

No. 1,176.—“On the Widening of the Victoria Bridge and Approaches to the Victoria Station, and on New Railways at Battersea.” By CHARLES DOUGLAS FOX, M. Inst. C.E.

THE system of railways designed by Sir Charles Fox, M. Inst. C.E., in the year 1862, for the purpose of improving the access to the Victoria Station, by providing additional lines, and avoiding the sharp curves and steep gradients of the then existing railways, comprises the following works:—

The widening of the Victoria Station and Pimlico Railway, and the widening of the Victoria Bridge over the Thames, carried out jointly by the London, Brighton, and South Coast, and the London, Chatham, and Dover Railway Companies.

The high-level line, from the south end of the Victoria Bridge to near Clapham Junction, with a branch to Wandsworth Road, carried out by the London, Brighton, and South Coast Railway Company.

The diversion and raising of the West End and Crystal Palace, and West London Extension Railways, the Longhedge Junction Railway, the high-level line from the Victoria Bridge to Wandsworth Road, and the two low-level lines from the same bridge to Stewart's Lane, carried out by the London, Chatham, and Dover Railway Company.

The connecting link between the London and South Western, and the London, Chatham, and Dover systems at Clapham Junction, carried out by the London and South Western Railway Company.

Plate 6, Fig. 1, shows the railways in this district as they existed in 1862, and Plate 6, Fig. 2, as they exist at present. The Author desires, as briefly as possible, to lay before the Institution a description of the more important features of this system of railways, which has been carried out in accordance with a comprehensive plan, determined upon from the commencement.

#### WIDENING OF THE VICTORIA STATION AND PIMLICO RAILWAY.

This railway was originally constructed by Mr. John Fowler (President Inst. C.E.), for two lines of way of mixed gauge; but the increasing traffic of the three Companies which already use this terminus, viz., the Brighton, the London, Chatham, and Dover, and the Great Western Companies, and the anticipation of other Companies desiring also to have access to it, rendered it essential to provide

<sup>1</sup> The discussion upon this and the preceding Paper was taken together, and occupied portions of four evenings, but an abstract of the whole is given consecutively.

additional lines, and to separate entirely the traffic of the first from that of the two last-named Companies. It was therefore determined to remove the broad gauge from the two existing lines, and to devote them, as also one additional line of narrow gauge, to be laid down beside them, entirely to the traffic of the London, Brighton and South Coast Company, and to construct for the London, Chatham, and Dover, and the Great Western traffic, three mixed and one narrow-gauge line. The works on this length of three-quarters of a mile are of an ordinary character, being in cutting between retaining walls for the greater portion of the distance, with three over-bridges for roads—one of them, Ebury Bridge, being fan-shaped in plan. The chief work was the removal of the retaining wall from one side of the existing railway—an operation of some difficulty, where, on account of trains so frequently passing, blasting could not be employed. It was also necessary, without interference with the constant traffic, to substitute a girder bridge in the place of an arch over the existing line, which was itself receiving a portion of the thrust of an arch over an adjoining canal. This was safely accomplished by cutting away a narrow strip of the arch, and inserting one girder at a time. In order to prevent annoyance to adjoining householders, the line was required to be roofed over; and this involved the use of heavy trusses, somewhat similar to those adopted for the original line. These are, in some instances, 120 feet span, 10 feet deep, and weigh 17 tons each. In several cases they act as cantilevers, and support one end of the original trusses. Cast-iron gutters are suspended from the bottom flanges of these trusses by means of bolts, and these gutters carry the light wrought-iron principals of the roof, which are generally 50 feet span, and placed 8 feet 4 inches apart. The purlins, louvres, and gables are of wood, the last-named being left unglazed, to allow of the escape of steam. To avoid the great breakage of glass caused by the blast of the locomotives, the lower half of the roof is covered with Vieille Montagne zinc, No. 15 gauge, fixed on wooden rolls, the upper half being glazed. The London, Chatham, and Dover portion of the station has been greatly enlarged. The signal arrangements for the whole station have been remodelled, and now consist of five boxes, fitted with apparatus, upon Messrs. Saxby and Farmer's principle, having altogether two hundred and thirty-five levers.

#### WIDENING OF THE VICTORIA BRIDGE.

It was the original intention to have constructed an independent bridge to carry three lines of way, for the London, Chatham, and Dover traffic; but, it having been determined to add, at the same time, a third line for the London, Brighton, and South Coast Railway Com-

pany, it became necessary to make arrangements for joining up the new work with the Victoria Bridge.

The new bridge, in common with the original one, consists of four river spans, of 175 feet each, having arched ribs, with a rise of 17 feet 6 inches, giving a headway above Trinity high-water mark of 22 feet, and of two land openings, carried by plate girders, one of 70 feet, the other of 65 feet span. Its width, from the outside of the original bridge to the parapet, is 100 feet, giving, with the old work, one structure, 132 feet 6 inches wide between the parapets. The total length of the piers and abutments, just below the springing, is 158 feet. It is constructed to carry at present, with the existing lines, three lines of narrow gauge for the Brighton traffic, and two mixed and two narrow-gauge lines for the Chatham and Dover, and the Great Western traffic; and also two platforms, one 24 feet, the other 12 feet wide, which are in connection with the stations at either end. The portion of the bridge carrying these platforms is, however, so arranged as to admit, upon the addition of one more rib only in each span, of three more narrow-gauge lines, so that the two bridges together, as now united, are capable of carrying ten lines of way, eight narrow and two mixed gauge.

The excavations for the abutments were got out by means of double cofferdams of whole timbers on the river front, continued on the land side by single rows of the same. The general length of the piles was 40 feet. The puddle, which was 5 feet in thickness, was brought from the River Medway. Woodford's centrifugal pumps were used with much success for both the abutments and the piers. The northern abutment was carried down to a depth of 30 feet, and the southern abutment to a depth of 26 feet below Trinity high-water mark, being in each case founded on good hard gravel. The whole of the space excavated was covered with cement concrete, 3 feet thick, filled close up to the inner row of piles all round; on this brickwork in cement 3 feet thick was laid, and then outside and cross walls of brick in cement were carried up, the pockets being filled with lime concrete. (Plate 3, Figs. 7 and 8). The inner row of piles on the river face was cut off just above the concrete, and all the other piles were drawn. In consequence of the proximity of the original bridge, it was impossible to drive the cofferdams so as to include the whole of the work, and a portion of the face is therefore carried on strong cast-iron girders, put in at low-water mark, resting at one end on the old, and at the other on the new work. By the use of cement, and the care taken to keep the joints thin, the abutments, though bonded up with the old work, have not shown the least sign of movement.

Some difficulty was experienced in designing the foundations for the piers, in consequence of the sheet piling used for the former

cofferdams projecting considerably beyond the nose of the piers. The foundations of each pier were carried down by means of four cast-iron cylinders (Plate 3, Figs. 3, 4, 5, and 6), each 21 feet internal diameter and 24 feet long, cast in segments 8 feet in length, and fitted together with flanges. These cylinders were  $1\frac{1}{4}$  inch only in thickness, except for about 2 feet at the bottom, where the metal was swelled out. Temporary wrought-iron cylinders, 19 feet in diameter, were used for 28 feet 6 inches at the top. (Plate 4, Figs. 21, 22, and 23). The joint between the temporary and the permanent cylinders was made by allowing the edge of the plate forming the bottom of the former to rest upon a piece of india-rubber inserted in a groove in the upper segments of the latter; this was found in every case to be perfectly water-tight. About 100 tons of kentledge were used in sinking the cylinders; this was laid upon stages slung within the cylinders, as being less liable to tilt the cylinders than when placed outside, and more easily thrown off when the requisite depth was reached. The bed of the river having been levelled by bag and spoon, the cast-iron cylinders were put together and lowered into their places; the wrought-iron cylinder was then attached, and the cylinders descended by their own weight assisted by that of the kentledge, and by clearing round the inside edge by the bag and spoon till the London clay was reached, when the water was pumped out, and men put in to excavate, following the cylinder as it descended. The whole of the cylinders were sunk without difficulty to an average depth of 45 feet below Trinity high-water mark, of which 13 feet were into the London clay, the total time occupied in sinking being on an average eight days. After the water was once pumped out they were so dry that water had to be laid on to properly wet the bricks. The cylinders were filled with cement concrete for a depth of 12 feet, and then with brick in cement up to low-water mark. The brickwork in each of the cylinders nearest to the old work was then loaded with 1,250 tons, that in the next two with 1,000 tons, and that in the outer cylinder with 750 tons, left on for a week. This was done in order to prevent cracks in the work when bonded up with the other bridge. The greatest movement under this load was  $\frac{3}{4}$ ths of an inch, with a slight return when the weight was removed. If the bridge were loaded all over with locomotives, the greatest weight upon the brickwork in the cylinders at low-water mark would be nearly 6 tons per superficial foot and upon the clay at the bottom 5 tons per foot, not deducting for friction. This test having been completed, the first course of masonry was laid in the cylinders, and the wrought-iron cylinders and the upper ring of the cast-iron cylinders was removed. Strong framework of cast iron was then fixed to carry the stonework face between the cylinders, a similar framework, though of greater span, forming the connection on the face

between the old and the new work. The weight of the superstructure is, however, mainly carried by strong arches of brick in cement turned between the cylinders in the hearting of the piers, which from this level to the springing line are of solid brickwork in cement faced with masonry. It will thus be seen that the new piers, though founded on cylinders, form, above low-water mark, one continuous face of masonry with those of the original bridge, altogether 158 feet in length. The gantries for the piers and for the erection of the superstructure were naturally very extensive, containing 286,000 cubic feet of timber, including that in the cofferdams, but they do not call for special remark. The abutments and the piers are faced from low-water to high-water mark with Portland roach stone, and above that level, with Bramley Fall ashlar, except between the spandrels, where gault bricks are used. The stonework removed from the face of the other bridge was worked in again as much as possible. A bedding course of Bramley Fall stone was laid right through the piers for each rib, and upon this was fixed a cast-iron skewback and standard (Plate 4, Fig. 9), of the whole width of the pier, running up to and connected with the underside of the horizontal girder forming the top member of the arch. Cast-iron skewbacks and standards were also fixed in the abutments.

The superstructure of each of the river spans is precisely the same, and consists of eight main ribs, with provision for a ninth (Plate 3, Fig. 3); of these the rib nearest the existing bridge is only one-half the strength of the others, which are each calculated to carry a single line of way. These arched ribs are of wrought iron 3 feet 4 inches deep and 1 foot 6 inches wide in the flanges; but for 38 feet in the centre of the span they merge into one with the horizontal girders, thus giving a total depth at the centre of 4 feet 6 inches. (Plate 4, Fig. 9). The flanges of the ribs diminish gradually from a thickness of 3 inches at the centre to  $1\frac{1}{2}$  inch at the springing, the webs being of  $\frac{3}{4}$  inch plate throughout. The sectional area of the rib at the centre is:—

	Without deducting Rivets.	Deducting Rivets.
Top flange . . . .	63·2	51·0
Bottom flange . . . .	63·2	51·0
Web . . . . .	40·5	40·5
Total square inches . .	<u>166·9</u>	<u>142·5</u>

The sectional area of the rib at the springing of the arch is:—

	Without deducting Rivets.	Deducting Rivets.
Top flange . . . .	36·2	28·25
Bottom flange . . . .	36·2	28·25
Web . . . . .	30·0	30·00
Total square inches . .	<u>102·4</u>	<u>86·50</u>

The spandrels are of wrought iron, except at the junction between the rib and the horizontal girder, where a small gusset piece of cast iron is introduced. The horizontal girder, which is 4 feet 6 inches deep with flanges 1 foot 6 inches wide, is continuous throughout, the whole bridge being riveted up for a length of 913 feet. It is firmly connected with the cast-iron standards at the piers, and at the abutments, in order to obtain the full advantage of continuity for the land spans, and is anchored by a plate running from the top flange right down to the cast-iron skewback. The flanges vary in thickness from 3 inches to  $\frac{1}{2}$  an inch, and the web from  $\frac{3}{4}$  inch to  $\frac{1}{2}$  inch. The area of the horizontal girder in the weakest place is 63·4 square inches, or 50·8 square inches after deducting rivets. The main ribs are strongly braced by transverse girders, 3 feet 4 inches deep, of which there are eight to each rib (Fig. 18), and by vertical diagonal bracing from these girders to special cross-girders inserted for the purpose. To stiffen the whole structure the four centre ribs are cross-braced horizontally, by means of bars 4 inches by  $\frac{5}{8}$  inch. The cross-girders and the rail-bearers are rolled beams of the Butterley Company's manufacture, the former 12 inches deep, 6 $\frac{1}{4}$  inches wide in the flanges, and placed 6 feet apart from centre to centre, and the latter 9 inches deep, 5 $\frac{1}{2}$  inches wide in the flanges, and firmly riveted to the cross-girders, forming a continuous bearing under each rail.

The passenger platforms (Plate 3, Fig. 3) are carried by cross-girders of the first-named section, in order that they may at any future time be available for additional lines of rails. The timber planking consists of baulks 12 inches by 10 inches, laid upon the rail-bearers, and secured by hook-bolts, with 3-inch planks in the intermediate spaces, except over the Grosvenor Road land-span, where a double platform with felt and sawdust is used, to meet the requirements of the Board of Works. The rails over the bridge are of steel, weighing 72 lbs. to the yard; they are flat-bottomed, and are firmly secured to the iron bearers at the joints by hook-bolts. The parapet of the existing bridge was removed from one side, and refixed with slight alterations to form the parapet of the new work. Full details of the construction of this bridge are shown in Plates 3 and 4.

The calculations of the strains, from which the superstructure was designed, leads to the conclusion that whilst cast iron is the best material for arched bridges of single spans, similar bridges of several spans, having piers whose perfect stability under horizontal stress could not be relied on, are under certain circumstances exposed to tensile strains, which render the use of wrought iron most desirable. The bridge was severely tested on several occasions by Major Rich, R.E., on behalf of the Board of Trade. Each rib, where practicable, with the exception of those adjoining



superficial foot of space covered, or about £38 per lineal foot of single line. The first stone of the new bridge was laid on the 22nd of February, 1865, and the first locomotive passed over in seventeen months from that date—on the 1st of August, 1866, when the bridge was tested by Major Rich.

#### HIGH-LEVEL LINE OF THE LONDON, BRIGHTON, AND SOUTH COAST RAILWAY COMPANY.

The West End and Crystal Palace Railway, between the Clapham Junction and the Thames, was constructed with a ruling gradient of 1 in 55, and a curve of 13 chains radius, in order to pass under the London and South Western Railway. As these were found to interfere with the safe and expeditious working of the traffic brought upon the line when the Victoria Station became the West End terminus of the London, Brighton, and South Coast Railway Company, it was determined to construct a high-level line passing over the South Western Railway, and having ruling gradients of 1 in 120, and curves in no case of less than 22 chains radius, and to lay down three lines of way thereon—one for the express 'up,' one for the local 'up,' and one for the mixed down traffic. This line is  $1\frac{1}{4}$  mile in length, and consists mainly of a viaduct of brickwork 35 feet 8 inches wide between the parapets, and varying from 15 feet to 40 feet in height to the rail level. The piers of this viaduct are carried down by means of cement concrete to a hard gravel substratum, except in one or two cases, where pile foundations were found to be necessary. The concrete is brought up to within 1 foot 6 inches of the natural surface, and the brickwork of the piers is then commenced. These, when not more than 8 feet high, are 3 feet  $4\frac{1}{2}$  inches in thickness, increasing by an offset or plinth of  $2\frac{1}{4}$  inches all round at every additional 8 feet. Each pier has a 'jack' arch in it of 6 feet span. The arches, which are built of gault bricks set in cement, are generally 30 feet span elliptical, with 10 feet rise, and show four rings on the face, but are increased where the load comes on to five rings. There are spandril walls of brick over each pier, the intervening spaces being filled with lime concrete, and the whole surface thoroughly asphalted to a thickness of 1 inch. Pipes are carried down each pier to a cesspool under the jack arch connected with a main drain. The plinths and copings are of blue Staffordshire bricks.

A branch line from the Wandsworth Road, three-quarters of a mile long, and forming a connection with the South London system, joins the high-level line, and is constructed for two lines of way. This branch is also on the high level passing over the London and South Western Railway, and is carried on a viaduct 24 ft. 8 in.



wide between the parapets, and averaging 30 feet in height to the rail level, of similar construction to that just described.

The bridges on these lines are of a heavy character, comprising

18 spans, wrought iron, from . . .	26 ft. to 150 ft.
3 spans, cast iron, from . . .	60 ft. to 70 ft.
9 spans, brick in cement . . .	30 ft. to 57 ft.

The two bridges, however, which are chiefly deserving of notice, are those for carrying the high-level line over the London and South Western Railway (Plate 5), and over the West London Extension—London, Chatham, and Dover, and Brighton low-level lines at Longhedge. The former bridge has a central span of 149 feet, and two side spans of 47 feet each, and crosses the London and South Western Railway at an angle of  $51^\circ$ . It is constructed to carry three lines of way, and has two main girders of lattice construction, continuous throughout, resting at each end of the central span on cast-iron columns 3 feet 6 inches diameter, and 14 feet 6 inches high, and anchored down at the ends into the brickwork of the abutments, by means of rolled links, passing through stones, 4 feet by 4 feet by 1 foot 6 inches, placed a few feet above the ground level, and secured by cast-iron anchors. The ends of the girders are left free to move horizontally, the usual rollers being provided. The main girders are 10 feet deep from centre to centre of pins; the top flange is 3 feet wide, and is composed in the centre of the large span of

2 horizontal plates . . .	$\frac{7}{16}$ in. and $\frac{3}{8}$ in. respectively.
5 vertical plates . . .	$\frac{1}{4}$ in. by 1 ft. 8 in.
2 angle irons . . .	$3\frac{1}{2}$ in. $\times$ $3\frac{1}{2}$ in. $\times$ $\frac{1}{2}$ in.
2 „ . . .	$3\frac{1}{2}$ in. $\times$ $3\frac{1}{2}$ in. $\times$ $\frac{3}{8}$ in.
2 „ . . .	$2\frac{1}{2}$ in. $\times$ $2\frac{1}{2}$ in. $\times$ $\frac{3}{8}$ in.

The bottom flange is 1 foot 11 inches wide, and is composed in the centre of the large span of

3 horizontal plates . . .	$\frac{7}{16}$ in.
5 vertical plates . . .	$\frac{1}{4}$ in. by 1 ft. 8 in.
2 angle irons . . .	$3\frac{1}{2}$ in. $\times$ $3\frac{1}{2}$ in. $\times$ $\frac{1}{2}$ in.
2 „ . . .	$3\frac{1}{2}$ in. $\times$ $3\frac{1}{2}$ in. $\times$ $\frac{3}{8}$ in.
2 „ . . .	$2\frac{1}{2}$ in. $\times$ $2\frac{1}{2}$ in. $\times$ $\frac{3}{8}$ in.

The bottom flange is increased by  $\frac{5}{8}$  inch in thickness over the columns. The struts, which are placed 5 feet  $11\frac{1}{2}$  inches apart from centre to centre, consist of two plates 1 foot wide, varying from  $\frac{1}{4}$  inch thick at the centre of the span to  $\frac{5}{8}$  inch over the columns. These plates are stiffened with two angle irons, each  $3\frac{1}{2}$  inches by  $3\frac{1}{2}$  inches by  $\frac{3}{8}$  inch. The struts contain a middle piece composed of two T irons 5 inches by  $2\frac{1}{2}$  inches by  $\frac{3}{8}$  inch, and two plates 5 inches by  $\frac{3}{8}$  inch, so that the pins have a bearing in three places. The struts are braced together with T irons 5 inches by  $2\frac{1}{2}$  inches by  $\frac{3}{8}$  inch. The tension bars, which are of Howard and Ravenhill's rolled

links, are swelled out round the pins, so as to give 10 per cent. more sectional area than in the body of the bar, the diameter of the pin being, in each case, as nearly as possible, two-thirds of the width of the bar in the narrowest part. The bars, of which there are two to each bay near the centre of the bridge, and four to each bay elsewhere, vary from 6 inches by  $\frac{1}{2}$  inch at the centre to 9 inches by 1 inch at the columns. The pins vary in diameter from  $3\frac{3}{4}$  inches to  $6\frac{1}{4}$  inches. The cross-girders are 40 feet 11 inches long and 2 feet 3 inches deep, 1 foot 7 inches wide in the flanges, and are placed as nearly 6 feet apart from centre to centre as possible. They are of ordinary plate-girder construction, and are suspended to the bottom flanges of the main girders by plates and angle irons. The rail-bearers are rolled beams manufactured by the Butterley Company. The whole bridge is stiffened horizontally by a system of cross bracing. The centre span of this bridge over the London and South Western Railway was erected without the use of scaffolding, by putting together the bottom flange and lifting it into its place, supporting it by temporary truss-rods, and then erecting the remainder of the girder upon it, the tension bars being inserted from either end till they met in the middle.<sup>1</sup>

The adjoining bridge, of 120 feet span, is of similar construction, but being only of one span, is not held down at the ends. The main girders, weighing 106 tons each, were built on the adjoining viaduct, and, when put together complete, were each rolled over into their places during the night, an operation occupying but four hours.<sup>2</sup>

The cast-iron bridges are composed of arched ribs, varying in span from 60 feet to 70 feet, and having a rise of 7 feet. These ribs are placed between the rails and under the parapets, and are 2 feet 6 inches deep, 1 foot 4 inches wide in the flanges, and are each cast in two segments.<sup>3</sup> (Plate 6, Figs. 3, 4, 5, 6, and 7). The skewbacks, spandrels, and parapets are of cast iron, the outer spandrels being filled with ornamental scrollwork. The cross-girders and rail-bearers are of Butterley rolled beams, of the same section as those for the Thames bridge. These beams are used wherever practicable throughout, as they are found to be considerably stronger than plate-girders of equal weight.

The brick arches, which vary in span from 30 feet to 57 feet, are generally segmental, constructed of gault bricks in cement, and faced with red bricks. They have a rise of 10 feet, and show five

<sup>1</sup> This bridge was tested with nine locomotives and tenders, weighing 430 tons. The deflection of the main girders in the centre was  $1\frac{1}{2}$  inch, including a permanent set of  $\frac{1}{4}$  of an inch.

<sup>2</sup> The deflection of the main girders under a test load of 430 tons was  $\frac{1}{8}$  of an inch, including a permanent set of  $\frac{1}{8}$  of an inch.

<sup>3</sup> The deflection of these ribs, when fully loaded, was  $\frac{3}{8}$  of an inch, with a very slight permanent set.

rings on the face, being thickened, where the load comes on, to six or seven rings, according to the span. Several of these bridges are very much on the skew.

A spacious and convenient station has been erected at the junction between the high-level main line and the South London branch, and the original Battersea Park Station has been entirely rebuilt. At this point a foot-bridge of lattice-work girders, having five spans of 65 feet each, carrying a platform 10 feet wide, supported upon cast-iron columns, has been erected to connect the station and pier with Battersea Park.

#### DIVERSION AND RAISING OF THE WEST END AND CRYSTAL PALACE AND WEST LONDON EXTENSION RAILWAYS.

This was one of the first alterations carried out in the district, and was necessary in order to provide separate lines for the Great Western traffic, and also to raise the lines to a height of 18 feet, so as to allow a new carriage-road to pass under them, and to bring them to the proper level for a junction-line to the south. As the whole main line and Crystal Palace traffic of the Brighton Company, as well as the Great Western traffic, was passing over these lines, this operation was one of some difficulty; but by diverting and raising one-half of the lines at a time, and slewing the roads at either end in the night, it was carried out without delay or accident.

#### HIGH-LEVEL LINE OF THE LONDON, CHATHAM, AND DOVER RAILWAY.

This line, which is constructed for three lines of way, is 1 mile in length, and is carried chiefly on a viaduct, similar to those already described, passing over the London and South Western Railway, and running from the southern end of the Victoria Bridge to the railways of the Company at Wandsworth Road. It has ruling gradients of 1 in 120, and minimum curves of 20 chains' radius. The bridges on this length are heavy, comprising fourteen spans of wrought iron, from 25 feet to 98 feet; but they do not call for special remark, with the exception of the bridge over the York Road. (Plate 6, Figs. 8, 9, and 10). The main girders are of lattice construction, 7 feet 2 inches deep from centre to centre of pins, and 112 feet in length, continuous throughout, the bridge being divided into two unequal spans of 72 feet and 43 feet, and supported by cast-iron fluted columns 2 feet 6 inches diameter and 13 feet in height. The girders are divided into bays of 7 feet 2 inches each, the struts and ties being inclined at an angle of  $45^\circ$ , but over the columns vertical struts are inserted.

The top flange of the main girders is 2 feet wide, and in the centre of the larger span is composed of:—

6 horizontal plates, altogether	. 2 ft. × 3 in.
2 vertical plates, each	. 1 ft. × $\frac{3}{4}$ in.
2 angle irons, each	. $3\frac{1}{2}$ in. × $3\frac{1}{2}$ in. × $\frac{1}{2}$ in.

The bottom flange is 1 foot 4 inches wide, and in the centre is composed of:—

9 horizontal plates, altogether	. 1 ft. 4 in. × $3\frac{1}{2}$ in.
2 vertical plates, each	. 1 ft. × $\frac{3}{4}$ in.
2 angle irons, each	. $3\frac{1}{2}$ in. × $3\frac{1}{2}$ in. × $\frac{1}{2}$ in.

The struts and ties alike consist of plain bars varying from 6 inches by  $\frac{3}{8}$  inch to 8 inches by  $\frac{9}{16}$  inch, and in sets of two or four, according to position. The struts are stiffened by angle iron lattice-work, and the ties are thickened round the holes for the pins by plates riveted on: the pins vary in diameter from  $2\frac{3}{4}$  inches to  $3\frac{3}{4}$  inches. The cross-girders are 3 feet deep, and are suspended from the bottom flange of the main girders. They, as well as the rail-bearers and horizontal bracing, are similar to those for the bridge over the South Western Railway already described. The ends of the cross-girders are hidden by cast-iron filling-pieces, and light ornaments are attached at the points of intersection and junction of the struts and ties. Near this bridge a station has been erected for the Battersea Park traffic.

#### LONGHEDGE JUNCTION RAILWAY.

This branch is a double line, 32 chains in length, and is carried on a brick viaduct, similar to those before described, through and over the Chatham and Dover workshop-sidings, and forms one of three railways which cross each other at different levels at this point. This branch, though not presenting any features of special interest, is of much importance, forming, as it does, the link by which the traffic from the north of London, Kensington, and the south-western district passes to the lines south of London and the City.

#### CONNECTING LINK TO CLAPHAM JUNCTION.

This is a double line  $1\frac{1}{4}$  mile in length, which, leaving the branch last described, and running for some distance on embankment side by side with the West London Extension Railway, passes under the London, Brighton, and London and South Western Railways, and then rising by a gradient of 1 in 54 on a curve of 16 chains' radius to the level of the London and South Western Railway, runs into Clapham Junction Station. For a length of 450 feet this line is on a viaduct 24 feet 8 inches wide between the

parapets, and of the average height of 20 feet. This viaduct is similar to those before described, except that the arches are semi-circular, and of 25-feet span only. The bridge under the railways is constructed to carry eleven lines of way over it. In order to construct this bridge without interference with the traffic, a closely-boarded heading was first driven for the abutment, which was carried forward only in short lengths at a time. This being done, baulks were laid under the rails and the main and cross-girders got into their places, the old embankment not being removed until after the completion of the bridge.

#### LOW-LEVEL LINES FROM VICTORIA BRIDGE.

These two single lines of mixed gauge, which leave the high-level line one on each side immediately south of the Thames, are each 24 chains in length, one being chiefly on viaduct and the other on embankment. They fall from the high to the low level with a gradient of 1 in 60, and are the means of connecting the low-level system and the West London Extension Railway with the Victoria Station. These two lines carried for a time the whole of the Chatham and Dover and the Great Western traffic, and it is worthy of remark that the whole of the lines formerly leading into the London, Chatham, and Dover portion of the station were cut off and new lines substituted during six hours in the early morning of December 20th, 1866.

#### GENERAL.

The permanent way on these lines does not call for special remark, being of the description used on the main lines of the respective companies, except that the London, Chatham, and Dover high-level line is laid with steel rails weighing 72 lbs. to the yard, manufactured by Sir John Brown and Co., and that a portion of the Brighton line is also laid with steel rails.

This system of railways, comprising a length equal to 9 miles of double line, of which 5 miles are on viaduct, has cost for works only, including the bridge over the Thames, the sum of £910,000. The high-level line of the Brighton Company, which is entirely on viaduct, has cost, including permanent way, stations, and signals, and the numerous heavy bridges, the sum of £45 per lineal yard of double line: 60,000,000 of bricks, 7,700 tons of wrought iron, and 1,600 tons of cast iron, have been used.

The works of the London, Chatham, and Dover Company have been carried out partly by Messrs. Peto, Betts, and Crampton, and partly by Messrs. Lucas Brothers; the general works of the London, Brighton, and South Coast Company by Messrs. William

and John Pickering, and the ironwork by Mr. James Heywood, Jun., of Derby; the works of the London and South Western Company by Messrs. Peto, Betts, and Crampton, who were represented throughout by Mr. Curry. The whole have been executed from the designs and under the superintendence of Sir Charles Fox, M. Inst. C.E., and the Author, Mr. Edmund Wragge being the Resident Engineer. The works have taken three years to complete.

The Author trusts that this record of works, all forming parts of the same design, and which have, by the separation of traffic and the improvement of gradients and curves, already effected a marked improvement in the working of the traffic, may be found interesting and useful. He has been unable, within the limits of this communication, to enter into any great amount of detail, but has endeavoured to describe the salient points of the railway system of a district which he believes has few equals, as regards the immense and daily increasing traffic which has called for the construction of the works described.

This Paper is illustrated by a series of diagrams, from which Plates 3, 4, 5, and 6 have been compiled.

## APPENDIX.

### WIDENING OF VICTORIA BRIDGE, PIMLICO.

#### PARTICULARS OF LOADING.

	tons. cwt.
Weight of metal in one rib . . . . .	65 0
,,     ,,     in rolled beams . . . . .	20 10
,,     ,,     in bracing girders, brackets, wind ties, &c. . . . .	13 10
<b>Total ironwork . . . . .</b>	<b>tons 99 0</b>
Weight of timber platform . . . . .	25 0
,,     rails and bolts . . . . .	7 0
<b>Total dead load . . . . .</b>	<b>tons 131 0</b>

Distance apart from centre to centre of piers, 187 feet 4 inches.

Dead load equal to  $\frac{3}{4}$  ton per foot run per rib.

Live load taken as  $1\frac{1}{4}$  ,, ,, ,,

**Total load . . . 2 tons ,, ,,**

Span being taken as 175 feet, load as 350 tons.

Rise of arch 17 feet 6 inches.

Compressive strain on rib at centre of loaded span = 419 tons.

    ,,     ,,     at springing     ,,     = 460 tons.

Mr. WILSON

G

[1867-68. N.S.]

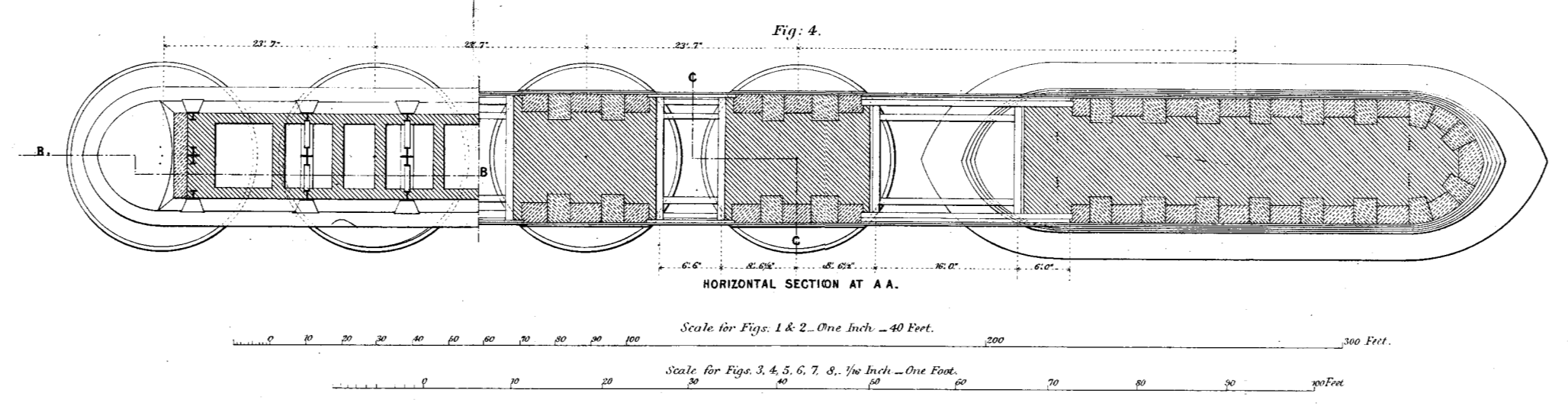
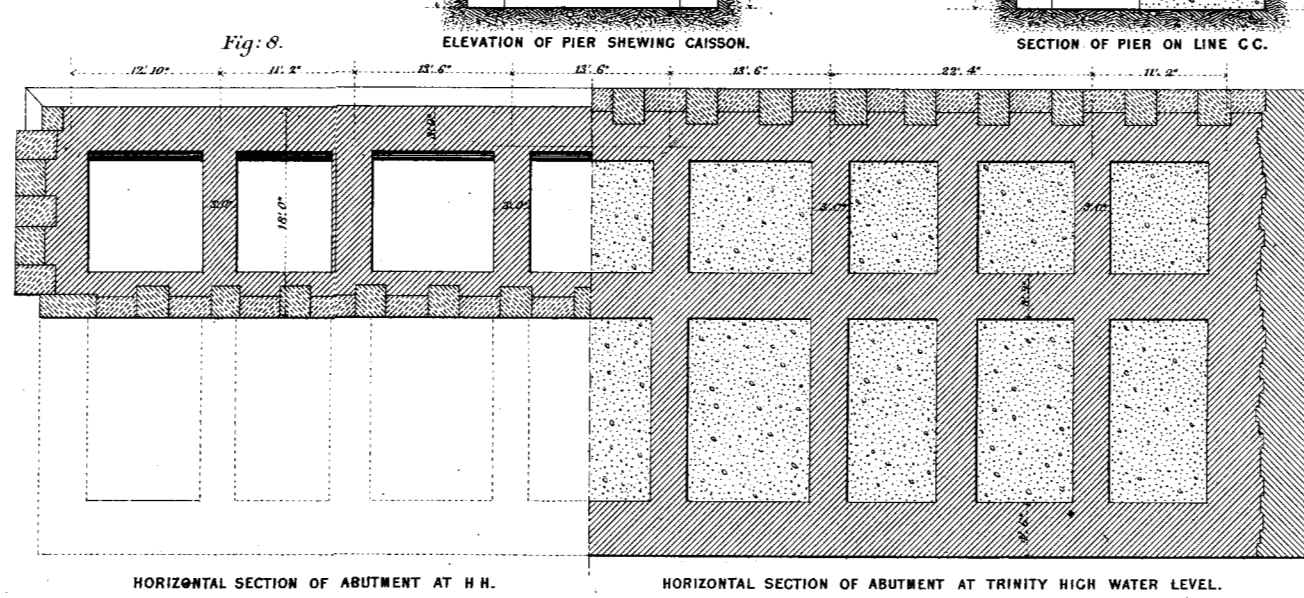
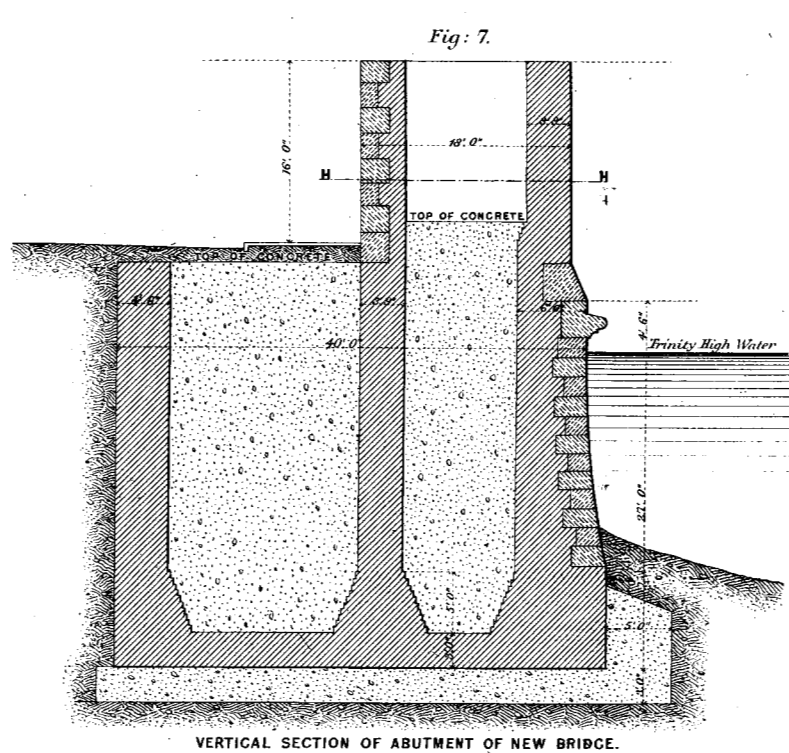
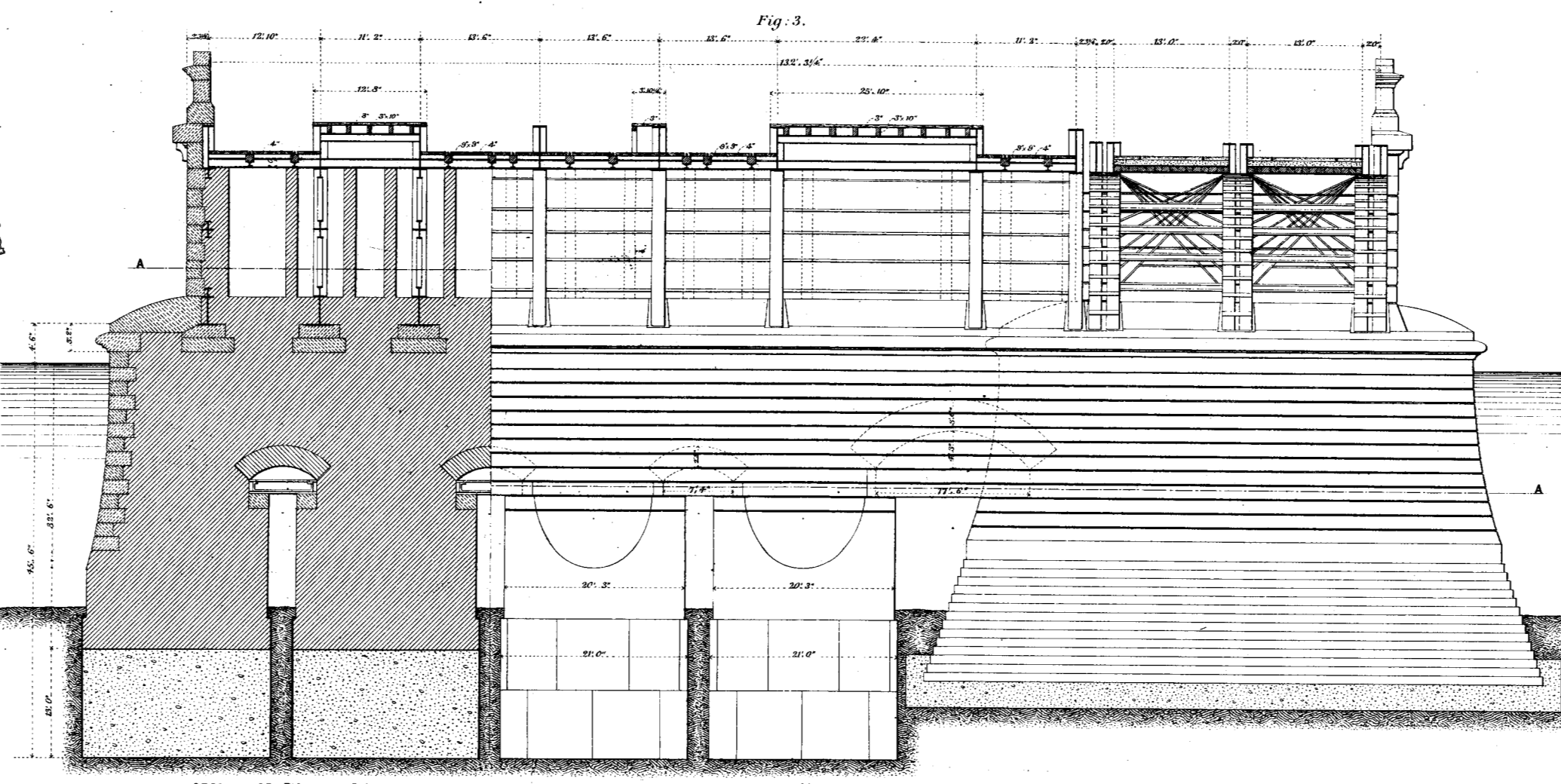
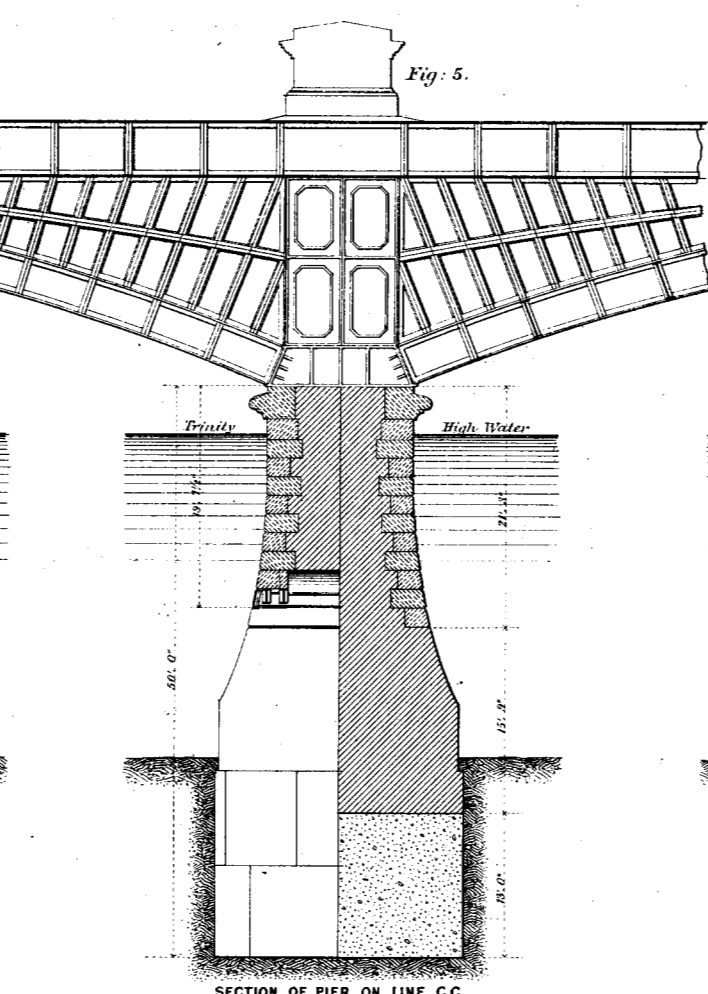
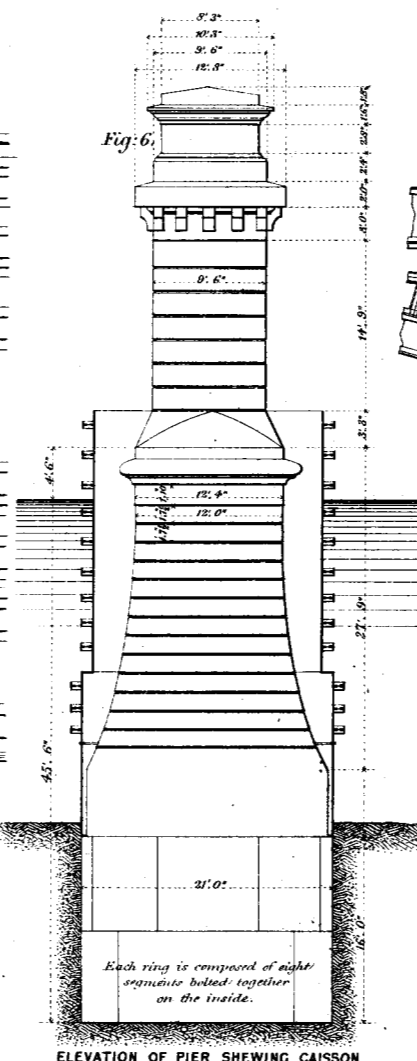
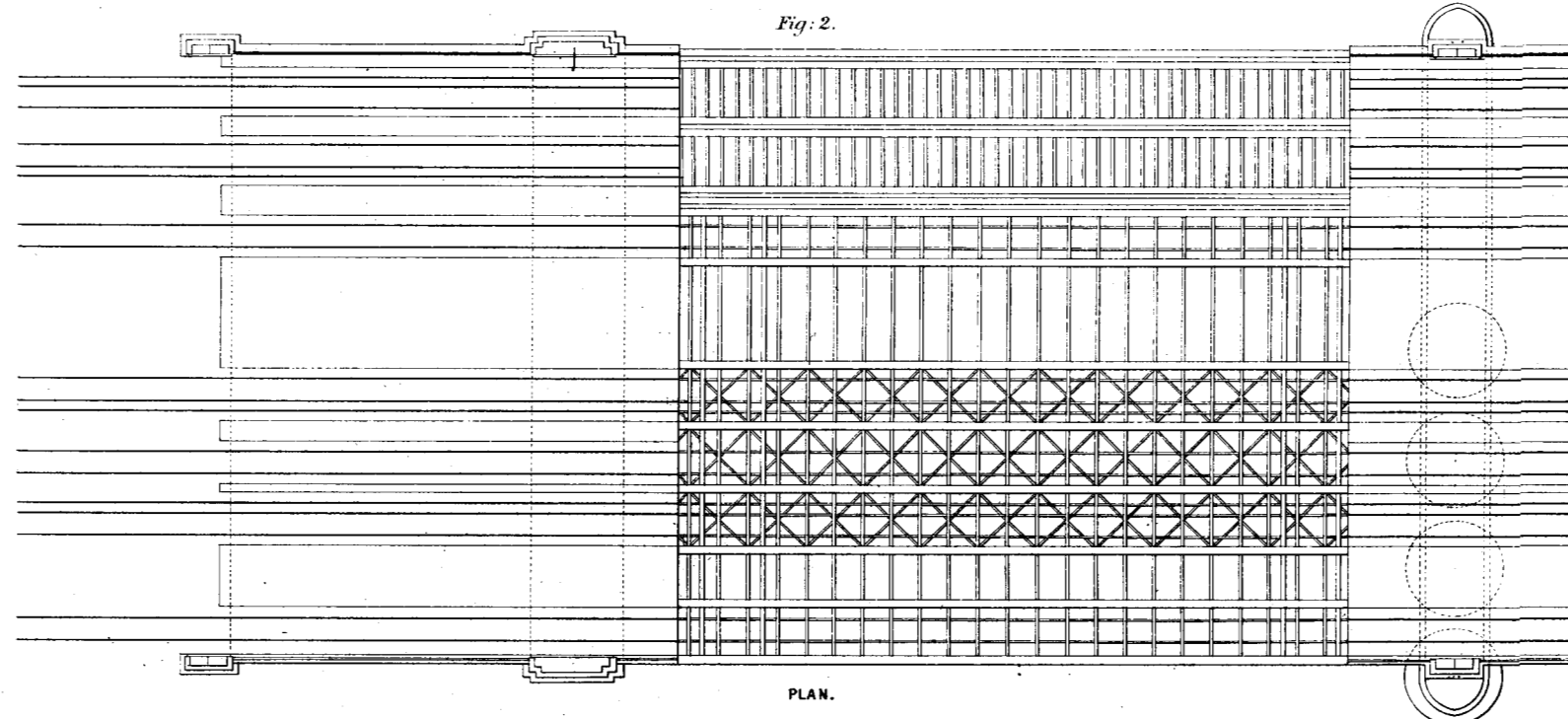
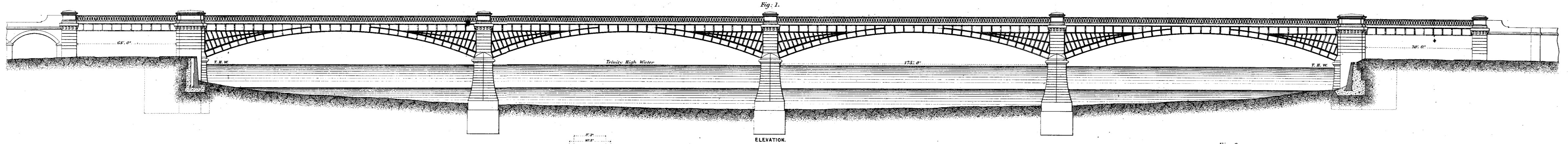




Fig. 10.

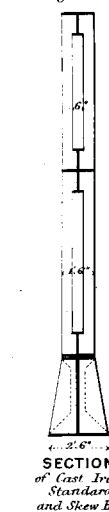
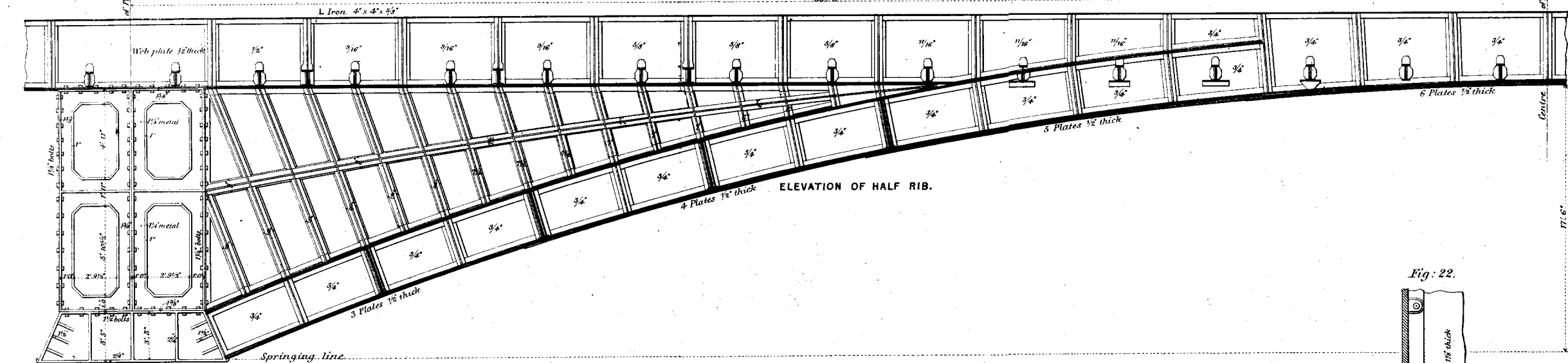


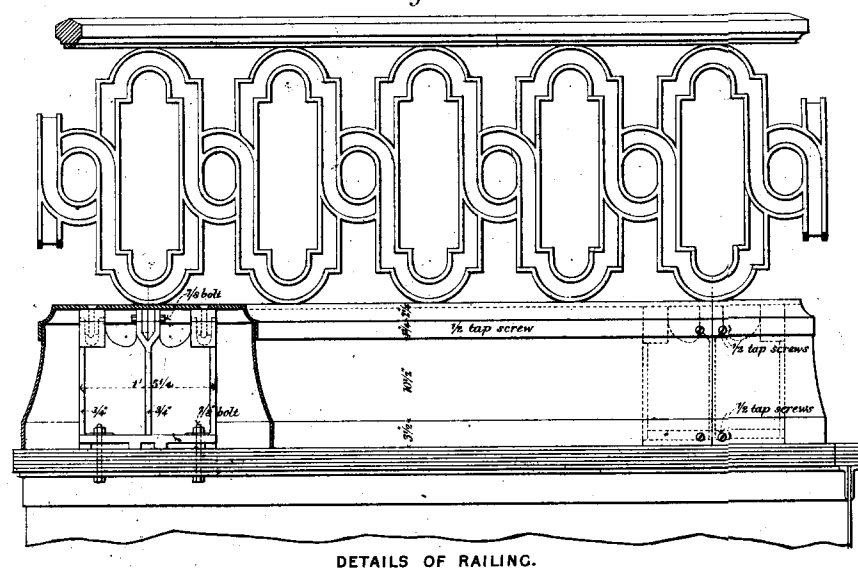
Fig. 9.

38' 8"



ELEVATION OF HALF RIB.

Fig. 24.



DETAILS OF RAILING.

Fig. 26.

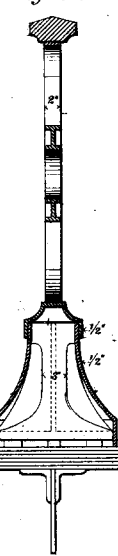


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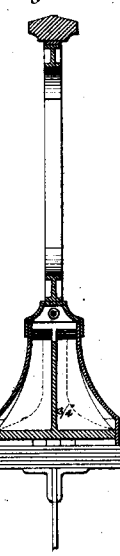
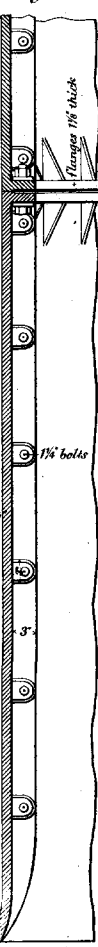


Fig. 22.



DETAILS OF WROUGHT IRON CYLINDERS.

Fig. 20.

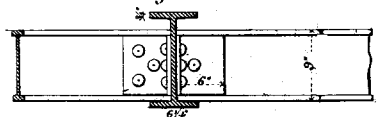
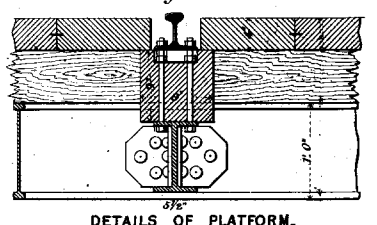
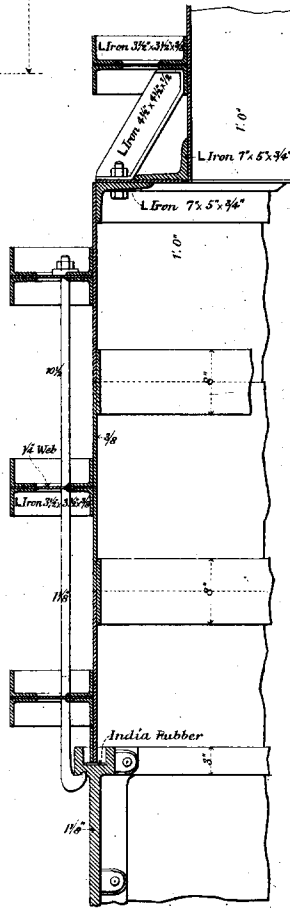


Fig. 19.



DETAILS OF PLATFORM.

Fig. 21.



SECTION OF RIB AT C.G.

Fig. 11.

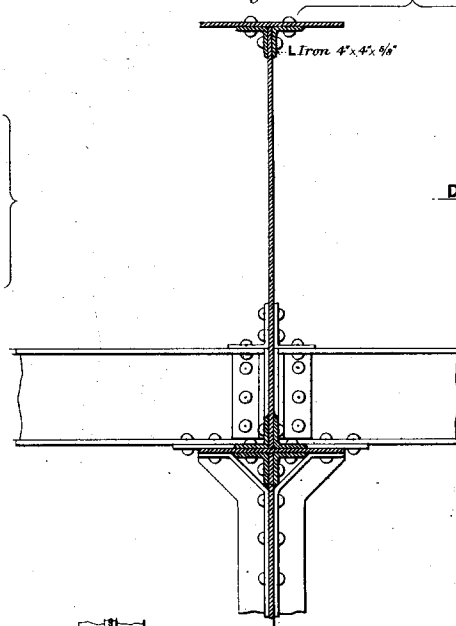
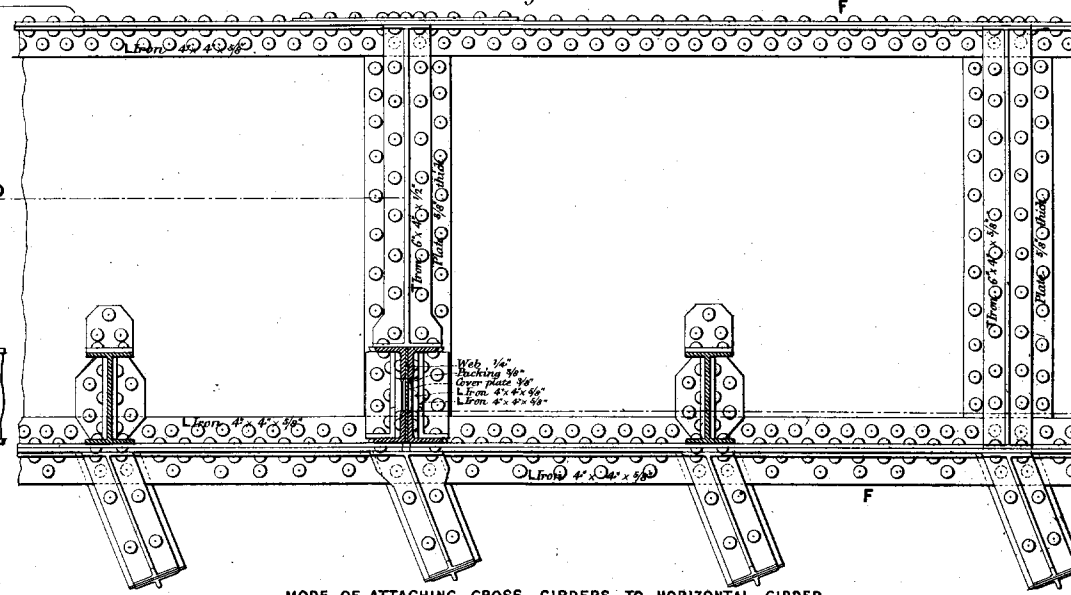
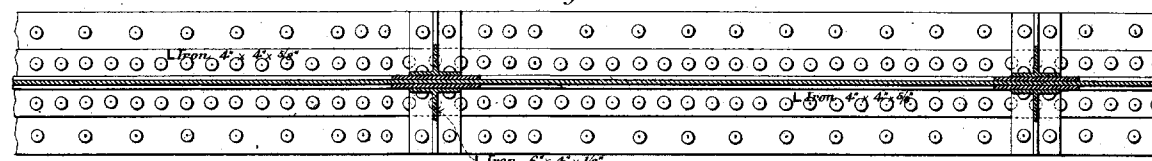


Fig. 12.



MODE OF ATTACHING CROSS GIRDERS TO HORIZONTAL GIRDER.

Fig. 15.



PLAN OF TOP FLANGE FROM BELOW.

Fig. 16.

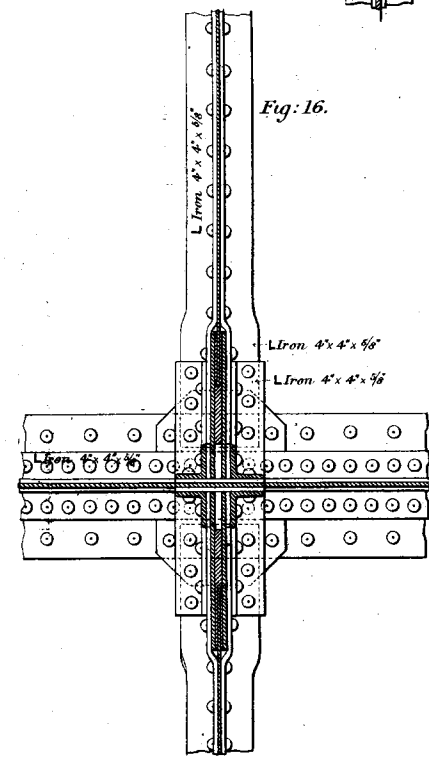
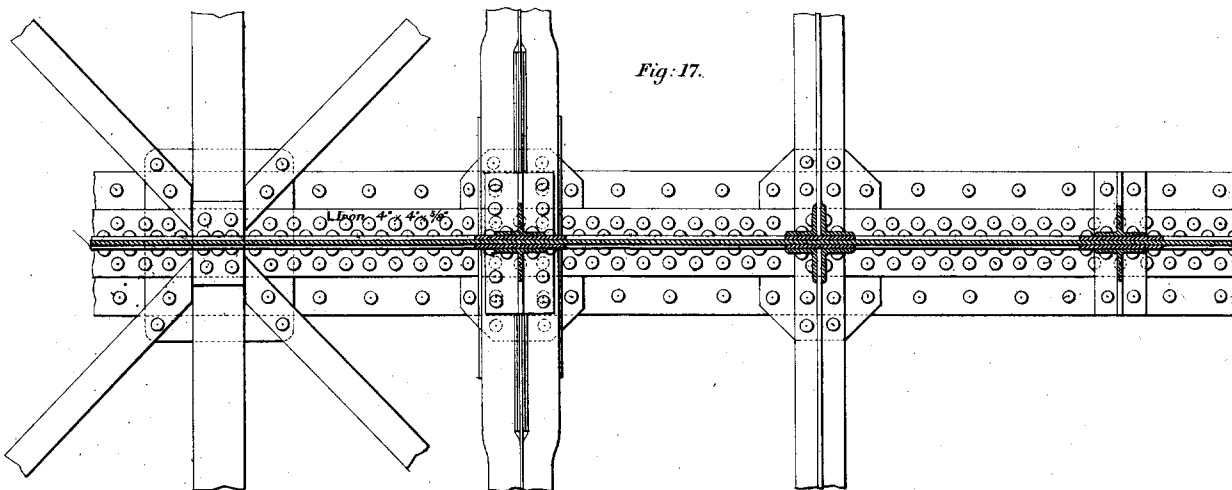
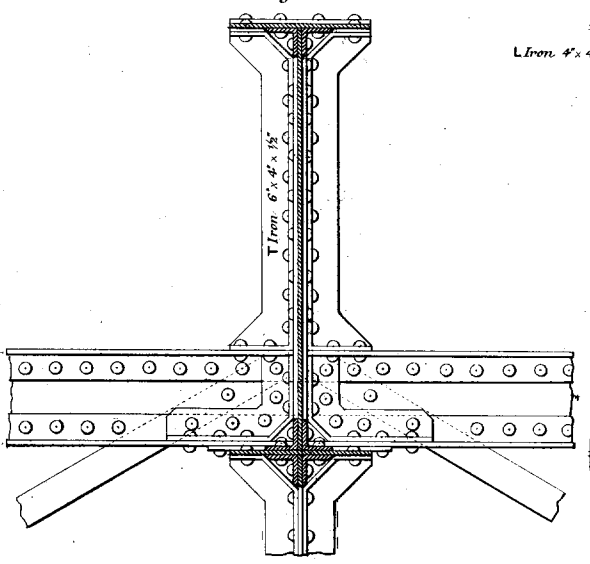


Fig. 17.



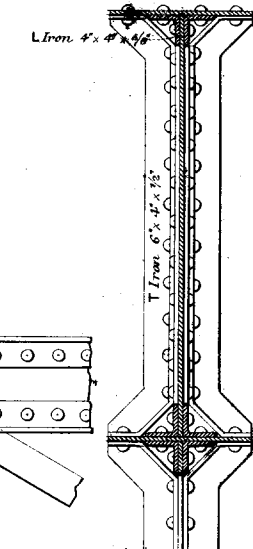
HORIZONTAL SECTION AT D.D.

Fig. 13.



SECTION AT F.F.

Fig. 14.



SECTION AT E.E. showing mode of attaching Bracing Girders.

Scale for Figs. 9 & 10. 1/4 Inch = One Foot.

Scale for Figs. 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23. 1/2 Inch = One Foot.



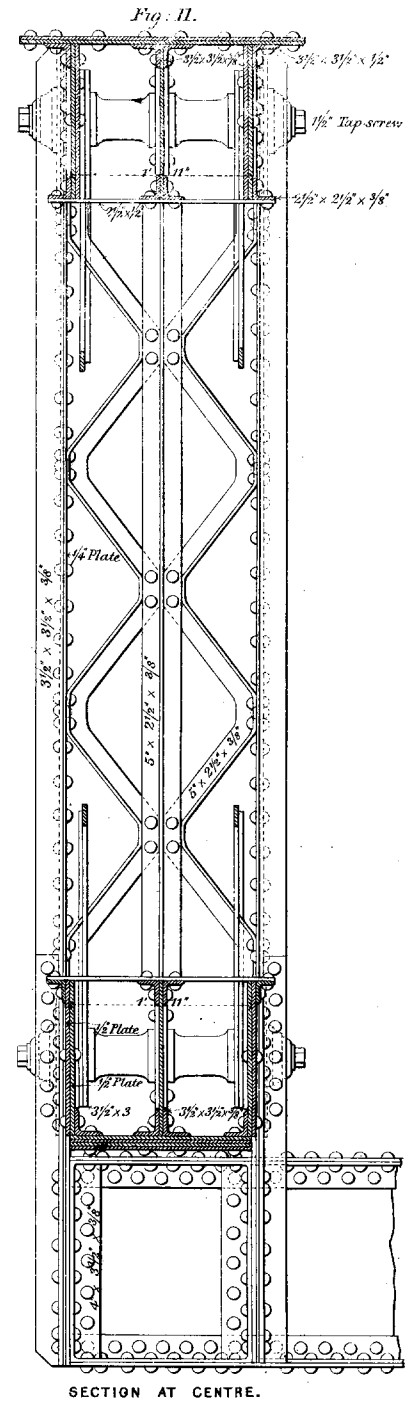
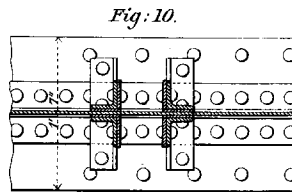
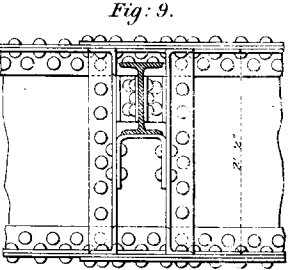
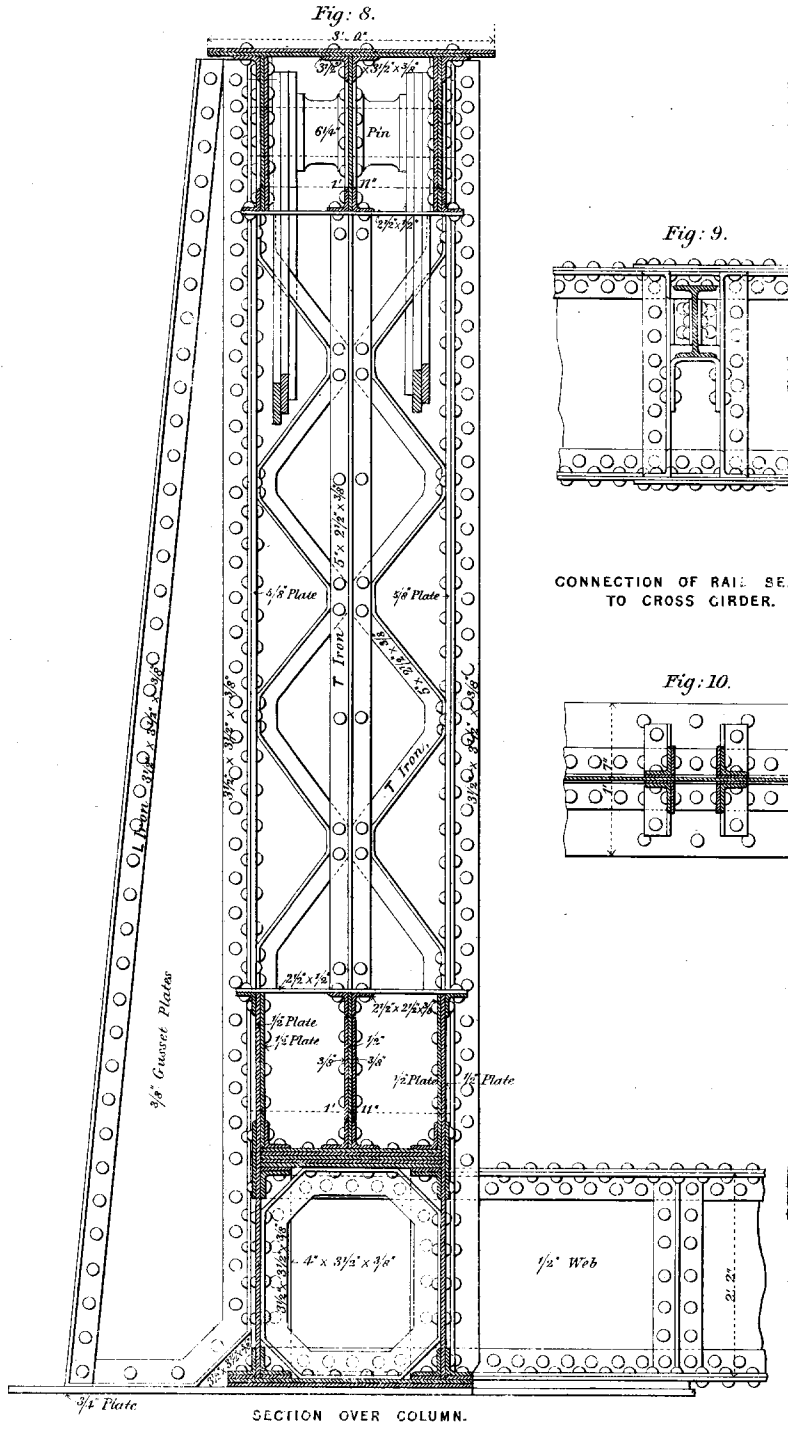
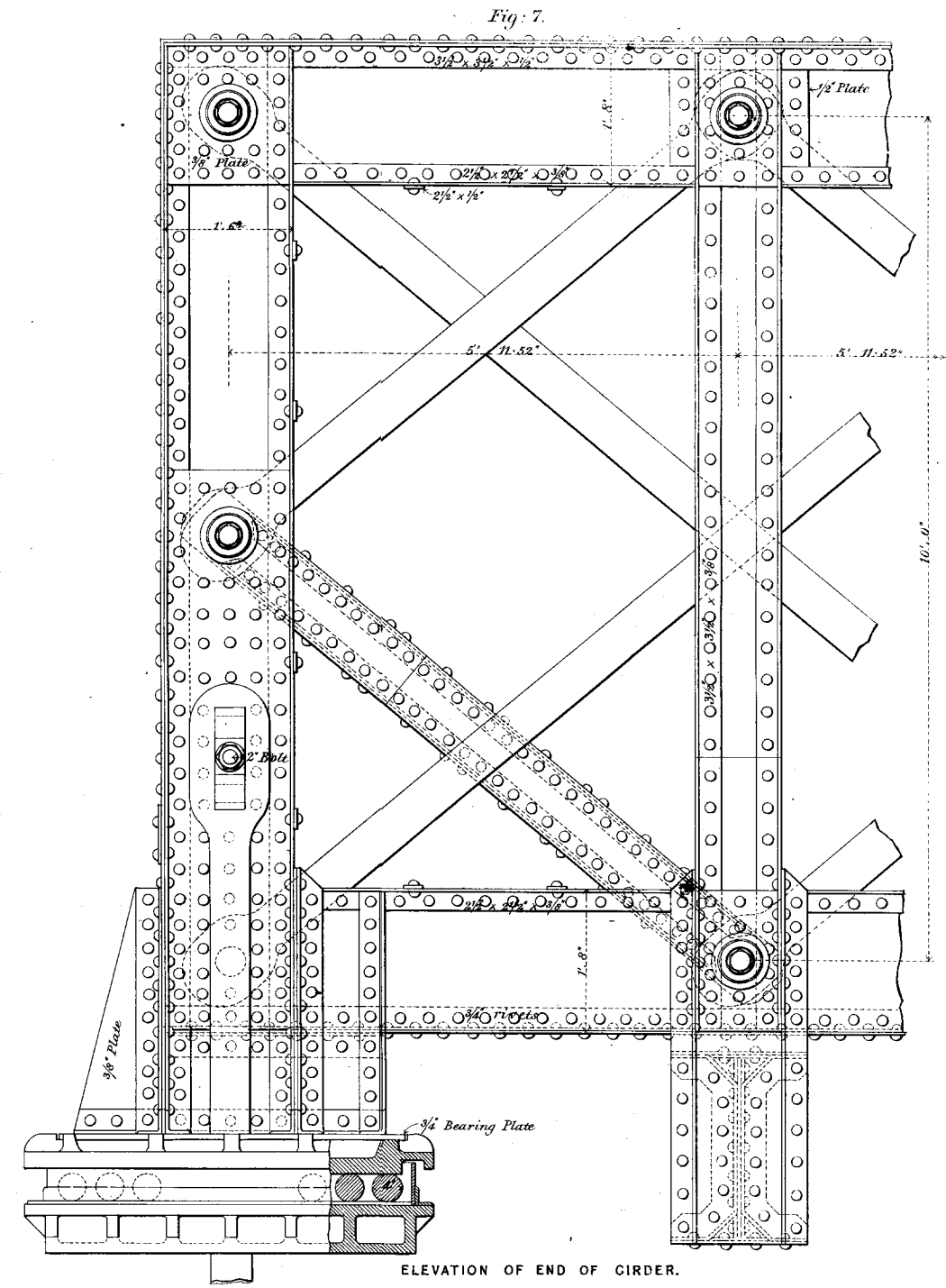
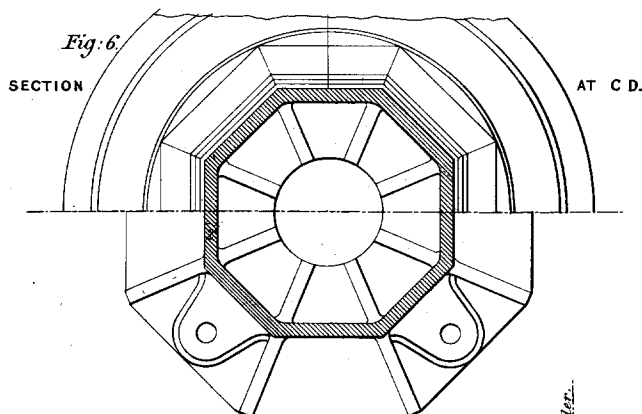
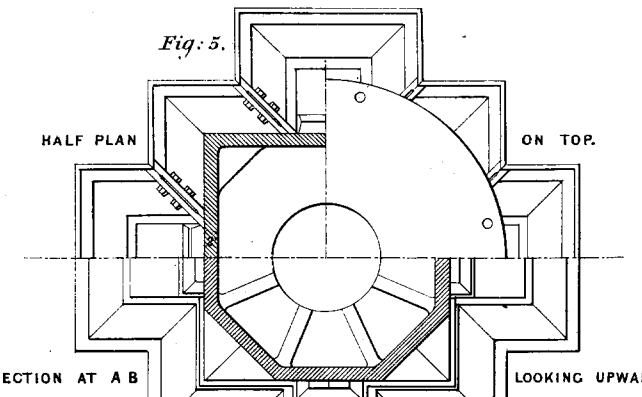
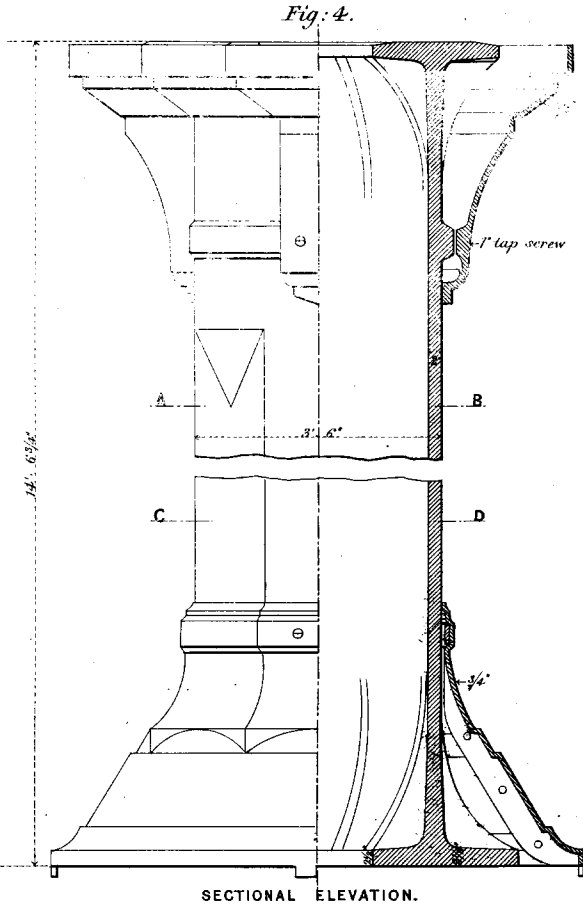
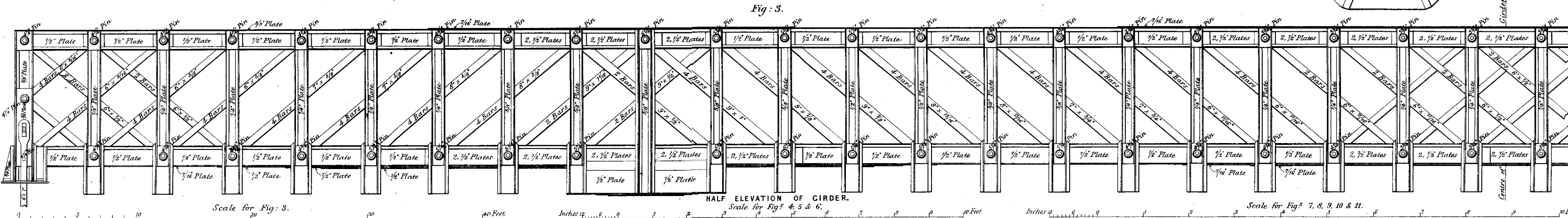
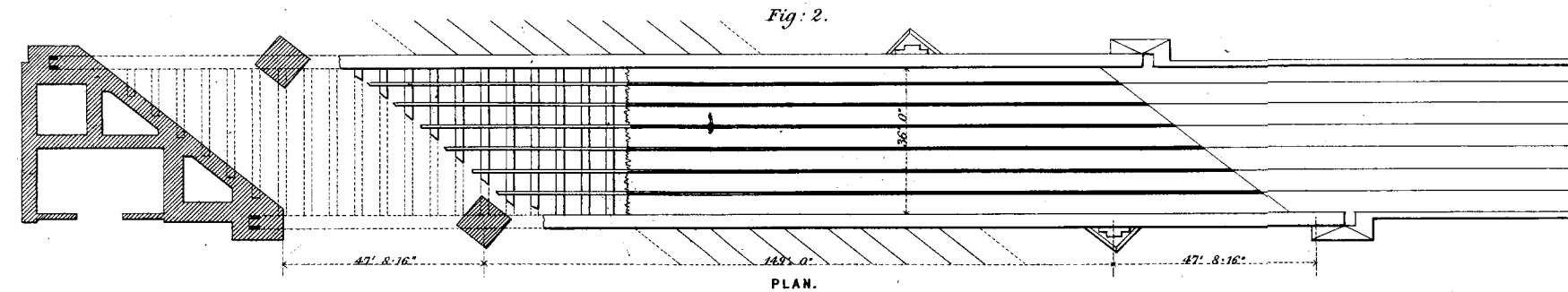
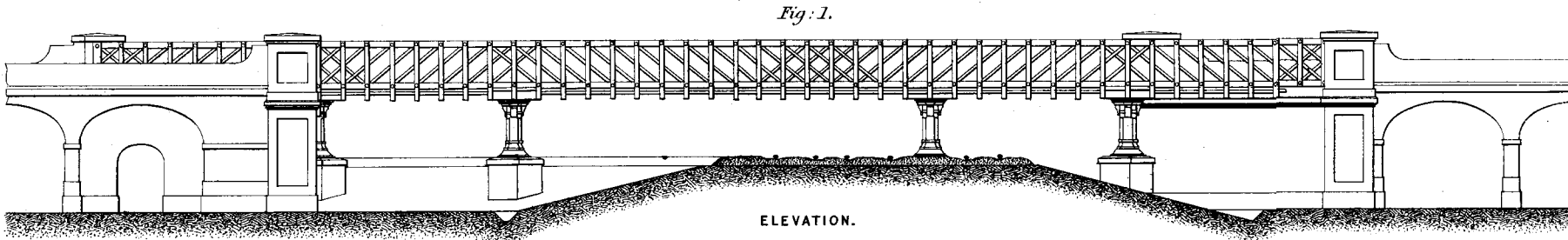


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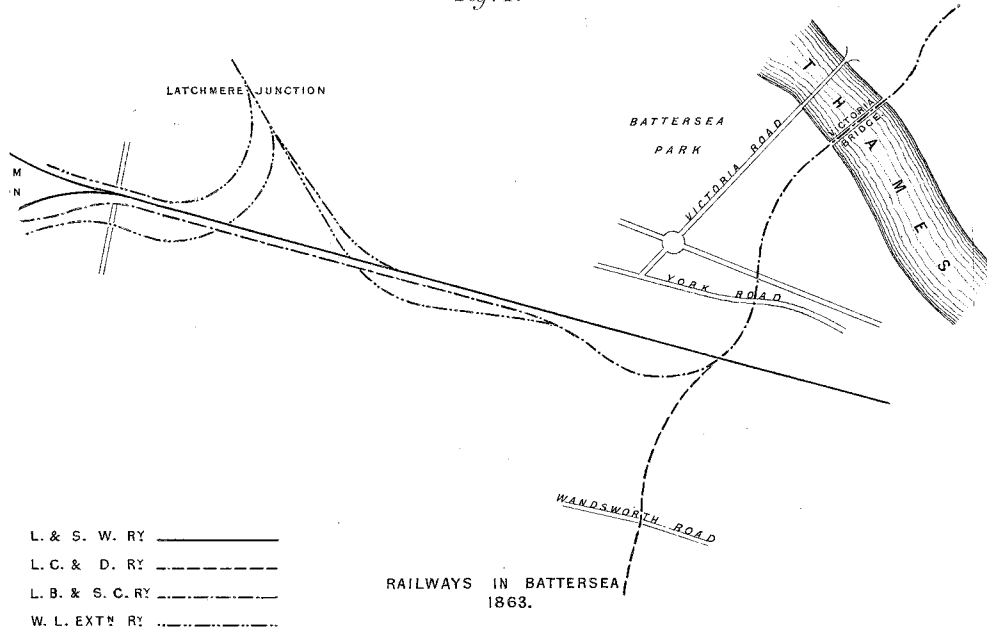


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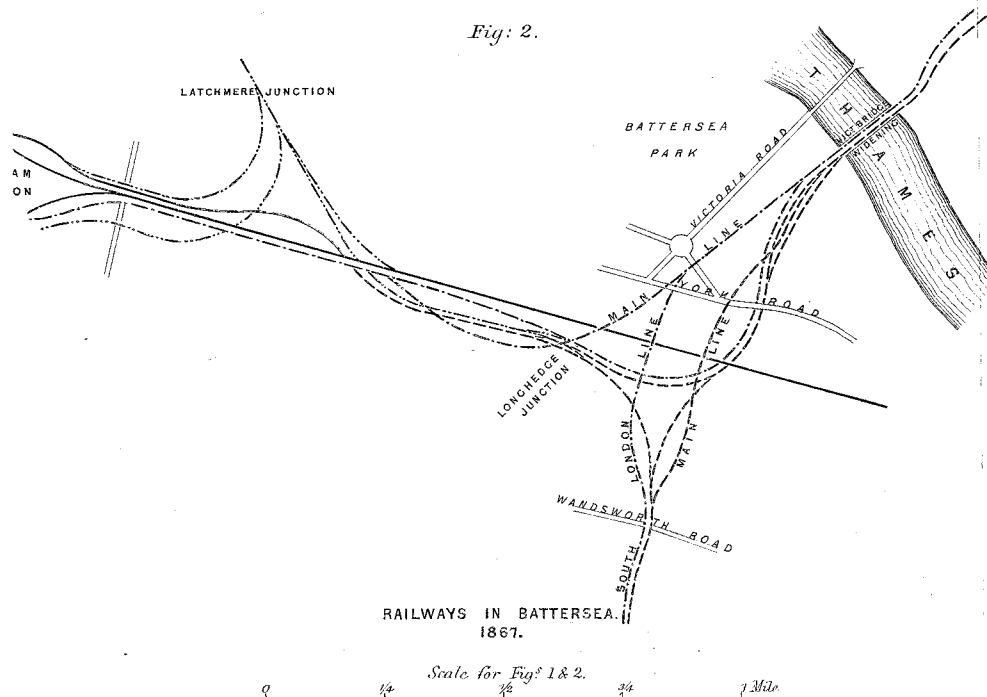


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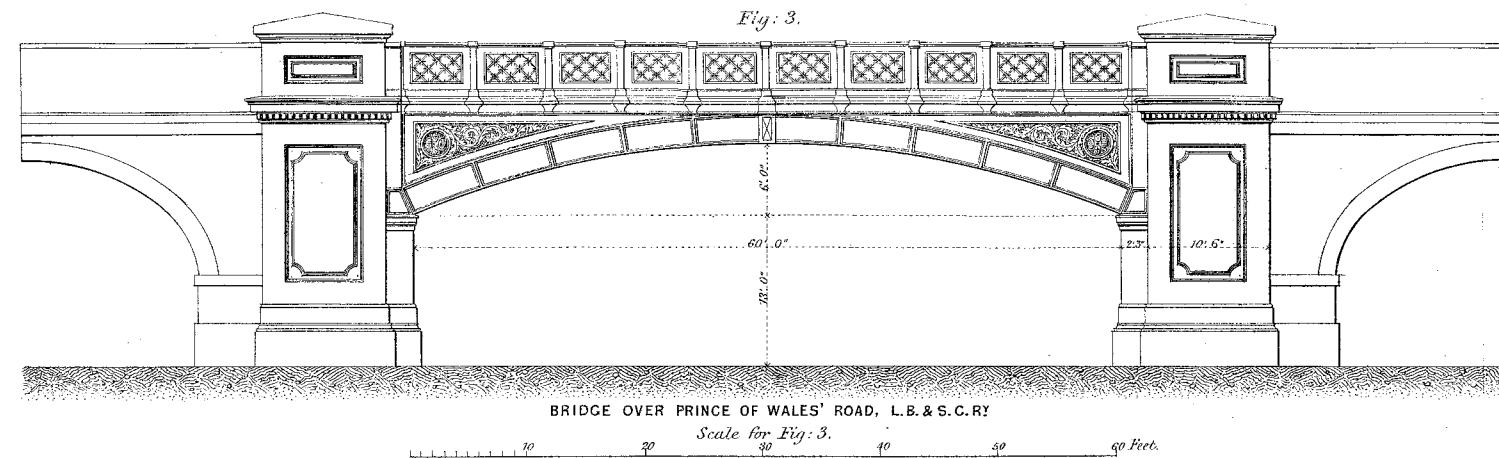


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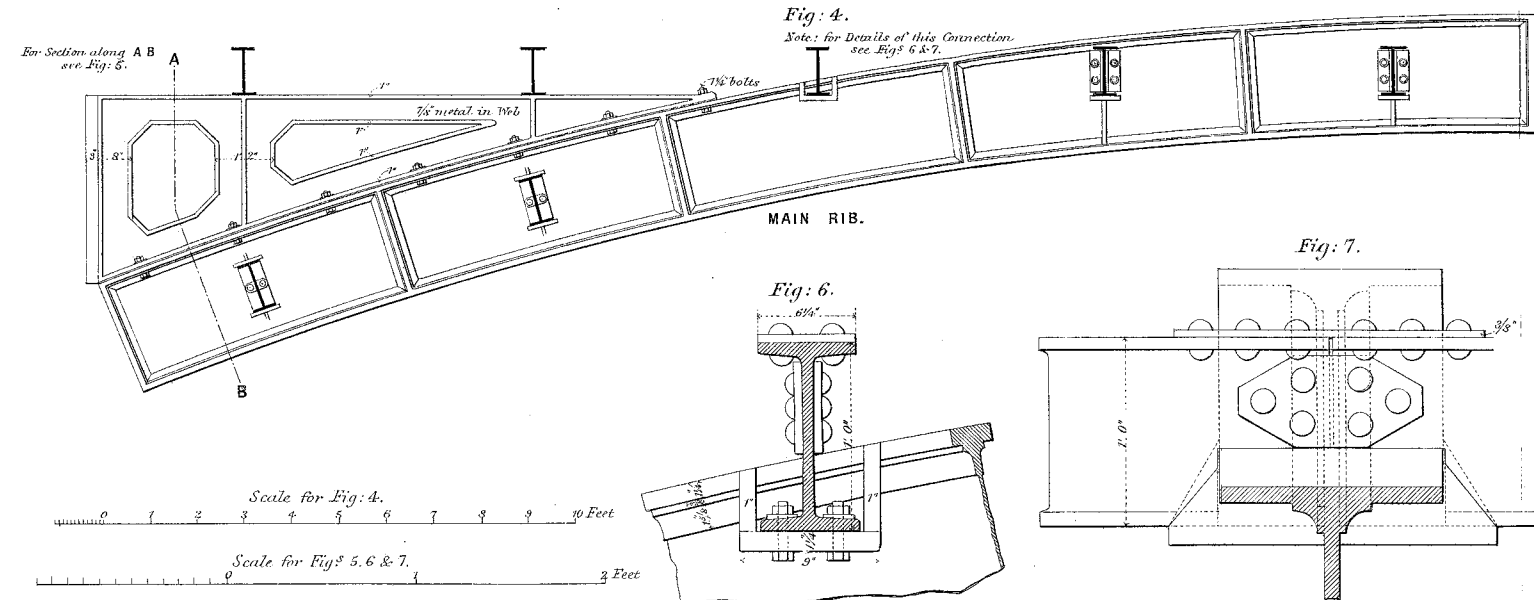


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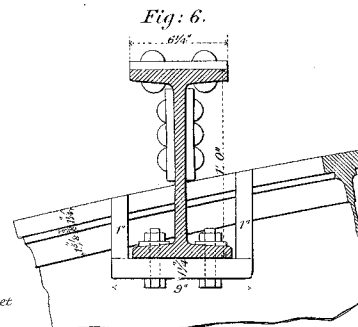


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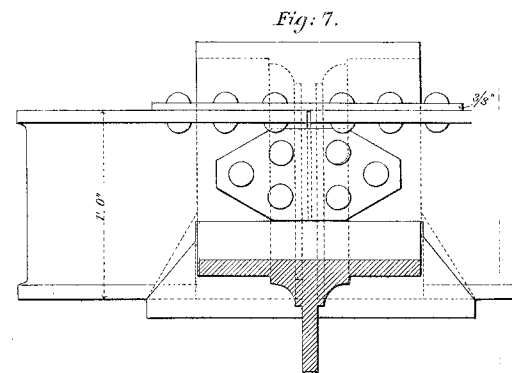


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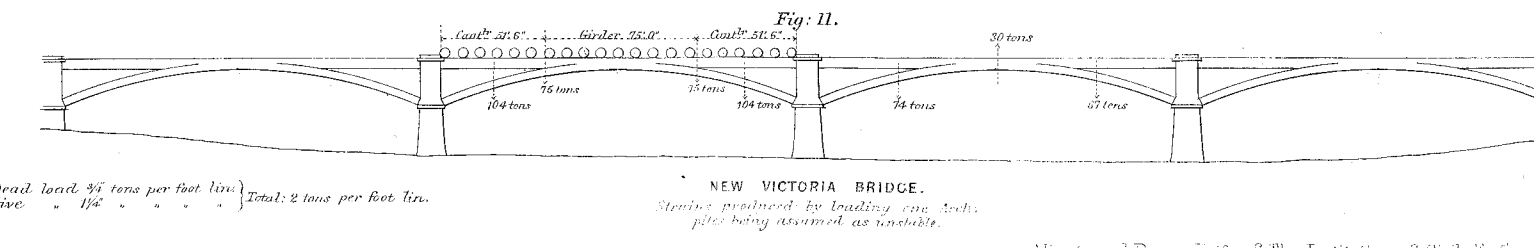


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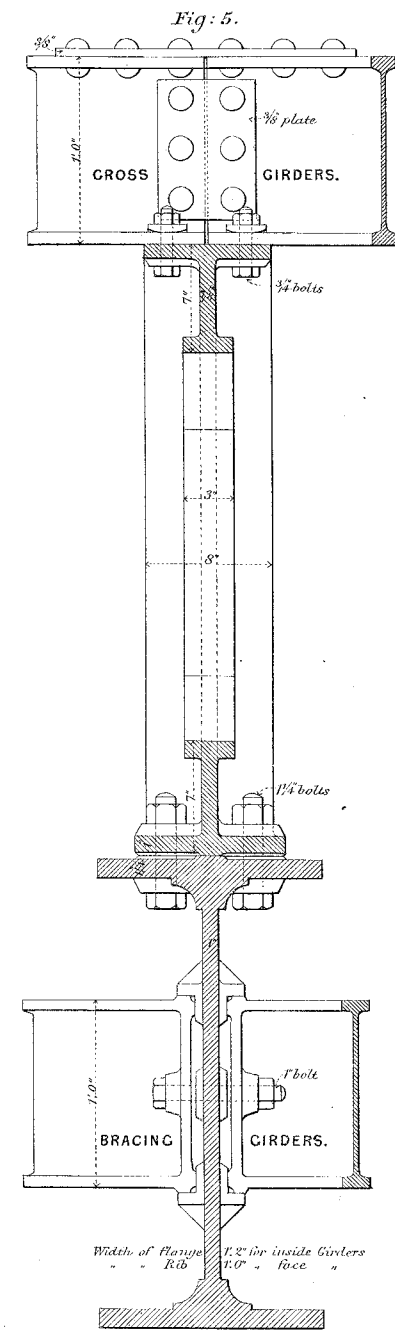


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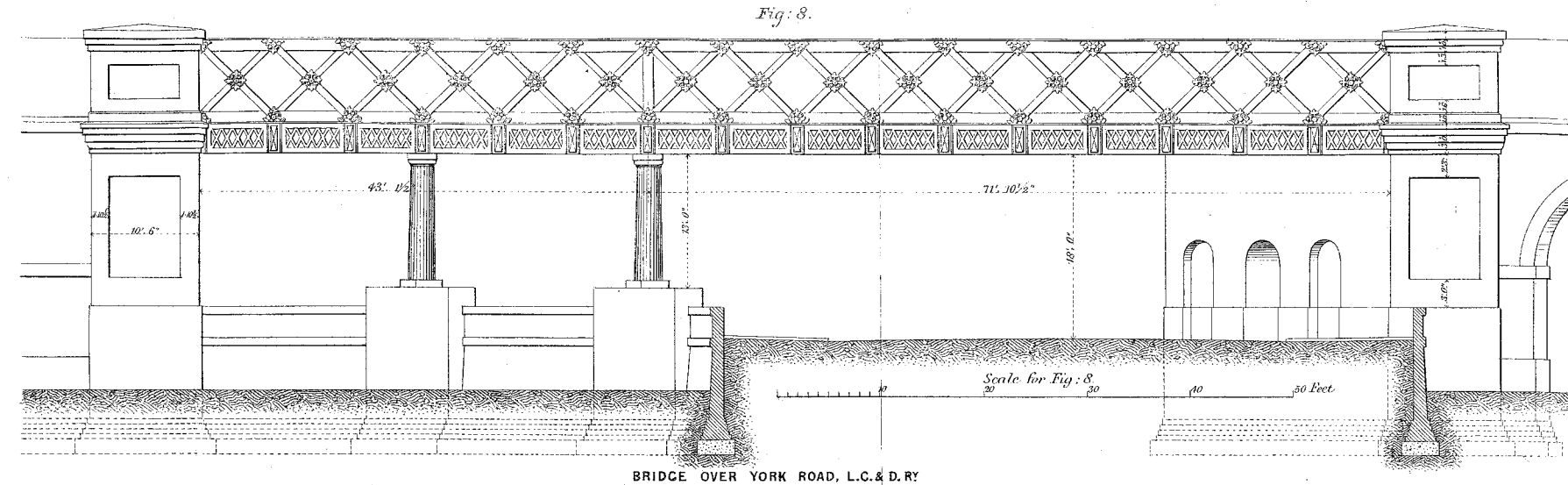


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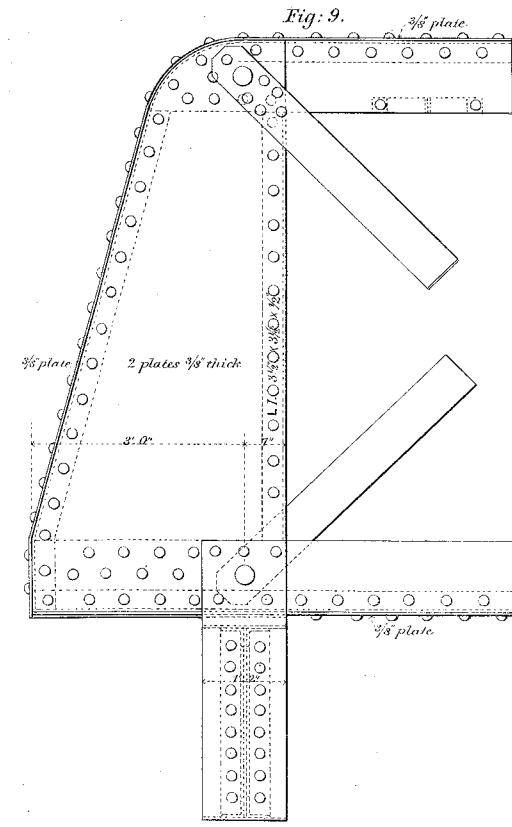


Fig: 10.

