flat bars diagonally. It may be mentioned that in some cases where a very



hard stratum occurred, the screws were dispensed with, and the ends of the piles pointed, and driven in by ordinary pile engine. The material used in a pier of this class is as follows:—

	Tons.cwts.qrs.lbs.	Tons.cwts.qrs.lbs.
6 screw lengths of pile, each 17 feet, at 15 cwt.	4 10 0 0	
12 intermediate pile lengths, at 9cwt. 1qr. 14lbs.	5 12 2 0	
6 upper " " at 9cwt. 2qr. 14lbs.	2 17 3 0	
Total cast-iron . . .		13 0 1 0
Wrought-iron bracing		1 2 3 8
" " bolts		0 3 2 0
Total		14 6 2 8

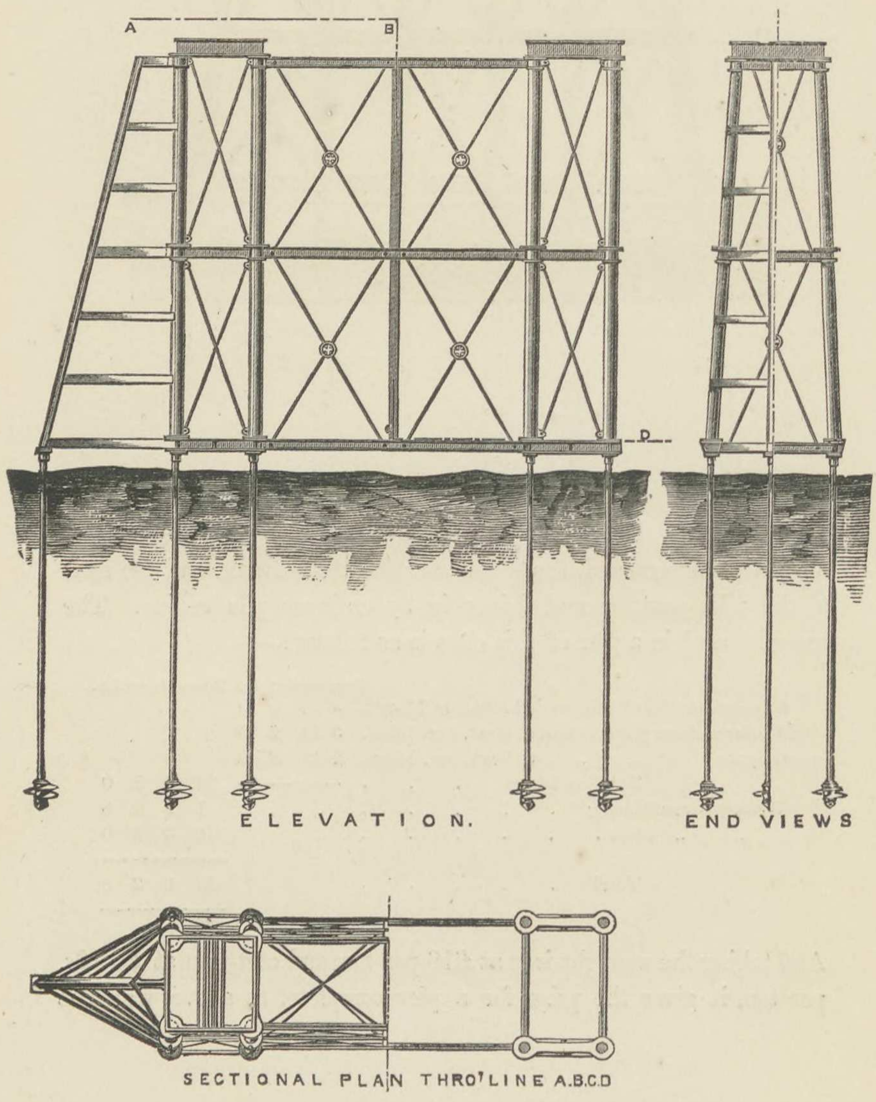
And taking the wrought-iron at £16 per ton, and cast-iron at £8 10*s*. per ton, it gives the price for a pier complete, as above, which is

47 feet high from point of screw upwards, at about £2 15*s.* per foot run of its height, f. o. b. in England.

The same class of pier can be used for a single line bridge by omitting two of the vertical piles with their bracing, which would reduce the price to about £2 5*s.* per foot run upon the same basis; and if required for larger spans, say up to 50 feet or 60 feet, a double row of piles may be used, with bracing between them.

The cost of erecting, in England, structures of this kind varies from £2 10*s.* to £4 10*s.* per ton.

The form of pier shown by the following sketch has been used



with advantage in a case where a bridge crosses a ravine, for the most part nearly dry, but occasionally subject to heavy and rapid floods, where also the foundation is of a soft nature. The up-stream side is protected by wrought-iron guards, against accident to the cast-iron columns that might happen by floating bodies striking them during flood times. The foundation is formed by screwing wrought-iron piles into the soil to as great depth as practicable, the heads are then cut off to the required height, and base plates are firmly attached to them.

Screw Piles.—Hollow tubes of cast-iron and solid bars of wrought-iron, cast or fitted with the "Mitchell" screws, are manufactured at the Viaduct Works for piers of bridges, foundation supports for lighthouses, landing stages, jetties, moorings, &c. The sustaining power of a well-made and well-fitted screw in a firm sand, is a load in *tons* equal to five or six times the square of the diameter of the screw in *feet*. Cast-iron tubes are generally found convenient in from 9-feet to 12-feet lengths, with their meeting surfaces planed; wrought-iron can be employed in much longer lengths, without risk of fracture in transit, and are less liable to be broken by concussion from vessels or floating timber, or other objects, when ultimately fixed in place. Wrought-iron solid piles are generally preferred in as long lengths as can conveniently be put on board ship; but it will frequently occur that small vessels only can approach the spot where it is desirable or necessary to load or tranship the work. Joints, simple in adjustment, can be made; it is desirable, however, that these be avoided as much as possible in so much of the length of the pile as will be subjected to torsion in the process of screwing down.

The process of screwing down is very simple. A light framing of wood is generally made so as to hold the pile to be screwed, and by driving a few temporary wood guide piles, the whole is adjusted to the exact spot; a capstan wheel, from 15 feet to 20 feet diameter, is then fitted on to the upper part of the pile, and held by temporary keys; a rope is passed round the circumference of this wheel and attached to a crab winch on shore, which causes the wheel and same to revolve when set in motion, and a slight pressure on top of the screw causes it to enter.

The cost of cast-iron piles is not materially affected by the diameter adopted; but with wrought-iron solid piles the cost increases very much with the diameter, whether the bars be produced by the rolls, or formed, as the larger sizes are, under the steam hammer, the difficulty of producing them from the rolls increasing with their weight.

The cost of cast-iron screw piles may be approximately calculated at per foot run from the following:—

					s.	d.
Piles 10 inches diameter,	$\frac{7}{8}$ inch thick,		per foot run		7	6
Ditto 12	ditto	1	ditto	ditto	10	11
Ditto 15	ditto	1	ditto	ditto	14	2
Ditto 18	ditto	1	ditto	ditto	17	5

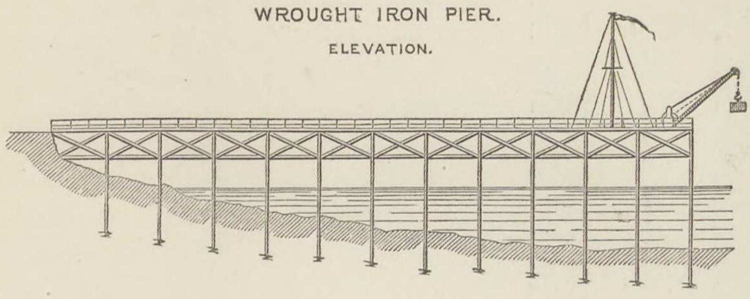
Wrought-iron screw piles would be, approximately, as follows:—

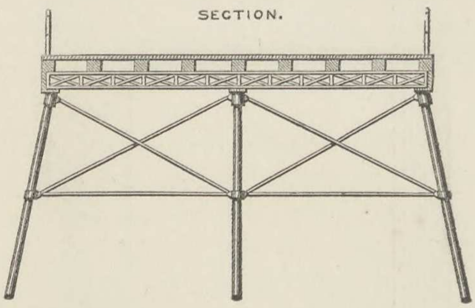
			20 feet.			30 feet.			40 feet.			
			£	s.	d.	£	s.	d.	£	s.	d.	
4 inches diameter,		per length	6	0	0	8	8	0	13	13	0	each
5	ditto	ditto	9	10	0	13	10	0	20	17	6	„
6	ditto	ditto	15	17	6	22	10	0	33	0	0	„
7	ditto	ditto	25	10	0	41	10	0	51	15	0	„

PIERS OR JETTIES AND LANDING-STAGES.

The following illustrations of a screw-pile jetty, 300 feet long, 33 feet wide, manufactured at Crumlin, may serve as a useful example on the wrought-iron "Mitchell" screw principle.

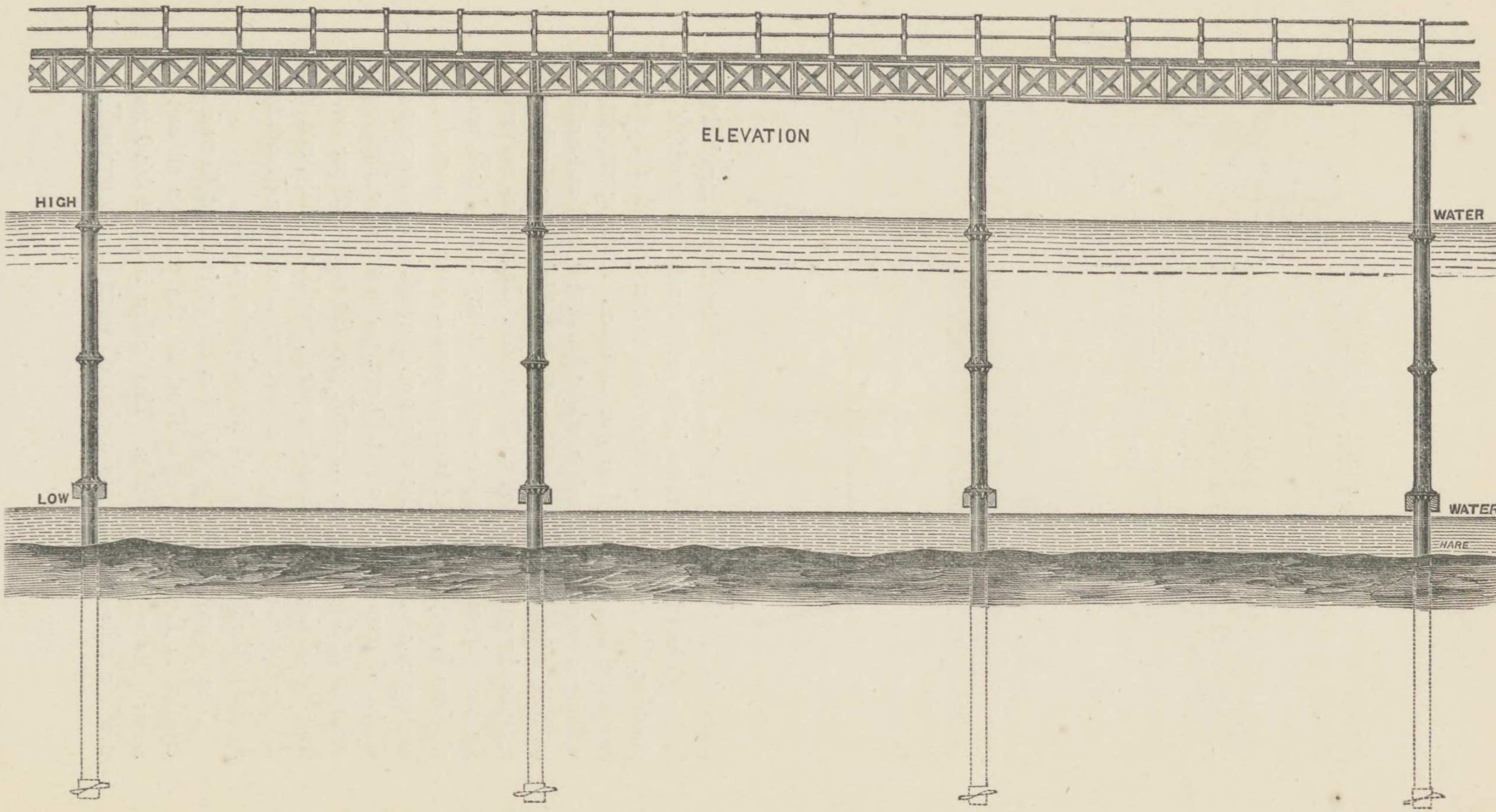
It is supported upon 60 piles of solid iron, 4 inches diameter, arranged in the form of fixed trestles, and placed 15 feet apart; the screws are of cast-iron, 3 feet diameter; each screw is carefully fitted to its wrought-iron shaft, and secured thereto by a turned steel pin passing horizontally through a corresponding hole drilled through the boss of screw and end of pile shaft; each pile extends about 12 feet into the ground, and the part above ground varies in height according to the slope of the surface, from 19 feet to 25 feet; the top of each trestle is surmounted by a light iron latticed girder, 33 feet long; the height from high-water mark to level of platform is 5 feet. The platform consists of timber, and is composed of longitudinal joists, 12 inches by 9 inches, placed about 3 feet 9 inches apart, centre to





centre, in 15-feet lengths, scarfed over each trestle, and attached to the lattice girders by bolts; these joists are covered all over with 4-inch planking. The whole is strong enough to carry a load of 1 cwt. per superficial foot, distributed all over its surface. A strong wrought-iron waleing is connected to each trestle at low-water level, and continued on both sides and front; and another at high-water level, which extends along the front and up-stream side. Iron stairs are provided for convenience of passengers landing at any state of tide, and the platform is complete with tram-plates and crane for convenience in landing merchandize. The weight of ironwork in this structure, exclusive of tram-plates, is about 10 cwt. per foot run, and taking the price at £16 per ton, f. o. b., would give the cost at £8 per foot run. The cost of timber, fitted and prepared, would, probably, add about £3 per foot run; but this will depend very much upon circumstances special to the locality in which it would be required.

The engraving at page 56, of a bridge made at Crumlin, for erection in England, serves to illustrate the principle of cast-iron screw piles applied to jetties. This bridge is about 5000 feet, or nearly a mile in length; is a class of work equally applicable for


ELEVATION
HIGH
WATER
LOW
WATER

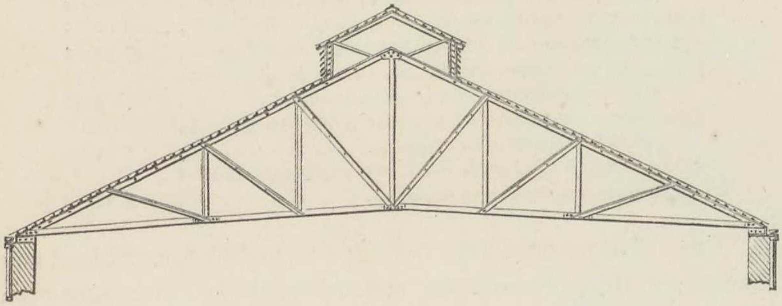
railway bridge of double line or for a jetty 26 feet wide. The transverse view of its supports will be found and described at pages 50 and 51. The superstructure is composed of wrought-iron lattice girders, of 30 feet spans, each span containing four inner and two outer girders; the whole of the floor is covered with buckle-plates, of $\frac{3}{16}$ths of an inch thick, rivetted to the girders and to cross stiffening strips at joints; handrail, bolted on each side, consists of cast standards and 1¼-inch wrought-iron gas pipe. The weight of iron in this superstructure is about 7½ cwt. per foot run; and taking the price at £16 per ton, f. o. b., it gives the price £6 per foot run, and adding the cost of piers, say one to each span, at the price named at page 52, namely, for 47 feet pier £2 15*s.* per foot of height, or £129 5*s.* each, which, divided by 30, gives about £4 5*s.* per foot run of jetty, making total cost per foot run £10.

Amongst other piers, jetties, &c., manufactured at the Viaduct Works, and erected by the proprietors, may be mentioned a pier at Wellington, New Zealand, for landing passengers and merchandize. The landing-stage is 300 feet long, 50 feet wide, and is connected to the shore by a somewhat narrower jetty, 160 feet long, 35 feet wide, sufficiently strong to carry a load equal to 1 cwt. per square foot all over its surface. The deepest water is about 25 feet at low water and 29 feet at high water; the level of floor is about 6 feet above high-water mark; the piles are sunk about 20 feet into the ground, and are about 55 feet total length. The landing stage is composed of 19 main girders, each 50 feet long, placed transversely about 16 feet 6 inches apart, each girder being supported by one cylinder pile, 4 feet diameter, and three screw piles, of 12 inches diameter, placed equidistant under it, the cylinders being on the sea-face of the stage; the last girder at each end of the stage is supported by four cylinders. Thus the whole of the supports on the sea-face and ends are composed of 4 feet cylinders, the inner supports being 12 inches diameter screw piles. Between the 50-feet main girders are placed lighter girders, in a direction at right angles to them, or longitudinally with the stage, the top flanges of which are even with those of the main girders, to which they are rivetted directly over their points of support. The piles are all braced together horizontally by wrought-iron girders, securely attached to them at a distance of 8 feet from the top, and between these and the floor girders, vertical bracings formed of T iron, placed diagonally, one end of each being fastened to the upper or floor girders, whilst the other end is made fast to the lower or bracing girders; there are two bars in this manner crossing each other in each space between the piles, both transversely and longitudinally. The floor is composed of wood joists, 13 inches by 6 inches, placed 3 feet 1 inch apart, and bolted to the girders, over which is nailed 4-inch wood planking. The total weight of iron in this portion of the work is about 478 tons of cast and 133 tons wrought-iron, or about 4 tons per square of 100 superficial feet. The jetty portion is composed of 11 main girders, each 35 feet long, placed transversely about 15 feet apart, each girder being supported by four cast-iron screw piles, of 12 inches diameter, screwed 20 feet into the ground. Lighter longitudinal girders, and bracing with floor, &c.; the same as described above. The iron in this portion of the work is about 130 tons cast and 65 tons wrought, or nearly 25 cwt. per foot run.

IRON ROOFS.

In the general acceptation of the term "iron roof" it includes all roofs in which the framing is of iron. They may be covered with slates, tiles, zinc, galvanized iron, &c., with or without woodwork interposed. The most durable coverings are those of *slates* and *tiles*. "Duchess" *slates* are generally employed with iron framing. They are each 24 inches by 12 inches. 1000 of them covers ten squares of 100 superficial feet, and the weight of 1000 is about 60 cwts. They are attached by copper bands to angle-iron laths; and the *tiles* called "pantiles." These are retained in place by small projections moulded on their under surfaces, and by the weight with which they overlap each other. They are about double the weight of slates, but are preferred in some cases. In respect of ventilation, they are convenient for many manufactories, the numerous interstices between them affording, as they do, apertures for the egress of heat and vapour, and they are less liable to be broken by heat from below, and hence are better for roofing over furnaces. Galvanized iron forms a very light covering, and its lightness and portability render it very suitable for export, whilst its rigidity when corrugated imparts great strength to the framing when properly secured to it. No. 16, B. W. G., corrugated iron is the thickness most generally used, and weighs about 350 pounds per square. Galvanized iron and zinc should not be used in situations much exposed to air impregnated with the gases arising from combustion of coal, as, for example, on the roof over a retort house of a gas works; the galvanized iron will decay very rapidly in such a situation by the decomposition of the zinc. Painted corrugated iron is very much used because it is cheaper than galvanized iron, and, when in pure air and kept well painted, is found to form a tolerably good and durable covering, but should be used somewhat thicker than galvanized iron.

The accompanying sketch represents the form of framework



or "truss" generally used for ordinary roofs up to about 60 feet span, the pitch or rise for slates being about 2 to 1. In the following table of approximate prices for roofs of this class, the price is given for a square of 100 superficial feet, measured up the slope of the rafter. In calculating the cost of a roof from this, without drawings, a near approximation may be obtained by taking the outside width of the building over the gutters and adding 10 per cent.; this multiplied by the length of building will give the number of superficial feet, and divided by 100 gives the number of squares. Example:—A building is to be covered which is 300 feet long, 40 feet wide, and the gutters project 6 inches each side; therefore 300 × 41 = 12,300, add 10 per cent. = 13,530, divide by 100 = 135·3 squares.

For slated roofs of the kind shown in sketch, with flat bar, ties, and truss rods, wrought-iron struts and rafters :—

	Approximate price. £	s.	d.
Ironwork for roofs up to 40 feet span, including gutters, but without laths, per square	4	19	3
Extra cost, per square, for roofs between 40 feet and 50 feet span	0	13	3
Extra cost, per square, for roofs between 50 feet and 60 feet span	1	6	2
Extra cost, per square, for laths of iron	1	14	0
„ „ slates (doubling) . . .	1	3	6
Extra cost, per square, for boarding under slates 1¼ inches thick, grooved and tongued	1	6	8
Extra cost, per square, on the part (if any is made) with Louvre ventilators, and without laths, of the proportions shown	6	5	10
Extra on the last item if ventilator be glazed . . .	5	8	10

For corrugated iron roofs :—

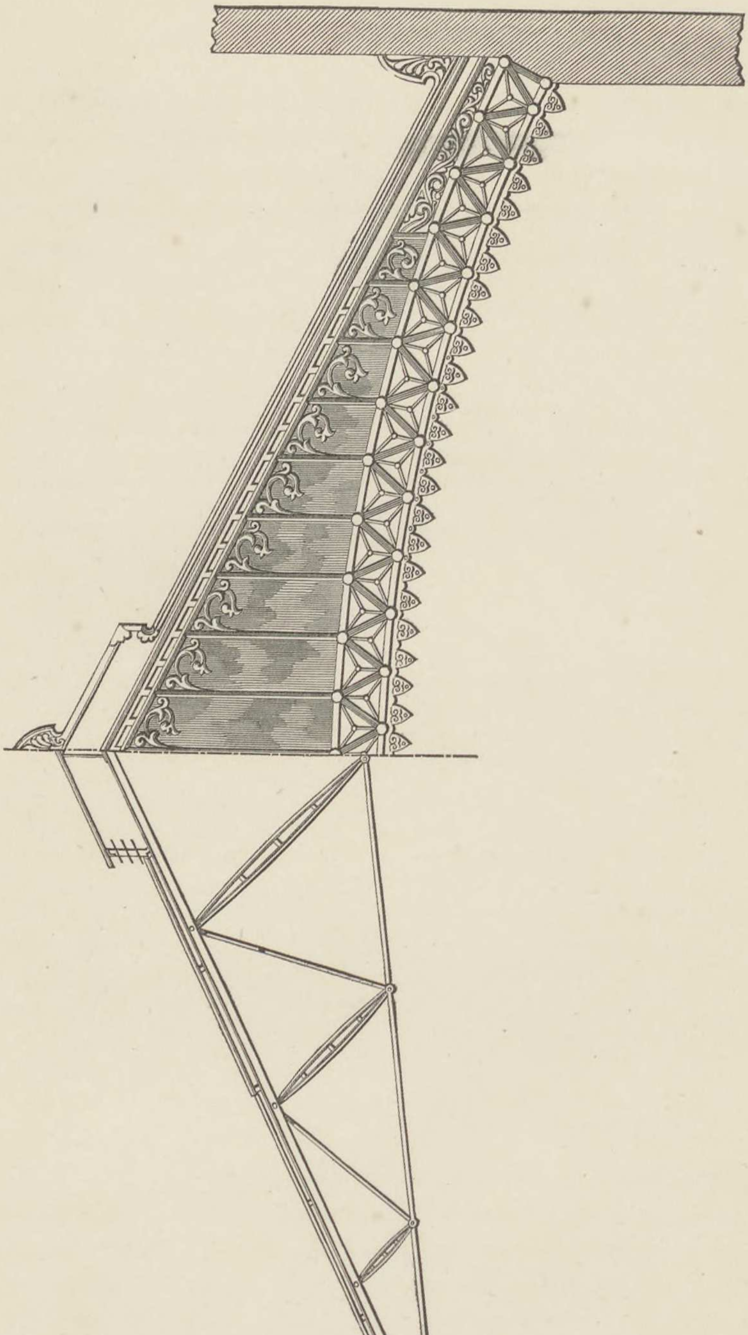
	£	s.	d.
Ironwork for roofs up to 40 feet span, including covering of painted corrugated iron, 16, B. W. G., per square .	7	6	0
Extra cost, per square, between 40 feet and 50 feet span .	0	12	3
Extra cost, per square, between 50 feet and 60 feet span .	0	18	3
Extra cost, per square, on the part (if any is made) with Louvre ventilators of the proportions shown . .	6	5	10
Extra cost, per square, on the part if the ventilator be covered with skylights of glass	9	1	0
If the covering is of galvanized iron instead of painted iron it adds about (per square)	0	17	6

Price of corrugated iron roofs in the arched form without any framework, except tie-rods and suspension rods for counteracting the strain on walls—

	Painted Iron per square. £	s.	d.	Galvanized Iron per square. £	s.	d.
Of No. 20 gauge iron for spans not exceeding 35 feet	2	0	6	2	9	6
„ 18 „ „ „ „	2	10	0	3	1	9
„ 16 „ „ „ „	3	2	6	3	18	0

From the above table approximate estimates of most of the ordinary kinds of iron roofing can be formed; but these prices are always affected by the market price of material and labour, and the place of delivery, quantity, mode of payment, &c.

The cost of "hipping" a roof, that is, sloping it down at the ends as at the sides, is considerable, notwithstanding that it may appear in theory to require but little, if any, additional material, the external surface remaining the same as though it were finished



with an open gable. Therefore it will be necessary to add 15 per cent. to the price of the roof for the extent of the hip, a regular hip being the width of the roof by half the width; or for two hips, the square of the span gives the area to be charged with this additional per centage.

If, instead of "hipping," the ends of the roof are filled in vertically with galvanized corrugated iron, the additional cost, in ordinary cases, may be taken at about 1*s*. the square foot.

The hip may be considered preferable in many cases, as it offers less surface to the wind, and adds to the strength of the roof, by acting as bracing to the whole structure, and is better in point of effect and compactness.

It may be well to state, that in giving prices of roofs above, the details are based upon the supposition, that the wind may possibly produce a stress of at least 30 lbs. on the square foot, and 23 lbs. per square foot is allowed for the weight of framing, covering, and congregated snow, making 53 lbs. per square foot, and in no case is the iron strained above 5 tons per square inch of section.

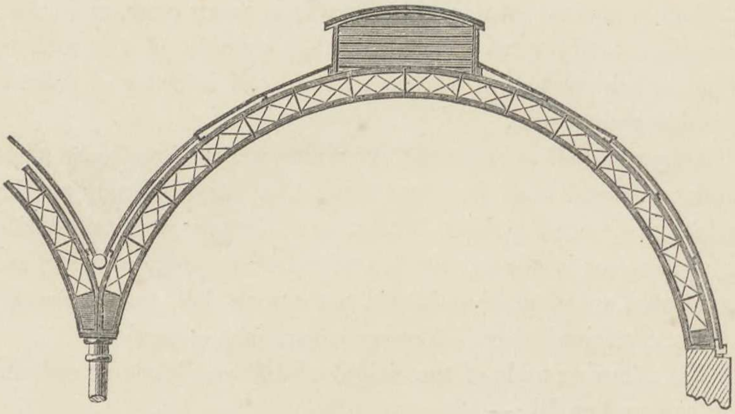
The following table of the weight of different kinds of covering may be found useful:—

Lead covering	weighs	about 7 cwt.	per square of	100 superficial feet.
Zinc	,, ,,	1½	,,	,,
Corrugated iron	,,	3¼	,,	,,
Slates		6 cwt. to 9 cwt.		,,
Tiles . . .		about 12 cwt.		,,
Boarding, 1¼ thick	,,	4½ cwt.		,,

Slate and tile roofs require a slope of from 25° to 30° as the minimum; the greater the slope the less liability of rain being driven under them by the force of the wind.

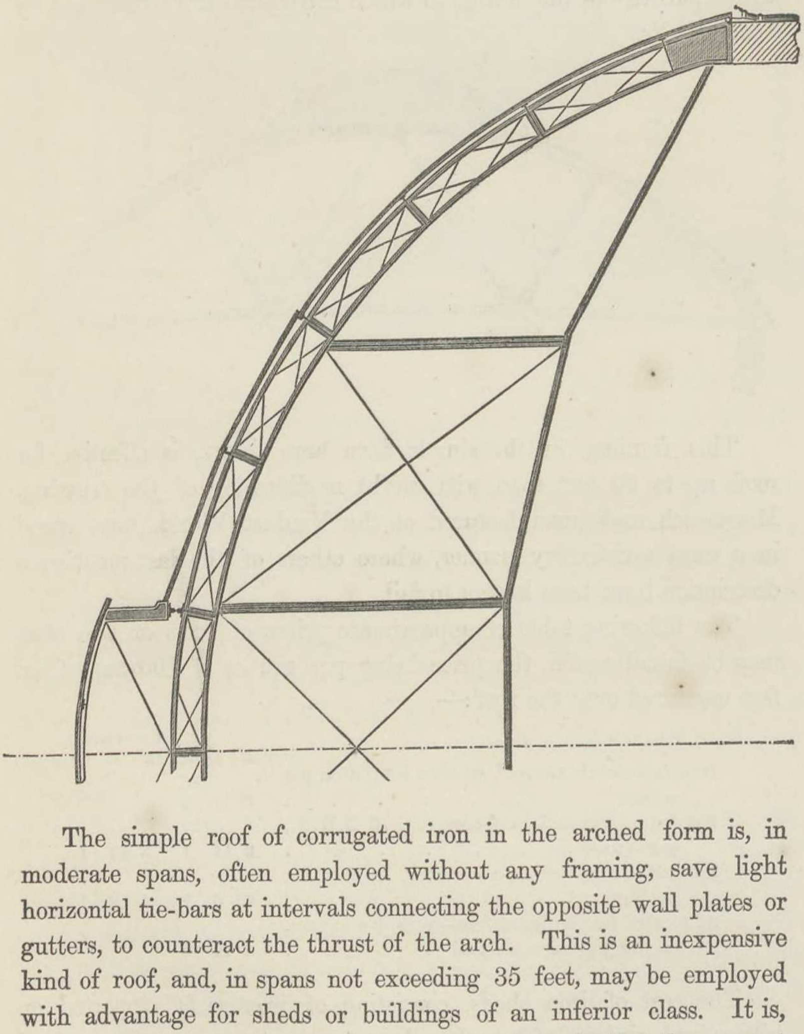
The accompanying sketch illustrates an example of a somewhat larger span roof made at Crumlin, and erected by Messrs. Kennard, for a railway station in Spain; it is 80 feet span, 232 feet long, covered with corrugated iron, and has a skylight of glass about 14 feet wide on each side the entire length; the ends are filled up with an ornamental arrangement of plain and coloured glass. The total cost of such a roof may be estimated at about £2,000.

Roofs of the arched form are sometimes preferred as presenting less surface to the wind, and as requiring less height of supporting walls or columns than the ordinary ridge roofs for the same height inside. When fine interior effect is desired, the arch may approach the semicircle, or assume the proportions of a bold ellipse, being in such cases formed to dispense with transverse ties or trussing. The following sketch is an example of this class of roofs recently made at



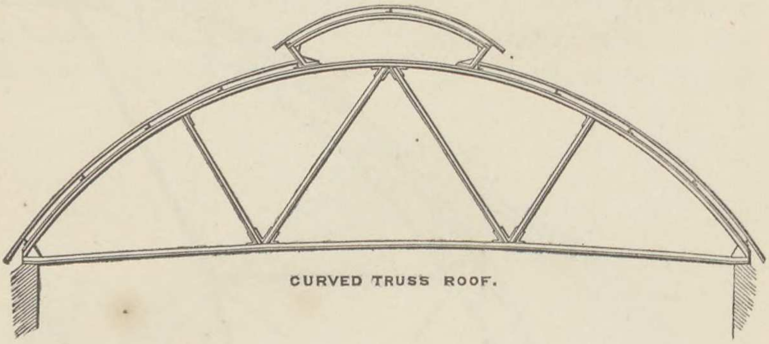
Crumlin, of very substantial scantlings, calculated to resist the most severe hurricane of a tropical climate. The ribs are of the latticed girder principle, varying in depth according to the span; covering is of very stout corrugated iron, and the top of the Louvre ventilator is covered with plate glass roughened on the inside for the purpose of moderating the effect of the sun's rays. If it is desired, an inner lining can be added of corrugated iron of a thinner description than that outside, forming a double roof with air space between. This arrangement is often adopted in a tropical climate, as it admits of a current of air passing between the two coverings, which greatly assists in cooling the atmosphere of the building.

Roofs of this class are made of very large spans. Some examples are now in course of erection in this country upwards of 200 feet clear span, but it is desirable, if circumstances will admit, to introduce some kind of internal bracing, in the manner shown by the following sketch, particularly where the spans are very large, and in an exposed position, or subject to hurricanes. Large roofs of this class, however, are exceptional, and it is not proposed to do more here than supply tables of the prices of different kinds of roof suitable for ordinary purposes.



The simple roof of corrugated iron in the arched form is, in moderate spans, often employed without any framing, save light horizontal tie-bars at intervals connecting the opposite wall plates or gutters, to counteract the thrust of the arch. This is an inexpensive kind of roof, and, in spans not exceeding 35 feet, may be employed with advantage for sheds or buildings of an inferior class. It is, however, necessary to say in reference to such roofs, that the amount of material of which they are composed is quite inconsistent with the results of calculation upon which the details of the roofs above referred to are designed; and they cannot be recommended as suitable for buildings of a permanent character, although they do often withstand for many years the periodical gales, in a manner difficult to reconcile with the small amount of material in them.

A great improvement upon these last-mentioned roofs is seen in the framing shown in the following sketch, consisting of T iron ribs with "purlins" of angle iron, to which corrugated iron is fastened by hooked bolts.



CURVED TRUSS ROOF.

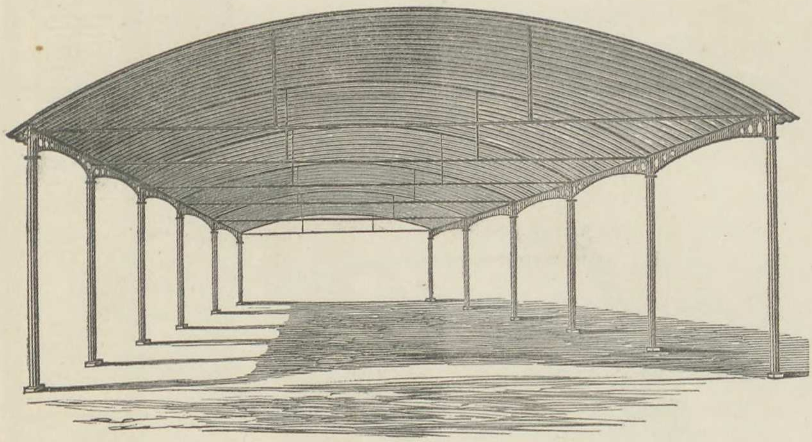
This framing, in the simple form here shown, is effective for roofs up to 60 feet span with slight modification of the trussing. Many such roofs, manufactured at the Viaduct Works, have stood in a most satisfactory manner, where others of the last-mentioned description have been known to fail.

The following table of approximate prices of roofs of this class may be found useful, the price being per square of 100 superficial feet measured over the roof:—

	£	s.	d.	If galvanized. £	s.	d.
Iron framework for roof, without ventilator, per square	3	17	2			
Painted corrugated iron covering, 16 B.W.G., per square	2	14	1	3	12	1
Painted corrugated iron covering, 14 B.W.G., per square	3	6	1	4	9	1
Add extra for ventilator framework, per square, on the portion ventilated	2	12	0			

The cost of iron sheds, consisting of iron roofs supported on pillars and girders, such as that shown on next page, may be arrived at by reference to the tables already given for the prices of roofs of different kinds and widths of span, with the addition of the cost of the pillars or columns and girders.

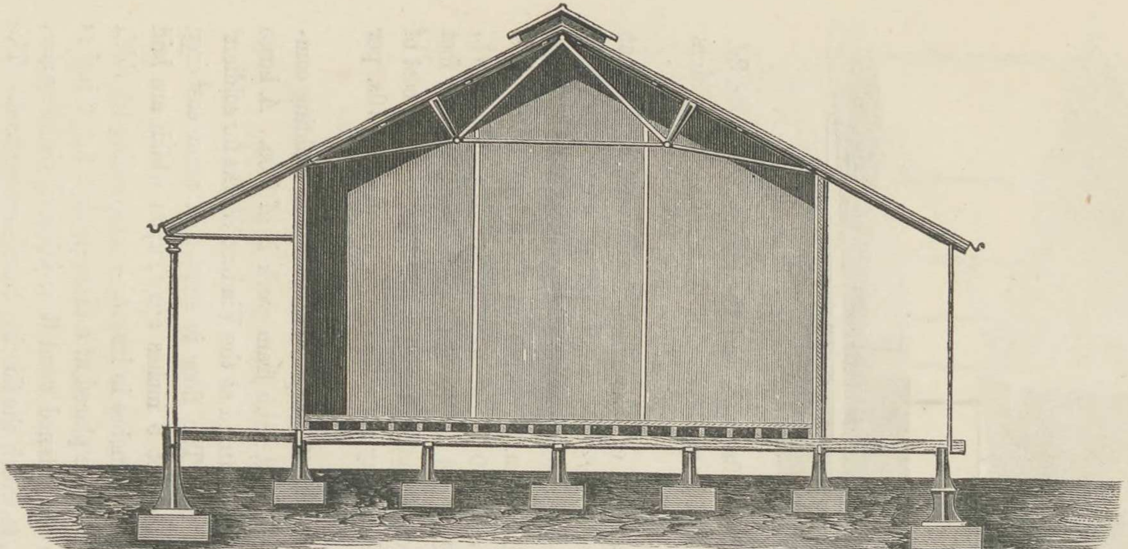
The pillars are of a simple kind of stanchion, of a cross section, in height about 12 feet, weighing about 2 cwt. each. The centre girders between them are 20 feet long, and weigh about 5½ cwt. each. The



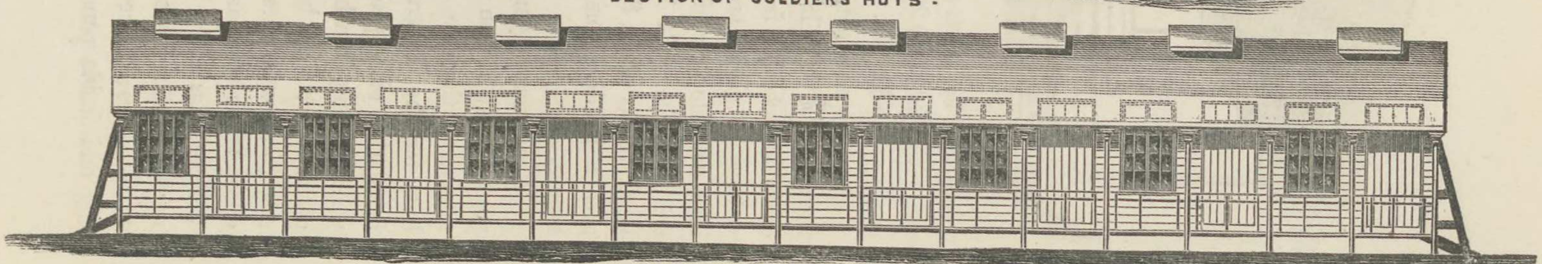
pillars may be taken at £1 12*s.* each, and the girders at £4 6*s.* 8*d.* each; this for a bay 20 feet length of shed of these pillars and girders would cost £11 17*s.* 4*d.*

A more substantial shed of this class, for framed roof, as at page 66, can be built with the same stanchions and girders for spans up to 35 feet; but from 40 feet up to 60 feet span requires stronger sections of girder and column. A wrought-iron stanchion, 16 feet high, suitable for roof up to 60 feet span, would weigh about 5¾ cwt., and cost about £4 12*s.*; and a wrought-iron gutter beam, 20 feet long, weighs about 8 cwt., and will cost about £6 8*s.* The cost of such a building complete may be reckoned at about £10 10*s.* per square.

The accompanying illustration represents a class of building composed chiefly of iron and wood; the framework is of iron. A large number of them are manufactured at the Viaduct Works for soldiers' huts for the Government. The floor is supported upon cast-iron foundation piers, placed 5 feet 6 inches apart, upon which are laid wood bearers, 6 inches by 3 inches in length, corresponding to width of building; these bearers are placed at a distance of 6 feet 6 inches apart, and upon these are fastened wood floor joists of ordinary size, about 16 inches apart, to which the flooring boards are secured. The walls or sides of the building are composed of iron and wood; vertical angle iron stanchions are placed 6 feet 6 inches apart, and bolted to the floor bearers; to these stanchions are secured outside weather boarding and inside panelling, all of boards ¾ of an inch thick. The



SECTION OF SOLDIER'S HUTS.

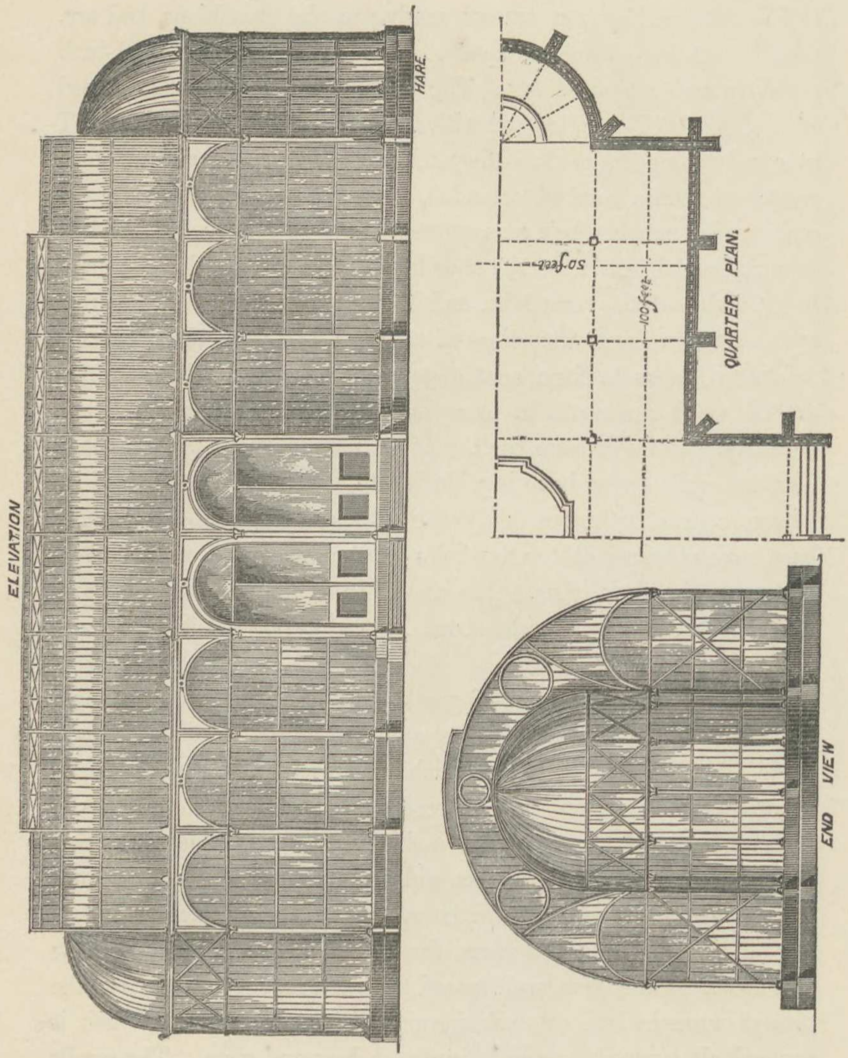


ELEVATION OF SOLDIERS HUTS

HARE

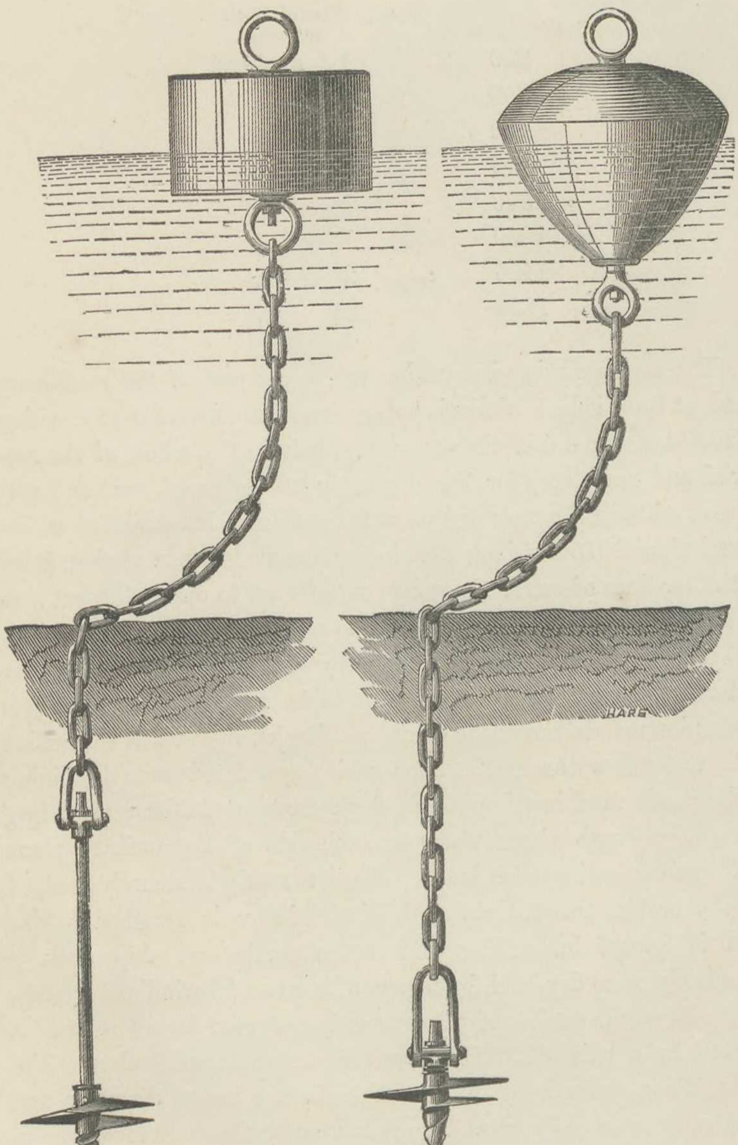
roof is composed of iron trusses resting on the stanchions, and are, therefore, 6 feet 6 inches apart; they are covered with 1½-inch boarding and asphalted felt. The trusses in the roof are composed of 3 × 3 × ⅜ T iron, trussed with round bars and struts, and the T iron and roofing are produced beyond the walls of the building sufficiently to form a covered verandah, 5 feet wide, on each side, the overhanging portion being supported at its extremity by cast-iron columns, which rest upon the floor bearers, which are also produced to the width of the verandahs, and have their extremities supported upon cast-iron foundation piers of a larger size than those already mentioned, so as to form anchorage in the ground. The windows are of wood casements in iron frames; partitions are of double boarding, two thicknesses each, ¾ of an inch, stiffened by iron bars. The end walls are of boarding, similar to the sides, but stiffened by triangular iron buttresses made of light angle iron and rivetted flat bars, and attached at top by bolts to the trusses of roof, and at bottom to the floor joists. The cost of ironwork for huts, as above, 100 feet long, 20 feet wide, about 14 feet average height, is about *2d.* per cube foot of building.

Other buildings in iron, of great variety, including wrought and cast-iron verandahs and staircases, and lighthouse buildings, are also made at these Works, from which we select one represented by the accompanying engraving, representing an example of a class of building made for Spain, composed chiefly of iron and glass, and this building is 100 feet long, 50 feet wide, and is used as a conservatory. The same class of work would be applicable to exhibition buildings, &c. It is made in three spans, the centre one being largest. The ribs are of light T iron, well braced together, and springing from the tops of wrought-iron columns, forming the main framing, which is covered all over with wrought-iron sash bars and glass. The scrolls and decorations are of cast-iron. The whole building is very economical and durable, and costs about £1600 deld. f. o. b. in this country, including doors and fittings, or about £30 per square covered on plan.



IRON BUOYS AND MOORINGS.

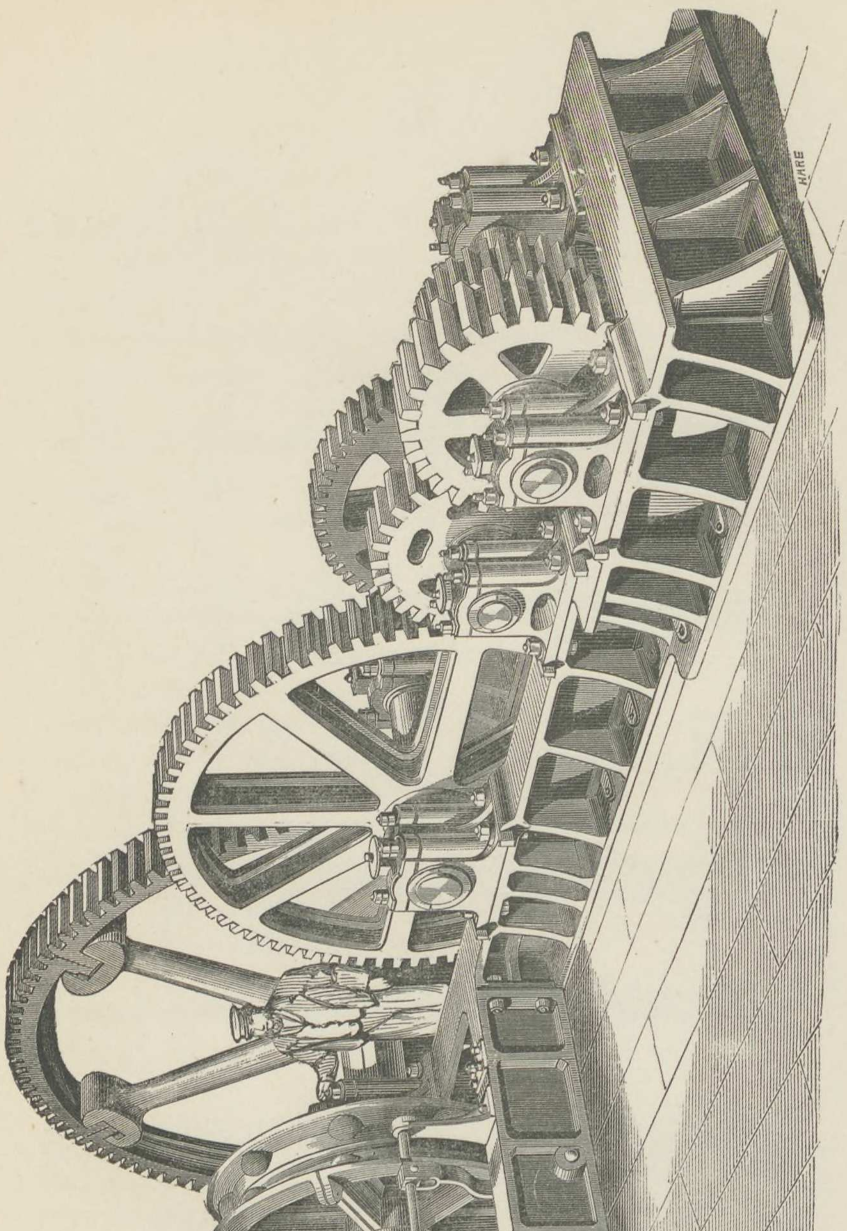
The following sketches show two classes of buoys of ordinary construction. Either of these is made suitable to moor vessels up to 2000 tons; the chain in that case would be about 2¼ inches diameter, with rings, shackles, &c., in proportion.



The cost of the above size, including chain 30 feet with screw, &c., complete, ready for fixing, is from £80 to about £90 each, and depends upon the size and quantity of chain and class of buoy required. The following table in reference to sizes of chains having reference to ship's tonnage, is approved by the principal shipowners, &c. :—

Ship's Tonnage.	Size of Chain in inches.
200	$1\frac{1}{16}$ diameter
300	$1\frac{1}{4}$ "
400	$1\frac{3}{8}$ "
600	$1\frac{5}{8}$ "
800	$1\frac{3}{4}$ "
1000	$1\frac{7}{8}$ "
1400	2 "
1800	$2\frac{1}{8}$ "

The accompanying illustration represents part of the machinery made at the Viaduct Works in connection with a patent slip for raising a 2000-ton ship out of the water for repairs. The whole of the material and machinery for this apparatus was prepared here and sent abroad with all the tools and plant for erection. It consists of an inclined plane 1075 feet long at an inclination of 1 foot in 24 feet, fitted with four lines of rails; the gauge of rails out to out is 30 feet; to be laid sufficiently far into the water to admit of a cradle or carriage 250 feet long being lowered thereon by means of a chain into the water underneath the ship intended to be raised, when the ship is floated immediately over the cradle and hauled in towards the incline until it touches the cradle, upon which are fitted suitable sliding wedges and machinery to work them from a platform extending the whole length above water on each side of the inclined plane and communicating with land. When the ship is securely wedged on the cradle, the chain by which the latter is attached to the land is hauled in, pulling with it the cradle and ship upon it completely on to dry land, by means of a powerful windlass or crab, which forms the subject of the illustration referred to. The crab is worked by a pair of 25 H.P. horizontal engines and boilers. The main lifting chain is of the stud-link class, 3 inches diameter, and weighs upwards of 70 tons. The rails forming the ways for cradle to run upon are of massive cast-iron in section, about 12 inches wide at base and 4 inches at top. The central pair of lines are placed as close together as convenient, and the outer pair as above named 30 feet apart. The rollers or wheels upon which the cradle travels are about 2 feet diameter, and placed about 3 feet apart throughout its entire length.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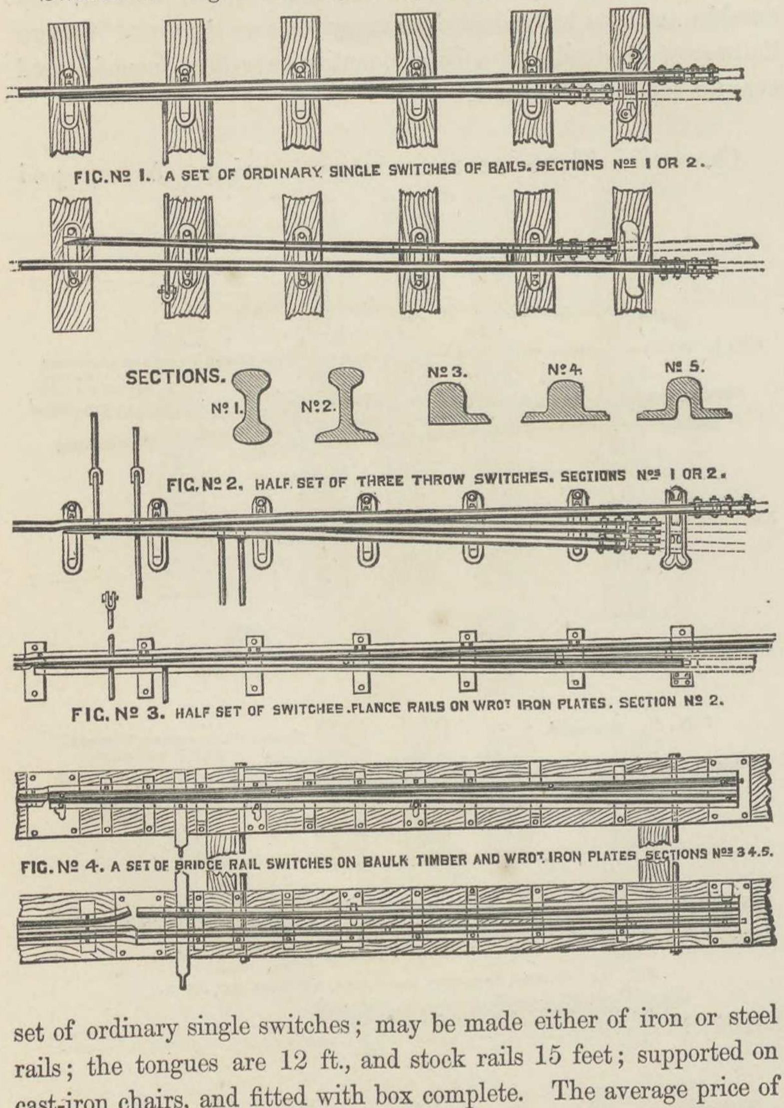
RAILWAY PLANT AND STATION FITTINGS MANUFACTURED AT THE VIADUCT WORKS.

Switches.—Fig. 1 in the accompanying illustration represents a



set of ordinary single switches; may be made either of iron or steel rails; the tongues are 12 ft., and stock rails 15 feet; supported on cast-iron chairs, and fitted with box complete. The average price of such is about £10 10*s.* per set. Fig. 2 represents the half of a set of three-throw switches, and are made of the same materials, and are generally about £9 per set more than the above. Fig. 3 represents the half of a set of ordinary flange or bridge-rail switches, rivetted to wrought-iron plates. Fig. 4 represents a pair of strong bridge rail switches, with wrought-iron plates, mounted on timber. These are more costly than the above; but they are, however, very durable, and have been adopted for many years on the Great Western Railway of England, and a large quantity have been manufactured here for export to Australia.

Crossings.—These are made in great variety. A very good

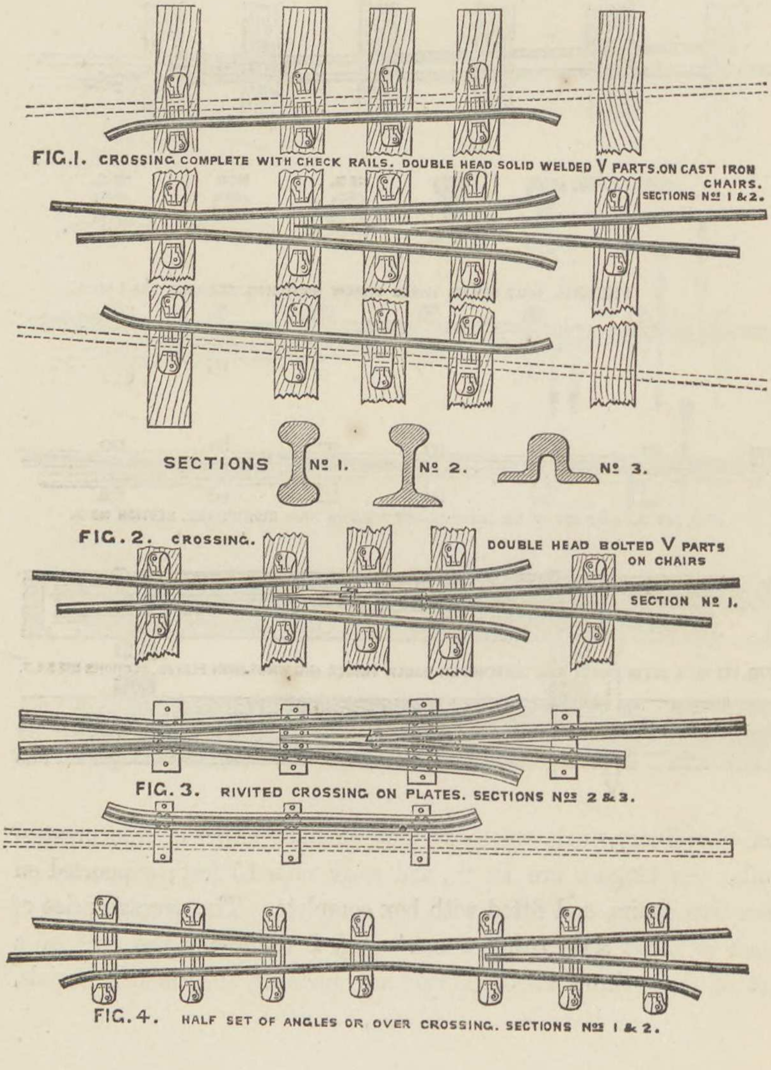


FIG. 1. CROSSING COMPLETE WITH CHECK RAILS. DOUBLE HEAD SOLID WELDED V PARTS ON CAST IRON CHAIRS. SECTIONS Nos 1 & 2.

FIG. 2. CROSSING. DOUBLE HEAD BOLTED V PARTS ON CHAIRS SECTION No 1.

FIG. 3. RIVITED CROSSING ON PLATES. SECTIONS Nos 2 & 3.

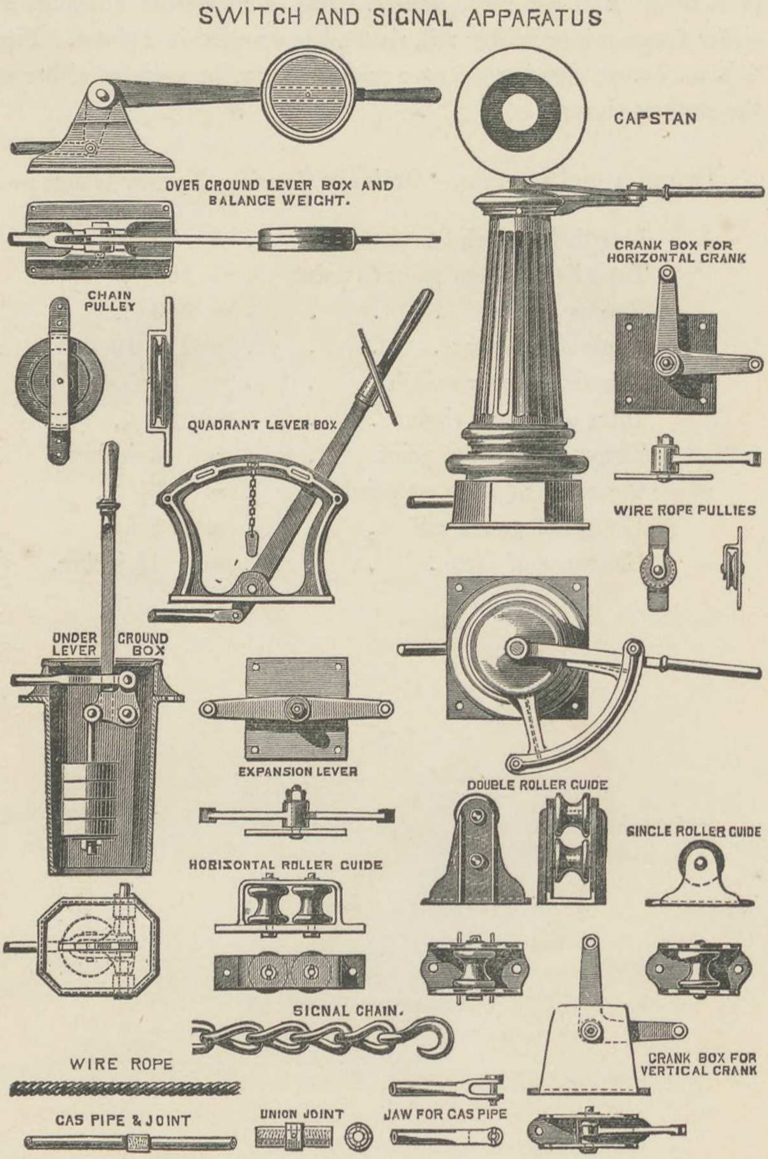
FIG. 4. HALF SET OF ANGLES OR OVER CROSSING. SECTIONS Nos 1 & 2.

ordinary crossing is represented in Fig. 1 of the accompanying illustration of double-headed rails, solid welded V part, and on cast-iron chairs. Fig 2 is a similar crossing; but with bolted V part: average price about £10 per set complete. Fig. 3 represents crossings of either flange rail or bridge rail, rivetted to wrought-iron plates. Fig. 4 is an obtuse crossing for over road, and may be made of either of the sections shown.

Points and Crossings.—Ordinary Crossing, Narrow Gauge:—

Length from point to crossing	. =	75 feet
Total length from point to point	. =	165 „
Radius	. =	600 „
Angle of crossing . . .	. =	1 in 10
Length of inner switch . .	. =	10 feet
Ditto of outer switch . .	. =	15 „
Throw of ditto, at point .	. =	4 inches
Clearance of ditto, at point .	. =	3½ „
Length of guard rail . .	. =	8 feet
Clearance of ditto . . .	. =	1½ inches.

Various Switch and Signal Fastenings and Fixings manufactured at Viaduct Works.



Patent Economical Switch and Signal Locking Gear manufactured at the Viaduct Works.

The use of locking gear in the working of switches and signals at station yards and junctions having recently been rendered compulsory by the regulations of the Board of Trade, it has become a necessity to railway companies proposing to open new or alter existing lines to procure apparatus fulfilling the conditions of safety and efficiency required by the Board, and, at the same time, protect their trains from accidents arising from forgetfulness or errors of judgment on the part of the switch and signal men.

The object of the arrangement shown in the engraving is to pro-

LOCKING LEVERS
FIG. 1.

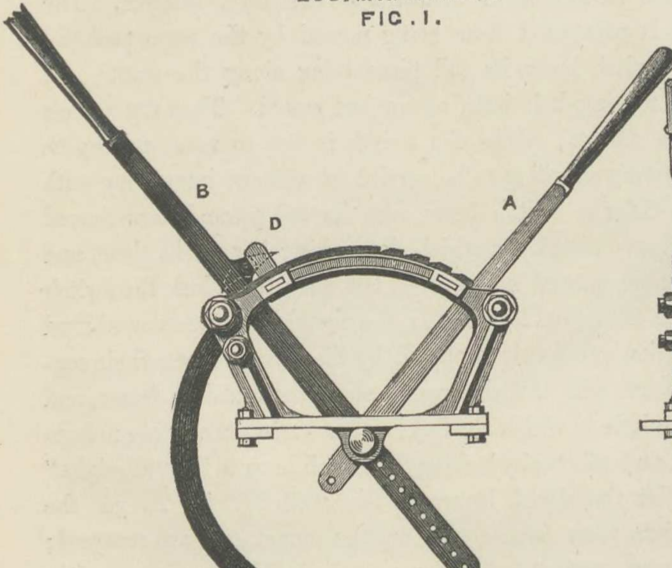
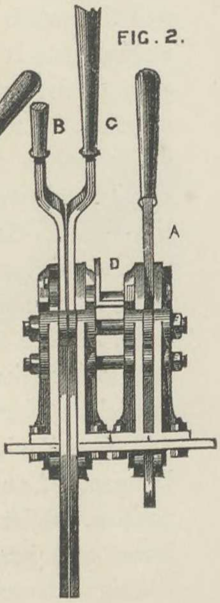


FIG. 2.



vide a cheap and efficient method of locking in conjunction switches and signals, crossing-gates and signals, or other machinery required to be worked in connexion with signals. It is specially intended for country districts of ordinary traffic, and does not attempt to rival the costly and elaborate machinery suitable for crowded junctions. In this arrangement the switch and signal levers work side by side in cast-iron frames of a similar description to ordinary switch lever frames. In the engravings, A is the switch lever, B and C are the signal levers, and D is the transverse locking bolt. The levers are provided with segmental tail pieces, of the same curvature as the cast-iron frames, and the frames have a slot at one end to allow the tails to pass through. They are also slotted transversely, and a sliding bolt works through the slots, and is made capable of alternately locking the switch lever or the signal levers. The tail pieces prevent the transverse movement of the locking bolt, except when the levers are in the right position for being locked, as the tails lie along the frames and cover the holes in which the transverse locking bolt works.

In the position shown in the engraving the signals in connexion with the signal levers are at danger, and locked by the locking bolt, and the switch in connexion with the switch lever is open. The locking bolt is prevented from being moved by the segmental tail piece of the switch lever, its tail piece lying along the frame, and covering the locking bolt hole, as we just stated. Thus the signals are locked to danger; whilst the switch is free to move as may be required, allowing shunting to be carried on without interfering with the signals. If the switch lever with its tail piece is now moved over, it will leave the slot in which the locking bar works clear, and this can then be moved so as to, at the same time, lock the switch lever, and free the signal levers. If the signal levers are now shifted into the position previously occupied by the switch lever, their segmental tail pieces will in their turn lie along the cast-iron frame, and will cover the hole in which the locking bar works, preventing it from being moved, and effectually locking the switch lever to the "all-right" position, whilst the signal levers remain "all-right." To get the levers back into their former position, the movements are reversed; the signal levers are first put to danger; the locking bar is moved in front of the signal levers and locks them, leaving the switch free to move as before. By this it will be seen that it is impossible to move the switch lever until the signal levers have been first locked to danger; neither can the signal levers be moved until the switch lever is locked to the "all-right" position. This prevents the possibility of any accident arising from a mistake in working the signals.

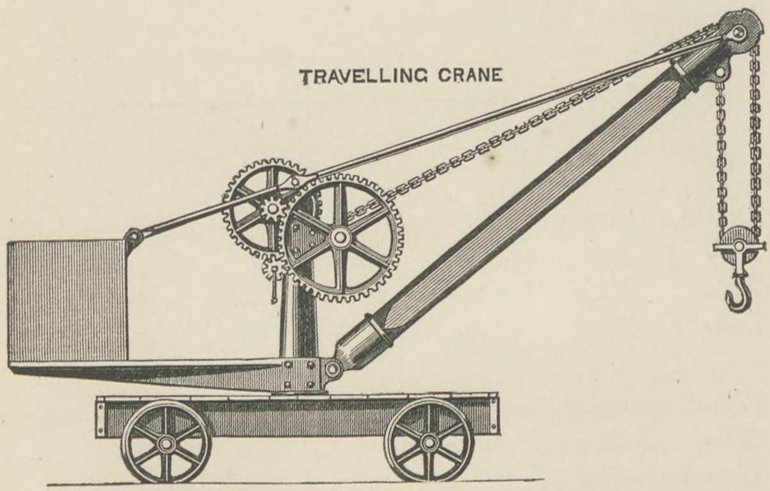
As will be seen, this arrangement is possessed of great simplicity in the working parts, and requires no protection from the weather;

therefore the special signal box usually employed at junctions may be dispensed with. An advantage, on account of simplicity, is found in fixing, as any ordinary platelayer or carpenter is quite capable of fixing it, the cost of the arrangement being only slightly in excess of the ordinary levers and frames, to cover the cost of the few additional parts required. These extra parts required, beyond those of an ordinary lever frame, being a tail piece to each lever, and one locking bar to the set of three levers.

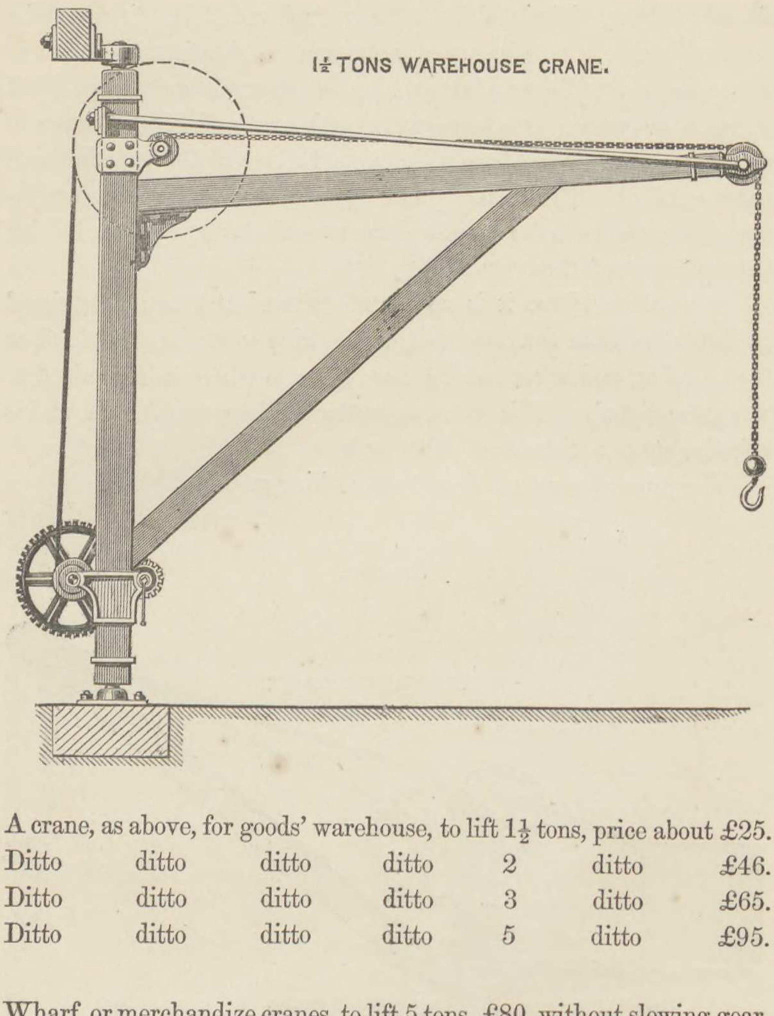
In stations where it is not found convenient to work the signal and switches from the same spot, the locking levers may be fixed at the switches, and wires carried from them to where it is required to work the signals. This saves the outlay for long switch rods, and is effective up to a distance of 600 yards.

The price of a set of three-lever locking gear is £10.

Cranes.



A crane, as above,	to lift	2 tons,	price about	£40.
Ditto	ditto	3	ditto	£75.
Ditto	ditto	5	ditto	£110.



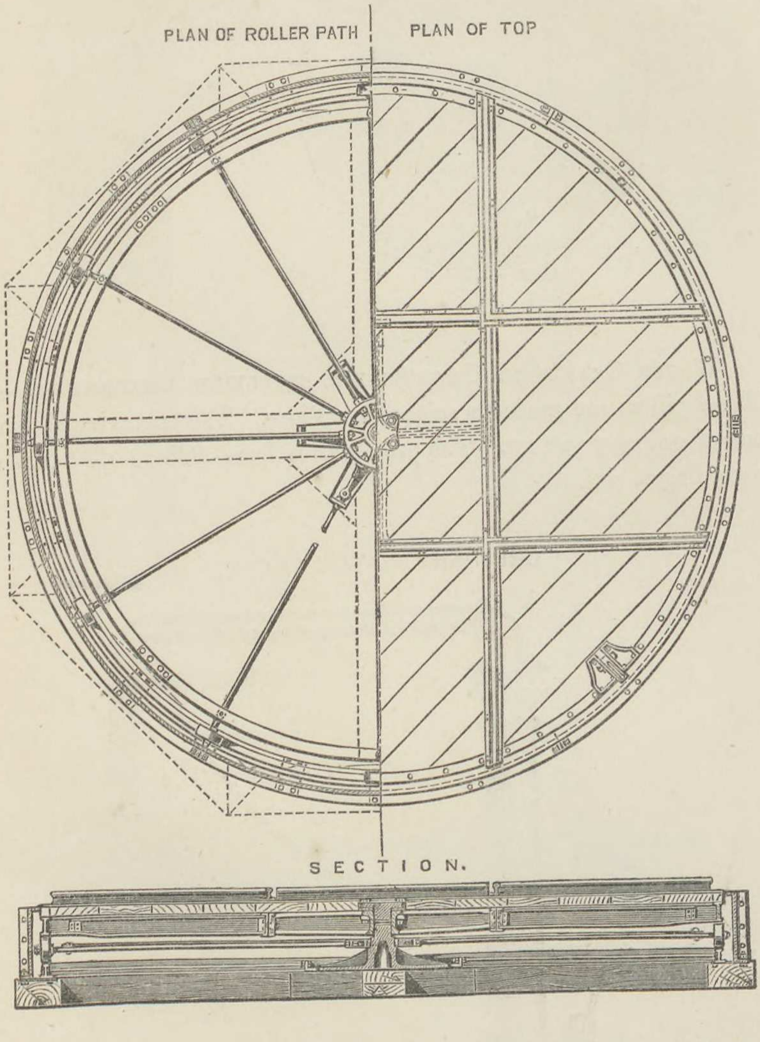
A crane, as above, for goods' warehouse, to lift				1½ tons,	price about	£25.
Ditto	ditto	ditto	ditto	2	ditto	£46.
Ditto	ditto	ditto	ditto	3	ditto	£65.
Ditto	ditto	ditto	ditto	5	ditto	£95.

Wharf or merchandize cranes, to lift			5 tons,	£80, without slewing gear.
Ditto	ditto	ditto	5 ,,	£90, with ditto.
Ditto	ditto	ditto	10 ,,	£145, without ditto.
Ditto	ditto	ditto	10 ,,	£160, with ditto.

Turntables.—The price of turntables varies according to their diameter, the class of material used in them, and the purpose for which they are intended.

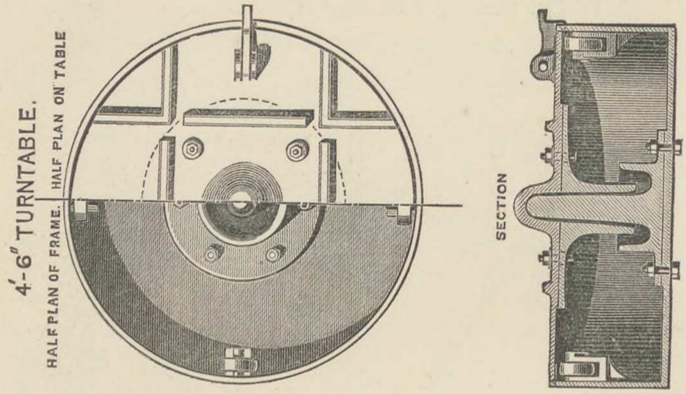
The engraving opposite is intended to give an idea of a simple kind of table suitable for turning carriages, and is strong enough to be laid in the main road. These are made from 12 feet to 15 feet diameter.

A 12-feet table of this class is about	.	£70
„ 15 „ „ „	.	£100



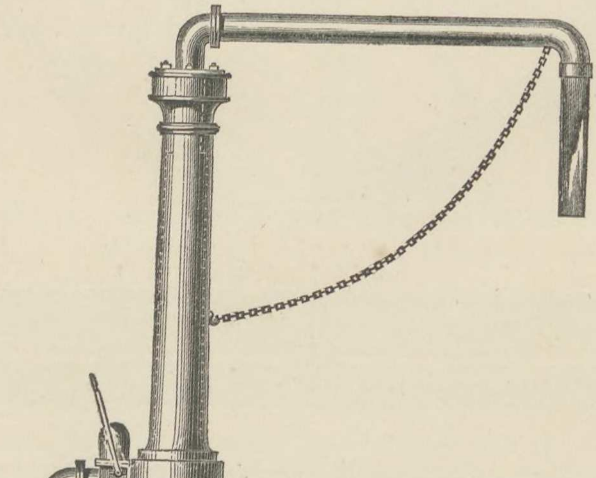
Tables for turning locomotive engines are usually about 40 feet diameter, and they are made on the most approved principle with wrought-iron beams and floor-plates, from £350 to £370 each.

A small, cheap, and useful table is made for tramroads, collieries, &c., as per sketch below.



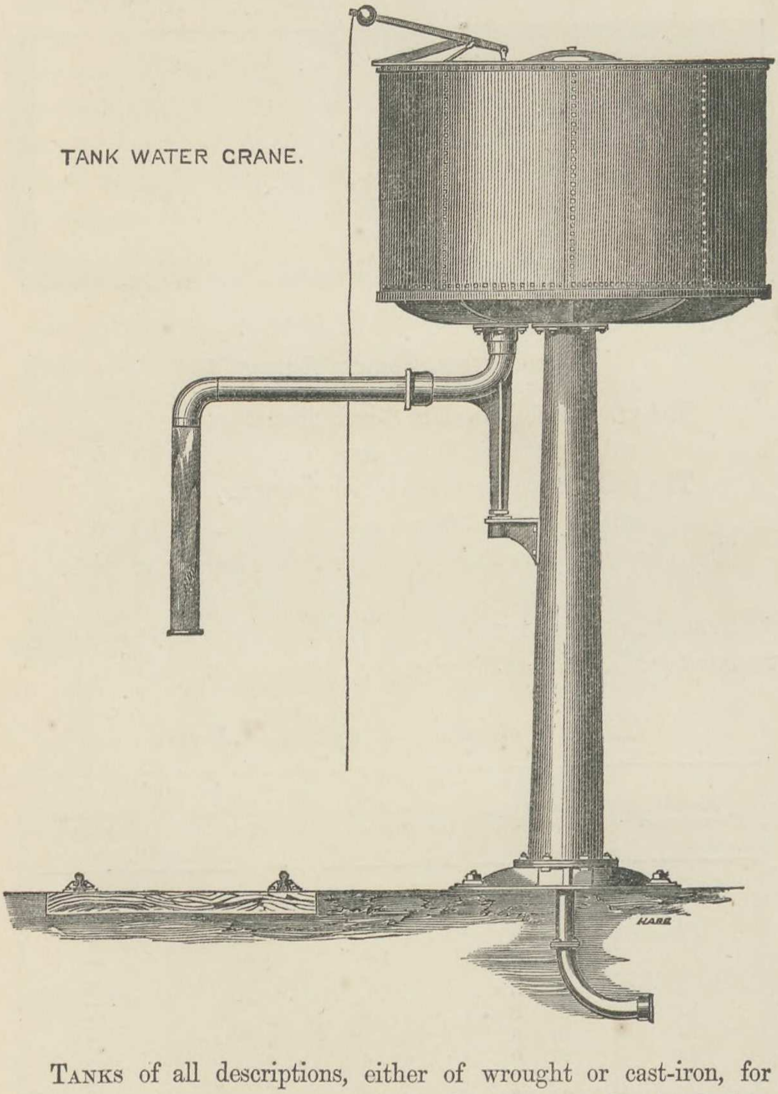
Water Cranes or Columns for supplying Locomotives.—These pillars are made to suit all situations. The engraving shows one of ordinary pattern. The price varies from £25 to £30 each, according to size.

ORDINARY WATER CRANE.



The following illustration is a very compact form of tank and bracket crane combined. The cost of this, with a tank to hold 2000 gallons, is about £90.

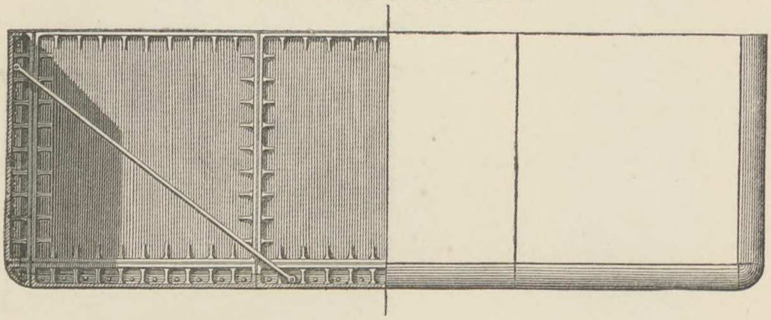
TANK WATER CRANE.



Tanks of all descriptions, either of wrought or cast-iron, for railway or other purposes, manufactured at Viaduct Works, lead to following results.

A cast-iron tank 13 feet 6 inches by 13 feet 6 inches by 4 feet 9 inches, to hold about 5400 gallons, may be reckoned to cost about $2\frac{1}{2}d.$ per gallon.

CAST IRON WATER TANK.



WATER PIPES, SLUICE VALVES, &c.

	£	s.	d.
The price of sluice valves 3-inch diameter, with spigot and faucet ends . .	2	15	0
The price of sluice valves 6-inch diameter, with spigot and faucet ends . .	4	15	0

The price increases about 15*s.* per inch diameter of pipe.

STEAM BOILERS AND BOILER FITTINGS for stationary engines manufactured at Viaduct Works.

TABLE *of dimensions of Cylindrical Boilers.*

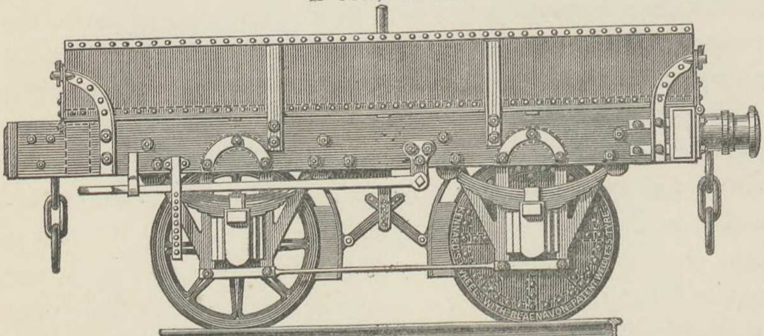
Nominal Horse-Power.	Length of Boiler.		Diameter of Boiler.		Diameter of Flues.		Number of Flues.
	ft.	in.	ft.	in.	ft.	in.	
1	6	0	1	9	—		None.
2	7	6	2	0	—		—
3	9	0	2	6	—		—
4	10	0	2	9	—		—
5	11	0	3	0	—		—
10	16	0	4	6	2	0	1
15	18	0	5	3	2	4	1
20	20	0	6	0	1	9	2
25	25	0	6	0	1	9	2
30	28	0	6	6	2	0	2
35	30	0	7	0	2	3	2

For more than 35 horse-power two or more boilers are required.

TEN-TONS' WAGONS, AS MANUFACTURED AT VIADUCT WORKS, CRUMLIN.—The framings are of English oak, floor and sides of stout iron plates strengthened by angle iron. They are especially adapted to carrying iron-ore from shipping port to works, and rails and bars from works to port, and are provided with bolsters. The wheels are either of Kennard's rivetted plate disc, or the ordinary spoke pattern. The tyres are of Blaenavon iron, wrought from the solid bloom into the required circular form, and then rolled into the patent *weldless tyre* to a condition of finish and truth, ready for putting on to the wheel without subjecting the iron to deterioration either by bending or welding, and without the necessity for either turning or boring. These tyres combine safety, durability, and economy.

The following results were obtained by testing pieces cut from some of these tyres made for the Delhi Railway Company. The pieces were turned to 1 square inch sectional area, and were broken by a tensional strain of 32 tons, the strain reaching 20 tons before any perceptible set took place.

10 TONS WAGON.



MACHINERY AND MACHINE TOOLS MANUFACTURED AT THE VIADUCT WORKS.

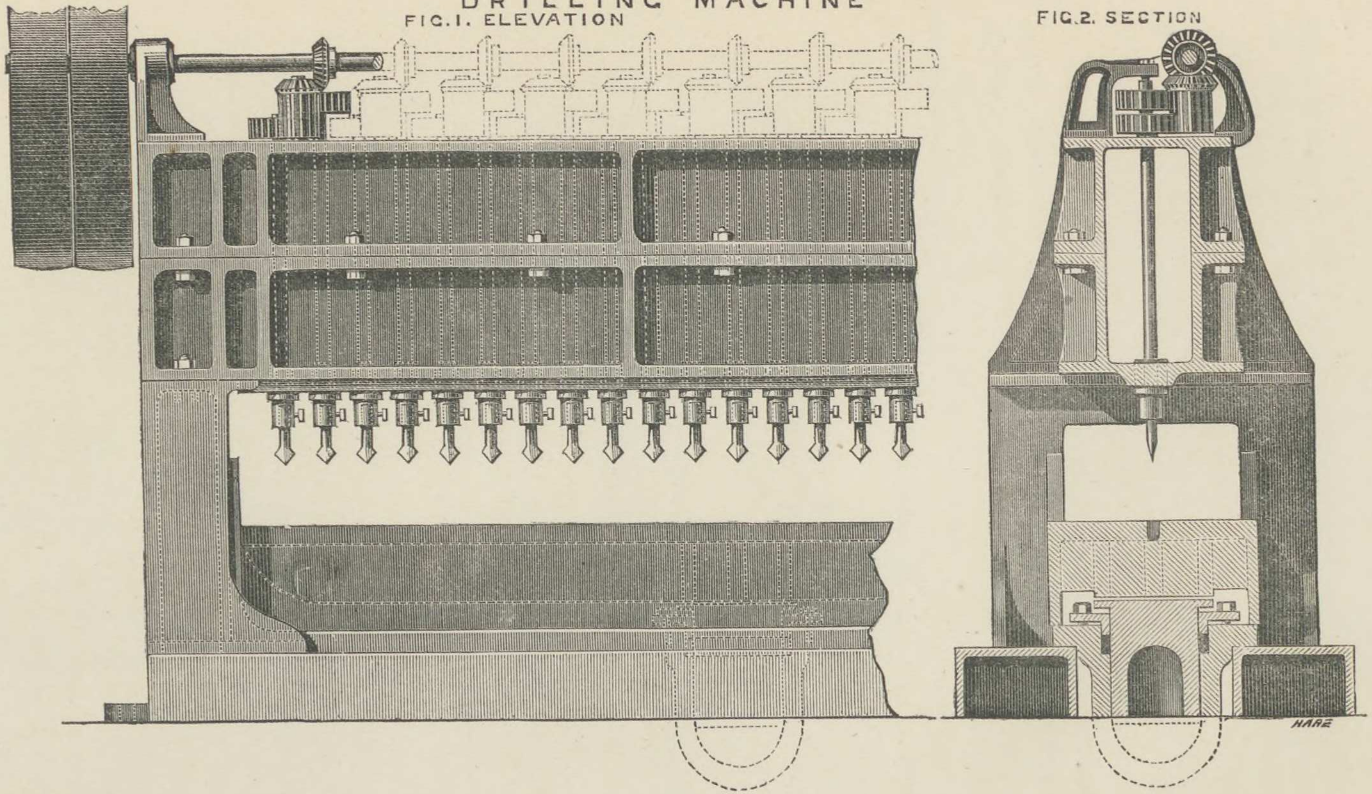
Amongst these may be mentioned multiple drilling machinery for drilling rivet holes of girders and other wrought-ironwork. Messrs. Kennard have constructed several such machines for the purpose of drilling the rivet holes in the girders of a bridge over the river Thames at Blackfriars, described in the preceding part of this book. These machines are collectively capable of drilling 552 holes at once, and one of them is constructed for drilling a straight row 26 feet in length, shown by the accompanying illustrations, Figs. 1 and 2. In this machine the drills are all placed at a distance apart suitable for ordinary work, namely, of 4 inches from centre to centre; but in other of their machines, arrangement is made by which this distance can be adjusted to suit special work. The plates or bars to be drilled are placed upon a table beneath the drills, and this table is raised by means of hydraulic pressure. The arrangement of the presses is shown in section, Fig. 2. As the pressure is put on, the table rises, and forces the work against the drills. This force is regulated by a valve which gives perfect control, and all the holes are drilled thereby at one operation, with great accuracy and speed. The hydraulic pressure is conveyed from a force pump into an accumulator, which consists of a vertical cylinder fitted with a piston, which is weighted to give the requisite pressure, and from this accumulator to the hydraulic presses of the various drilling machines. The working pressure is about 336 lbs. per square inch, and produces a pressure of about 6 cwt. on each drill.

In punching holes through a plate, a certain amount of distortion takes place in the iron surrounding the holes, leaving the upper surface slightly concave and a nearly corresponding amount of convexity on the lower surface, so that after punching, when two or more plates are put together, they do not lie close to each other, and require flattening by hammer or some other means. This disturbance of the fibre of the iron necessarily weakens it, and experiments have shown where holes have been drilled and others punched in similar plates, which were afterwards torn asunder in tension, that drilled bars broke with 31 tons where punched bars broke with 26 tons. It is difficult to give any accurate idea of the cost of drilled work as compared with punched; so much depends upon the arrangement of the detailed drawings, and it is desirable to consult the parties who are to carry out the work as to these details. The extra cost is, however, preponderated by the superior work it makes, the truth of which is so complete, that of a number of plates placed together indiscriminately, the holes fit so accurately that a turned pin can be

DRILLING MACHINE

FIG. 1. ELEVATION

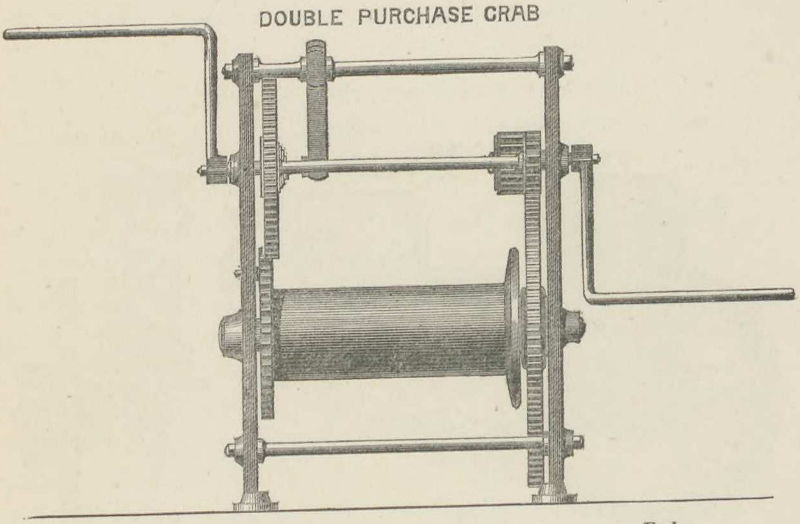
FIG. 2. SECTION



driven through the lot, at any hole, with a light hand hammer. In the bridge before referred to, for which Messrs. Kennard made these machines, the flanges of the girders have as many as six thicknesses of $\frac{3}{4}$-inch plates; and all the diagonal bars are drilled, some of them requiring very intricate patterns, and special machines were made for each different pattern.

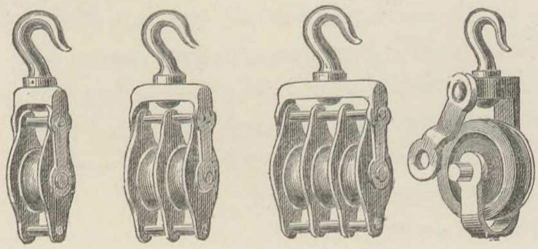
Crabs, Pulley Blocks, and Lifting Tackle.—The accompanying illustration represents a double-purchase crab. The prices of single and double purchase crabs are approximately as under:—

DOUBLE PURCHASE CRAB



	Each.
Double purchase, 3 tons	£8 0 0
" " 6 "	12 0 0
Single purchase, 1 ton	3 10 0
" " 2 "	6 10 0

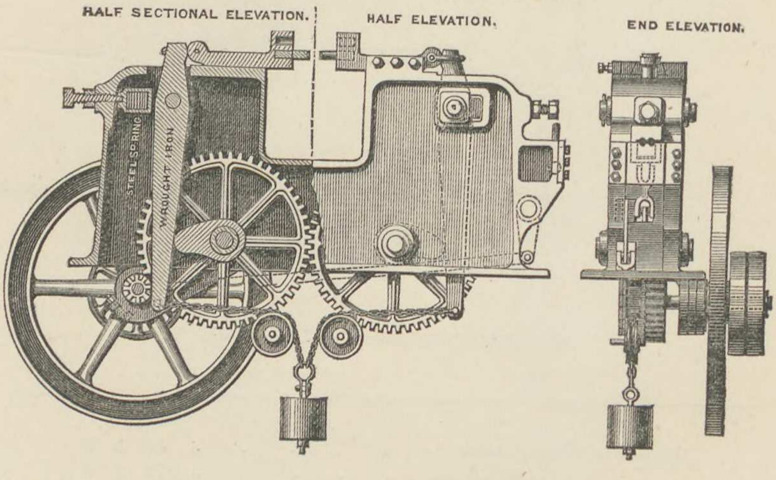
Best make Pulley Blocks, with turned pins, and pulleys all turned and bored:—



Diameter of Sheave.	Diameter of Chain.	Girth of Rope.	Price per pair, 1 & 2 Sheave.	Price per pair, 2 & 3 Sheave.	Snatch Blocks each.
In.	In.	In.	£ s. d.	£ s. d.	£ s. d.
3	$\frac{1}{4}$	$2\frac{1}{2}$	1 10 0	2 6 0	1 0 0
4	$\frac{5}{16}$	3	2 0 0	2 17 6	1 12 0
5	$\frac{3}{8}$	$3\frac{1}{2}$	2 12 6	3 10 0	2 5 0
6	$\frac{7}{16}$	4	3 5 0	4 2 6	2 16 0
7	$\frac{1}{2}$	5	4 15 0	6 12 6	3 10 0
8	$\frac{9}{16}$	6	6 15 0	8 15 0	4 0 0

Common articles may be had 20 per cent. less.

KENNARD'S DUPLEX RIVETTING MACHINE.



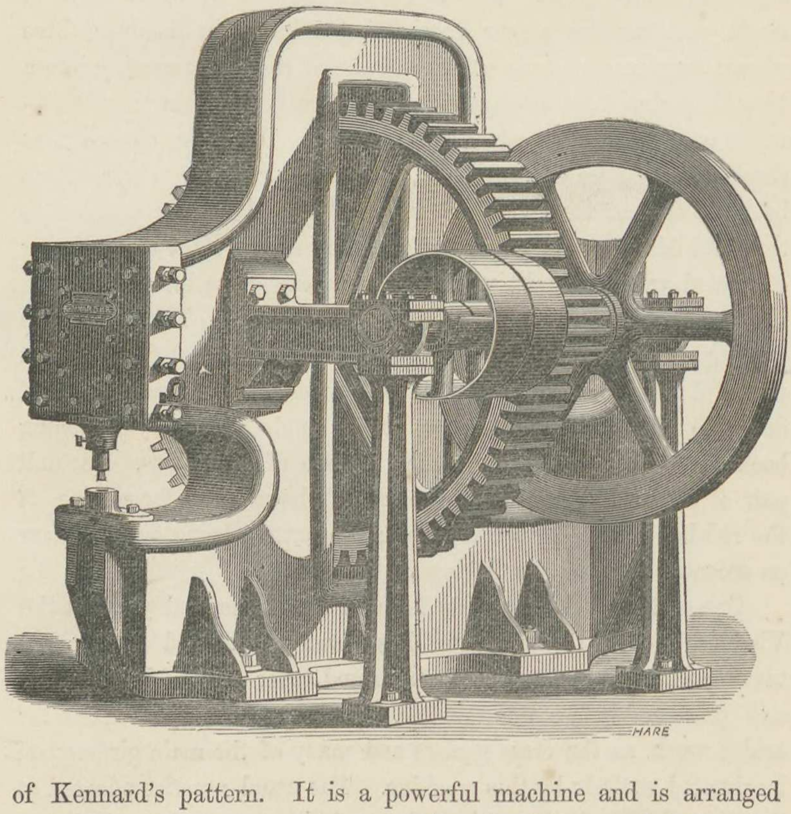
This machine is adapted for performing all kinds of work usually done by ordinary rivetting machinery; but instead of forming only one of the heads of the rivets as such machines usually do, it forms both heads at the same time. The rivets, or, more properly speaking, the blanks, are merely short pieces of rod iron, cut off by the shears at the end of the machine from bars of ordinary round iron. The bars are heated in a furnace close at hand; the blanks are then cut off to the proper length regulated by gauge, and placed in the work to be rivetted between the snaps, when the slides advance simultaneously from both heads at the same instant.

The machine, as will be seen by reference to the engraving, consists of a strong cast-iron hollow framing, inside which is contained the whole of the working mechanism, with the exception of the top slides, driving pullies, and fly wheel. This arrangement is very compact, and allows free access to the work being rivetted without danger of accident from the working machinery; the mechanism is got at from a pit below. The slides, which carry the rivetting snaps, are of wrought-iron, and are made to project upwards, so as to stand higher than the top of the machine, and each slide is provided with two sockets, one above the other, the snaps being used in either socket according to the class of work which is to be rivetted. These slides work in dovetailed grooves, on the top of the main casting, and are moved backwards and forwards by wrought-iron levers, to which they are attached by links. The levers are worked by cams fixed on shafts, each carrying a spur wheel 3 feet 5 inches in diameter, these wheels gearing into each other, and one of them also gearing into a 5½-inch pinion fixed on the driving shaft gear, which carries the fly-wheel and actuates the whole arrangement. It will be noticed that the cams only force the levers and slides to their work; to bring them back the ends of the levers are prolonged, and chains are attached to them, which pass over small pulleys, the ends of these chains being connected with a weight which is heavy enough to bring the levers into their proper position ready for the next stroke. To regulate the varying strain on the dies, the bearings of the levers are fixed against powerful steel springs, adjustable by set screws. When considered desirable the machine can be made single acting, by fastening back one of the levers, and taking off one of the chains. A small pair of shears is provided at the end of the machine for cutting off the red-hot iron as described above; the cutters being worked from an eccentric fixed on the driving shaft.

One of these machines has been in use for several years at the Viaduct Works, Crumlin, and has given unqualified satisfaction, turning out a large quantity of girder and other work with a rapidity and precision before unattainable. It is particularly adapted for bridge work, as the cross girders and many of the main girders can be rivetted entirely by this machine. The usual practice adopted at the Crumlin Works is to rivet the angle irons on to the web-plates, with the snaps in the lower sockets of slides; the snaps are then removed to the upper sockets, and the girder under operation is turned over on its side, in such a position that the top flange to be rivetted is situated between the two dies, whilst the web and the other flange of the girder overhang one of the projecting slides. The whole girder is completely rivetted by the machine. A great advantage of this machine is, that it dispenses with the keeping in stock of a large number of rivets of various lengths and sizes, the rod iron being the only material required. As this machine is brought into use it will, probably, reduce the cost per ton of girder and bridge work, and will thus extend the use of wrought-iron for building and other purposes.

The price of the machine is £220.

Punching and Shearing Machines, of various sizes, are manufactured at the Viaduct Works. The following sketch represents one

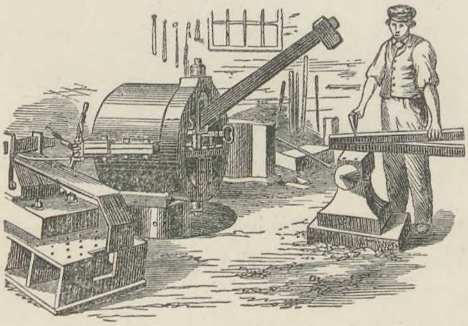


of Kennard's pattern. It is a powerful machine and is arranged with skew shears, so as to cut any length of bar, and knives for cutting angle iron up to 4 inches. The punch has a stop motion, which can be used at any moment to prevent the punch piercing should the puncher find his plate not properly adjusted. These machines have been in use many years, and found substantial, and requiring but very little attention, and have punched 2½-inch diameter holes in ¾-inch plate.

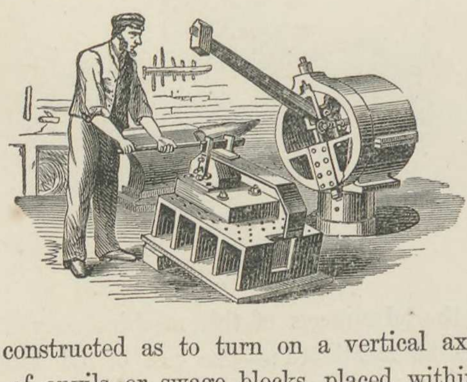
Several patterns of smaller punching and shearing machines always on hand.

DAVIES' PATENT SELF-ACTING STEAM STRIKERS, manufactured at the Viaduct Works, Crumlin. The silver medal was awarded to this invention, Paris Exhibition, 1867.

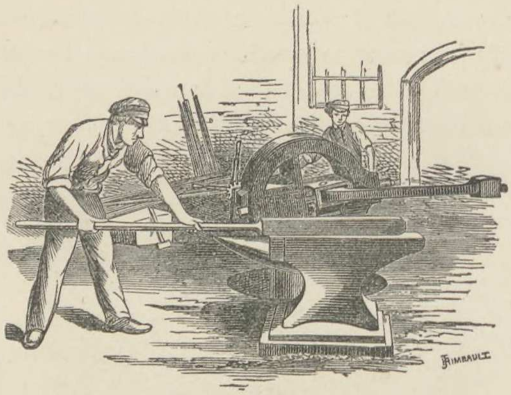
A machine capable of taking the place of ordinary hand strikers at the smith's anvil, and is specially constructed for striking blows *at any angle inclined to the face of the anvil,* from the vertical to the horizontal direction. Fig. 1 shows the striker in position for delivering vertical blows. It is adapted for all kinds of forgings



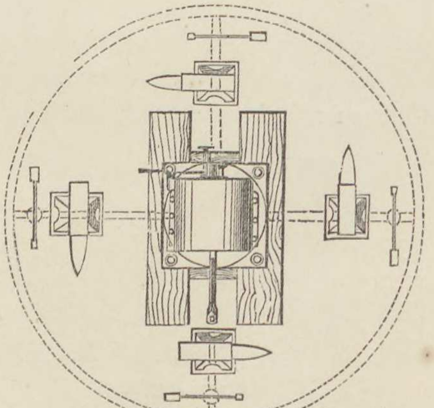
required in engine, bridge, railway, anchor, ship, and general smith's work. Fig. 2 shows the striker in position for delivering blows at an angle of 45 degrees, for bending angle and T-iron, stiffeners, &c.



It is so constructed as to turn on a vertical axis to work at any number of anvils or swage blocks placed within a circle of its radius; and the space occupied by it is not more than one-fourth of that required by hand strikers when working upon the same number of anvils. It is adapted to working by steam, compressed air, or water pressure, and its fixings and connections are simple. The smith can regulate the force or rapidity of the blows by means of a valve worked by his foot, the treadle of which is even with the floor. The striker is supported upon a hydraulic ram, and thereby elevated or lowered, and the steam and exhaust may either be supplied through the bottom or by pipes from above. Fig. 3 shows the



striker in a position for striking horizontal blows for upsetting; and Fig. 4 shows, in plan, the arrangement of anvils, swage blocks, &c.

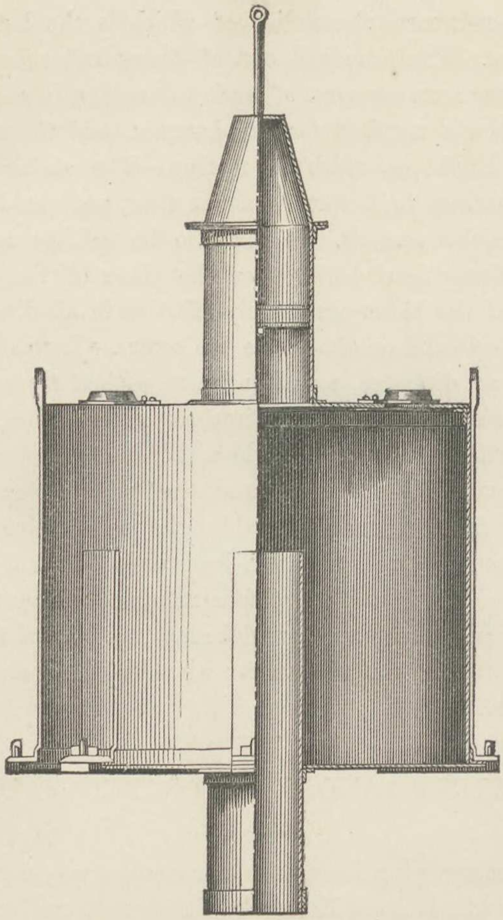


Amongst the advantages of this machine over ordinary steam hammers may be mentioned:—The cost of all kinds of swages is reduced to a minimum, because the hammer can be readily adapted to any angle or height of swage.—As the striker can be turned round in a horizontal plane, the swages can remain in their places arranged on the circumference, the radius of which is the length of the hammer arm. The time and cost of fixing and refixing swages, when changing from one class of work to another, is saved.—There are no standards required for the hammer, and the smith is not confined to height or width of forging.—The striker will work at any height up to 6 feet from the floor, and can be raised or lowered in a few seconds. It can also be quickly arranged for striking perfectly level blows upon the plane of the anvil in all positions, and the blows are equally effective in all directions, from vertical to horizontal on either side the centre.—It will forge shafts or bolts of any diameter, round and true, *without the use of swage.* —It will *weld* plates, bars, angle-iron, ships' beams, &c., and is very useful in bending and setting angle and T-iron stiffeners for bridge and girder work.—The hammer head when not at work is raised off the face of the anvil, which enables the smith to place his heat under it at once.—One striker will keep eight fires and a furnace in operation, and take the place of four men, and produce the work at about one-third the price of hand labour. The price of these strikers varies according to the appliances with which they are fitted, from £70 to £180.

PATENT SAND PUMP OR EXCAVATOR.

The accompanying illustration represents a very useful machine, invented by Mr. Howard Kennard. It was first used in sinking the cylindrical piers of the Tagus bridge, and afterwards at Mondego and other bridges, referred to in the former part of this book; and it has recently been employed with much success in erecting the cylindrical piers of the bridges on the Delhi Railway,—at the Sutlej bridge the sand pump, in one day of *seven* working hours, having sunk a pile 12 feet 6 inches in diameter 6 feet, or excavating 736 *cubic feet of sand*, the pile at the time being about 36 feet in the ground. It also sunk 15 feet *in eighteen hours*, part of the time working in black clay and kunkur.

The pump, as now made, consists essentially of a wrought-iron cylinder, the length of which is somewhat less than its diameter, and its diameter about half that of the pile to be sunk by it. Its top is closed, and at the centre thereof is attached a small cast-iron



cylinder, having a piston fitting somewhat loosely in it, the piston rod terminating with an eye at its upper end, to which a chain may be attached for working it; the bottom of the wrought-iron cylinder is formed by a wrought-iron plate, and is attached to the sides by cottar bolts passing through projecting lugs (as shown in the drawing),—these lugs are so arranged as to admit of easy removal of the bottom; in the centre of the bottom plate a vertical tube is inserted, projecting outwards for a distance equal to its own diameter, and inwards far enough to reach nearly to the top of the wrought-iron cylinder.

The mode of working may be explained as follows:—The machine is lowered by a winch or steam hoist (by means of sling chains being attached to lugs at the upper portion of its circumference) into the pile to be sunk, when the projecting tube partly enters the soil; a small chain, attached to the piston already described, is put in motion by a common reciprocating lever, similar to a portable smith's forge handle, or any other convenient means, and immediately the piston is moved it agitates the water and causes a partial vacuum in the wrought-iron cylinder, into which the water and sand are drawn through the projecting pipe, the water escaping through suitable valves arranged in the top in the manner shown by sketch, whilst the sand falls inside; a few strokes of the piston causes the machine to become filled with sand, when it is hoisted to the top, and a small suitable truck is ready to receive it; when in the truck the cottars are loosened, and the bottom of the machine is separated and another bottom is put on, and it is again lowered for a repetition.

In some cases, where clay in small patches has to be encountered, the bottom of the machine is made with radial feathers of wrought-iron plate, ½ an inch thick, sharpened and steeled at edges; these are about 9 inches deep. When anything hard is met with the pump is lifted 3 or 4 feet and let fall again several times, and by this means the clay, or whatever it may be, is broken up, and can be easily drawn into the pump. The pump will lift stones, or even bricks if not too large for the projecting pipe; it has lifted many of 14 lbs. weight.

The price varies according to the size of the pump, and is from £25 upwards.

STRAINS ON GIRDERS.

The method of ascertaining the amount of strain upon various parts of a girder, of class No. 1, is very simple. It may be

FIG. 1. DIAGRAM OF STRAINS ON HALF THE GIRDER WHEN EQUALLY LOADED.

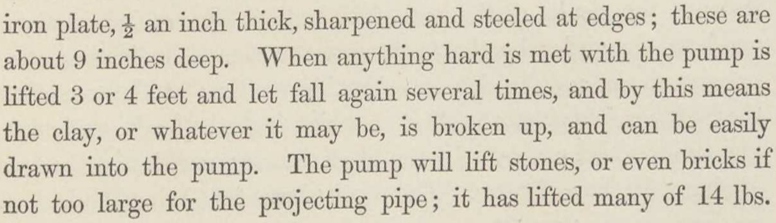
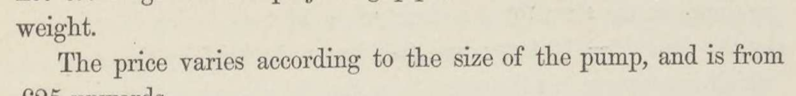


FIG. 2 DIAGRAM OF STRAINS WHEN PARTLY LOADED.



described as follows:—Assume the weight for a pair of girders, including the floor, railway, and heaviest load that will be passed over them, to be 270 tons evenly distributed, the half of this weight, or 135 tons, will be supported by each girder, and distributed. Thus, $\frac{135}{9} = 15$ tons to be supported on each division of the top flange; the top flange being considered inflexible between the points of support, or intersection of the diagonals, may be considered as nine separate beams, each 15 tons weight, supported on the points of the triangles formed by the diagonal struts and ties, as indicated by Fig. 1. Now, if we trace the effect of these loads upon the diagonals, and mark the results on each, after we have gone through the whole number of weights, we have only to add up the results on each diagonal to give the maximum strain on it. For instance, the results of the load of 15 tons at @ are indicated for one-half the girder by the ○ figures, the sign + indicating compressive strain, and the sign — indicating tension; at the same time the load $\overset{\frown}{b}$ is supported, the effect of which is shown by the ⌒ figures; likewise the load *c*, shown by the black figures; and, lastly, the load $\underset{\smile}{d}$ shown by the ‿ figures. The result shows (in ○) that the load @ produces on the strut @ 1 a strain of + 15 tons, which is supported by the tie $\overset{\frown}{b}$ 1, — 15 tons; and this has to be held by the strut $\overset{\frown}{b}$ 2, which is supported at the point 2 by the tie *c* 2, which presses upon the point 3 through the strut *c* 3; and so on to the point of support *e*. The strut $\overset{\frown}{b}$ 2 has to support, in addition to the load 15 tons from @, similar weight $\overset{\frown}{b}$, 15 tons, which is pressed upon the point 2, and supported by *c* 2, and so on; making the total + strain on $\overset{\frown}{b}$ 2 equal to 30 tons. In like manner, *c* 3 has to support + 45 tons and $\overset{\frown}{d}$ 4 has to support + 60 tons; the other half of the girder being loaded equally, precisely similar strains take place in the similar parts. It will be noticed that only half the weight at each end division from $\underset{\smile}{d}$ to *e*, Fig. 1, or 7½ tons, has to be supported by the diagonals; the other half is directly supported by the pier, and has no effect upon the girder. The total addition of strains passing through the diagonals is concentrated in the end tie *e*, No. 4, and amounts to 60 tons; this, added to the 7½ tons passing down the pier, makes 67½ tons at each support, which is half the total load, 135 tons, being supported half by one pier and half by the other.

The girders are not always under equally distributed loads. On the approach of a train to the centre, only half, or a part, of the girder is loaded, the other half being without, causing variation in the direction and amount of strain on the diagonals. Some of those which are wholly in tension when the girder is equally loaded being brought into compression, and *vice versâ.* These diagonals may be seen by careful inspection of diagram, Fig. 2, which represents a girder loaded at two points. (To avoid fractions, I have here fixed upon 18 as a unit, instead of 15, as before.) The effect of (18) is shown by the Figs. marked ○; $\frac{1}{9}$th being supported by one end of the girder must pass through all the diagonals to the left, the remaining $\frac{8}{9}$ths passing to the right; the effect of the next weight is shown by the plain figures.

It should be stated that the results thus arrived at are not exactly correct; but are sufficiently near for a rough approximation.

The amount of strain on top and bottom flanges can be found from the principle of the bent lever. The proportions of such lever are as the depth of girder being one arm, and half the length of span being the other arm; thus, supposing the depth of girder to be 15·5 feet, and the half span 75 feet, the leverage is in the proportion of 4·8 to 1, and this multiplied by $\frac{1}{4}$th of the distributed load on a girder, gives the strain at centre.

Example.—A pair of girders carry a distributed load of 270 tons, including their own weight, or 135 tons for one girder; therefore, $\frac{135}{4} = 33{\cdot}7 \times 4.8 = 161$ tons strain.

PERMANENT LOADS ON BRIDGES, &c.

For rough calculations the weight of the bridge itself may be assumed to be (in wrought-iron bridges) :—

For 30	feet spans,	single line,	5 cwt.	per foot run
60	,,	,,	6	,,
100	,,	,,	9	,,
150	,,	,,	12	,,
200	,,	,,	15	,,

Dense crowds average 120 lbs. per square foot.

For flooring, $1\frac{1}{2}$ to 2 cwt. per square foot, exclusive of the weight of the flooring, is generally allowed. In store-houses from 2 to 4 cwt. per square foot.

BOWSTRING BRIDGES.

T = Tension of main tie and
= Thrust of arch at crown, in tons.
S = Span ,, ,, in feet.
R = Rise ,, ,, in feet.
L = Total load distributed, in tons.
x = Distance of any part from centre of girder, in feet.

$$T = \frac{L\,S}{8\,R}$$

Thrust at any other part of arc $= \sqrt{T^2 + \left(\frac{L}{S}\right)^2 . x^2}$

Greatest tension at any perpendicular $= \frac{L}{N}$ nearly, when

N = number of parts into which the arc is divided by the perpendiculars.

PILE DRIVING.

D = Set of pile by the last blow in inches.
H = Height the ram has fallen in inches.
L = Safe load for the pile in cwts.

$L = \frac{W\,H}{8\,D}$ approximately.

W = 4 cwt. in ordinary pile engines.

WROUGHT-IRON GIRDERS.

D = Depth of girder, in inches.
A = Area of bottom flange, in inches.
S = Span, in inches.
W = Breaking weight, in tons.

$\frac{80\ A.D.}{S} = W.$ For girders supported at both ends, load in centre.

$\frac{160\ A.D.}{S} = W.$ For girders supported at both ends, and load distributed.

Area of top flange = 1.18 A.

Depth $= \frac{S}{13}$ or $\frac{S}{12}$.

Rivets ¾ and 1 inch diameter { 6 inches apart in the top. 3 inches apart in bottom.

If $D = \frac{S}{12}$ then W = 13.3 A.
If $D = \frac{S}{10}$ then W = 16. A. } Weight distributed.

TABLE *of the Weight of a Lineal Foot of Flat Bar Iron, in lbs.*

Breadth in inches.	Thickness, in parts of an inch.								
	¼	5/16	⅜	7/16	½	⅝	¾	⅞	1
1	.835	1.044	1.253	1.461	1.670	2.088	2.506	2.923	3.340
1⅛	.939	1.174	1.409	1.644	1.878	2.348	2.818	3.287	3.756
1¼	1.044	1.305	1.566	1.826	2.088	2.609	3.132	3.653	4.176
1⅜	1.148	1.435	1.722	2.009	2.296	2.870	3.444	4.018	4.592
1½	1.252	1.566	1.879	2.192	2.504	3.131	3.758	4.384	5.008
1⅝	1.358	1.696	2.035	2.374	2.716	3.392	4.070	4.749	5.432
1¾	1.462	1.827	2.192	2.557	2.924	3.653	4.384	5.114	5.848
1⅞	1.566	1.957	2.348	2.740	3.132	3.914	4.696	5.479	6.264
2	1.671	2.088	2.505	2.922	3.342	4.175	5.010	5.845	6.684
2⅛	1.775	2.218	2.662	3.105	3.550	4.435	5.324	6.210	7.100
2¼	1.880	2.348	2.818	3.288	3.760	4.696	5.636	6.575	7.520
2⅜	1.984	2.479	2.975	3.470	3.968	4.957	5.950	6.941	7.936
2½	2.088	2.609	3.131	3.653	4.176	5.218	6.262	7.306	8.352
2⅝	2.193	2.740	3.288	3.836	4.386	5.479	6.576	7.671	8.772
2¾	2.297	2.870	3.444	4.018	4.594	5.740	6.888	8.036	9.188
2⅞	2.402	3.001	3.601	4.201	4.804	6.001	7.202	8.402	9.608
3	2.506	3.131	3.758	4.384	5.012	6.262	7.516	8.767	10.024
3¼	2.715	3.392	4.071	4.749	5.430	6.784	8.142	9.498	10.860
3½	2.923	3.653	4.384	5.114	5.846	7.306	8.768	10.228	11.692
3¾	3.132	3.914	4.697	5.479	6.264	7.828	9.394	10.959	12.528
4	3.341	4.175	5.010	5.845	6.682	8.350	10.020	11.690	13.364
4¼	3.549	4.436	5.323	6.210	7.098	8.871	10.646	12.421	14.196
4½	3.758	4.697	5.636	6.575	7.516	9.393	11.272	13.151	15.032
4¾	3.966	4.958	5.949	6.941	7.932	9.915	11.898	13.881	15.864
5	4.175	5.219	6.263	7.306	8.350	10.437	12.526	14.612	16.700
5¼	4.384	5.479	6.576	7.671	8.768	10.958	13.152	15.343	17.536
5½	4.593	5.741	6.889	8.037	9.186	11.480	13.778	16.073	18.372
5¾	4.801	6.001	7.202	8.402	9.602	12.002	14.404	16.804	19.204
6	5.010	6.262	7.515	8.767	10.020	12.524	15.030	17.535	20.042

TABLE *of the Weight of a Superficial Foot of various Metals, in lbs.*

Names.	Thickness by the Birmingham Wire Gauge.														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Iron . .	12.50	12.00	11.00	10.00	8.74	8.12	7.50	6.86	6.24	5.62	5.00	4.38	3.75	3.12	2.82
Copper .	14.50	13.90	12.75	11.60	10.10	9.40	8.70	7.90	7.20	6.50	5.80	5.08	4.34	3.60	3.27
Brass . .	13.75	13.20	12.10	11.00	9.61	8.93	8.25	7.54	6.86	6.18	5.50	4.81	4.12	3.43	3.10
	Thickness by the Wire Gauge.														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Iron . .	2.50	2.18	1.86	1.70	1.54	1.40	1.25	1.12	1.00	.90	.80	.72	.64	.56	.5
Copper .	2.90	2.52	2.15	1.97	1.78	1.62	1.45	1.30	1.16	1.04	.92	.83	.74	.64	.58
Brass . .	2.75	2.40	2.04	1.87	1.69	1.54	1.37	1.23	1.10	.99	.88	.79	.70	.61	.55
	Thickness, in parts of an inch.														
	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1			
Iron . .	2.5	5.	7.5	10.	12.5	15.	17.5	20.	25.	30.	35.	40.			
Copper .	2.9	5.8	8.7	11.6	14.5	17.4	20.3	23.2	28.9	34.7	40.4	46.2			
Brass . .	2.7	5.5	8.2	10.9	13.6	16.3	19.0	31.8	27.1	32.5	37.9	43.3			
Lead . .	3.7	7.4	11.1	14.8	18.5	22.2	25.9	29.6	37.0	44.4	57.8	59.2			

TABLE *exhibiting the Weight of a Lineal Foot of Square and Round Bar-Iron.*

Side and diameter, in inches.	Square, in lbs.	Number of lineal feet in 1 cwt.	Round, in lbs.	Number of lineal feet in 1 cwt.	Side and diameter, in inches.	Square, in lbs.	Number of lineal feet in 1 cwt.	Round, in lbs.	Number of lineal feet in 1 cwt.
¼	.209	536	.164	683	3⅛	32.618	3½	25.620	4¼
5/16	.326	343½	.256	437½	3¼	35.279	3	27.709	4
⅜	.470	238	.369	303½	3⅜	38.045	3	29.881	3¾
7/16	.640	175	.503	224½	3½	40.916	2¾	32.170	3½
½	.835	134	.656	170¾	3⅝	43.890	2½	34.472	3¼
9/16	1.057	106	.831	134¾	3¾	46.969	2¼	36.895	3
⅝	1.305	86	1.025	109¼	3⅞	50.153	2¼	39.390	2¾
11/16	1.579	71	1.241	90¼	4	53.440	2	41.984	2½
¾	1.879	59½	1.476	76	4⅛	56.833	2	44.637	2½
13/16	2.205	51	1.732	64½	4¼	60.329	1¾	47.385	2¼
⅞	2.558	44	2.011	55½	4⅜	63.930	1¾	50.211	2¼
15/16	2.936	38	2.306	48½	4½	67.637	1½	53.132	2⅛
1	3.340	33½	2.624	42½	4⅝	71.445	1½	56.113	2
1⅛	4.228	26½	3.321	33¾	4¾	75.359	1½	59.187	1¾
1¼	5.219	21½	4.099	27½	4⅞	79.378	1¼	62.344	1¾
1⅜	6.315	17¾	4.961	22½	5	83.510	1¼	65.585	1½
1½	7.516	15	5.913	19	5¼	92.459	1¼	72.618	1½
1⅝	8.826	12¾	6.928	16⅛	5½	101.036	1⅛	79.370	1½
1¾	10.229	11	8.043	14	5¾	110.429	1	86.731	1¼
1⅞	11.743	9½	9.224	12½	6	120.243		94.610	1⅛
2	13.360	8¼	10.496	10½					
2⅛	15.083	7½	11.846	6½					
2¼	16.909	6¾	13.283	8½					
2⅜	18.840	6	14.797	7½					
2½	20.875	5¼	16.396	6¾					
2⅝	23.115	5	18.146	6⅛					
2¾	25.259	4½	19.842	5½					
2⅞	27.608	4	21.684	4¾					
3	30.070	3¾	23.653	5⅛					

NOTE.—The weight of bar-iron being 1;

The weight of		cast-iron	=	.95
,,	,,	steel	=	1.02
,,	,,	copper	=	1.16
,,	,,	brass	=	1.09
,,	,,	lead	=	1.48

Hoop-Iron.—*Weight of Ten Lineal Feet.*

Width in inches and parts ..	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2
No. of gauge	21	20	19	18	17	16	15	14	13	12
Weight in lbs. and decimal parts	.685	.885	1.24	1.60	2.05	2.73	3.40	3.72	4.72	6.06

Velocity of Wind.

Miles per hour.	Feet per second.	Names.	Miles per hour.	Feet per second.	Names.
1	1.47	—	30	40.01	Strong Gale
2	2.93	Light Airs	35	51.34	Strong Gale
3	4.40	Light Airs	40	58.68	Hard Gale
4	5.87	Breeze	45	66.01	Hard Gale
5	7.33	Breeze	50	73.35	Storm
10	11.67	Brisk Gale	55	88.02	Storm
15	22.00	Brisk Gale	80	117.36	Hurricane
20	29.34	Fresh Gale	100	146.70	Hurricane
25	36.67	Fresh Gale			

Wind's Impulse.

Velocity feet per second.	Impulse on a square foot, in pounds.	Velocity feet per second.	Impulse on a square foot, in pounds.
10	0.229	90	18.526
20	0.915	100	22.872
30	2.059	110	27.675
40	3.660	120	32.926
50	5.718	130	38.654
60	8.234	140	44.830
70	11.207	150	51.462
80	14.638		

FRENCH MEASURES.

Modern System.

Comparative Table *of French Metres reduced to English Feet.*

Metrical Measures.		Met.		Eng. Meas. Ft.	In.
Metre.				°	′ ″
1	is written	1·000	equals	3	3·37
2	„	2·000	=	6	6·74
3	„	3·000	=	9	10·11
4	„	4·000	=	13	1·48
5	„	5·000	=	16	4·85
6	„	6·000	=	19	8.22
7	„	7·000	=	22	11·59
8	„	8·000	=	26	2·96
9	„	9·000	=	29	6·33
10	„	10·000	=	32	9·70
Decimetre.					
1	is written	0·100	=	0	3·94
2	„	0·200	=	0	7·87
3	„	0·300	=	0	11·81
4	„	0·400	=	1	3·75
5	„	0·500	=	1	7·69
6	„	0·600	=	1	11·62
7	„	0·700	=	2	3·56
8	„	0·800	=	2	7·50
9	„	0·900	=	2	11·43
10	„	1·000	=	3	3·37

Metrical Measures.		Met.		Eng. Meas. Ft.	In.
Centimetre.				°	′ ″
1	is written	0 010	=	0	0·39
2	„	0·020	=	0	0·79
3	„	0·030	=	0	1·18
4	„	0·040	=	0	1·58
5	„	0·050	=	0	1·97
6	„	0·060	=	0	2·36
7	„	0·070	=	0	2·76
8	„	0·080	=	0	3·15
9	„	0·090	=	0	3·54
10	„	0·100	=	0	3·94
Millimetre.					
1	is written	0·001	=	0	0·04
2	„	0·002	=	0	0·08
3	„	0·003	=	0	0·12
4	„	0·004	=	0	0·16
5	„	0·005	=	0	0·20
6	„	0·006	=	0	0·24
7	„	0·007	=	0	0·28
8	„	0·008	=	0	0·31
9	„	0·009	=	0	0·35
10	„	0 010	=	0	0·39

Units of the French Measures compared with English Imperial Measures.

The are, or unit of square measure = 119 square yards.
The stere, or unit of solid measure = 35·31716 cubic feet.
The litre, or unit of measure for liquids = 61·028 cubic inches, or about 220 of an imperial gallon.
The gramme, or unit of weight =15·438 troy grains, or ·002205 of a pound avoirdupois.
The kilogramme = 2·205 pounds avoirdupois.

Measure of Surface.

1 milliare . .	·1196 sq. yds.
10 milliares . .	1 centiare.
10 centiares . .	1 deciare.
10 deciares . .	1 are.
10 ares . . .	1 decare.
10 decares . .	1 hectare.
	or 2·473614 imperial acres

The are is a square decametre.

Measure of Solidity.

1 millistere . .	·035317 cubic ft.
10 millisteres . .	1 centistere.
10 centisteres . .	1 decistere.
10 decisteres . .	1 stere.
10 steres . . .	1 decastere.
10 decasteres . .	1 hectostere.
10 hectosteres . .	1 kilostere.
10 kilosteres . .	1 myriastere.

The stere is a cubic metre.

Safe Load in Structures.

In cast-iron columns . . . . . = $\frac{1}{4}$ breaking weight.
Wrought-iron structures . . . . . = $\frac{1}{4}$ " "
In cast-iron girders for tanks . . . = $\frac{1}{4}$ " "
In ditto for bridges and floors . . . = $\frac{1}{6}$ " "
In timber . . . . = $\frac{1}{10}$ " "
Stone and bricks . . . . . . = $\frac{1}{8}$ " "

Relative Strength of Beams or Girders.

	Relative strength.
Supported at one end and loaded at the other . . .	= 1
Supported at one end and load distributed	= 2
Supported at both ends and load at centre	= 4
Supported at both ends and load distributed . . .	= 8

OR CONVERSELY.

Supported at both ends and load distributed . . .	= 1
Supported at both ends and load at centre	= $\frac{1}{2}$
Supported at one end, load distributed	= $\frac{1}{4}$
Supported at one end, load at the other end . . .	= $\frac{1}{8}$

Strength of Rolled-iron Beams.

B W = Breaking Weight distributed in Tons.

Depth of Beam.	Size of Flange.	B W for different Spans			
		10 ft.	15 ft.	20 ft.	25 ft.
5 in.	2 × $\frac{1}{2}$ in.	6·6	..	..	..
6 "	$2\frac{1}{2}$ × $\frac{1}{2}$ "	10	6·6	5	..
7 "	3 × $\frac{1}{2}$ "	14	9	7	5
8 "	3 × $\frac{5}{8}$ "	20	13	10	8
9 "	4 × $\frac{3}{4}$ "	36	24	18	14
10 "	$4\frac{1}{2}$ × 1 "	60	40	30	24