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“Iron and Steel Bridges on the Buenos Ayres and Valparaiso Transandine Railway.”

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THE Buenos Ayres and Valparaiso Transandine Railway has a total length of 109 miles, from Mendoza to the Chilian frontier, and is laid to a gauge of one metre, or 3 feet $3\frac{3}{8}$ inches. On this line of railway there are about sixty bridges and culverts, varying in span from 3 metres to 75 metres; and the object of this Paper is to describe some of the principal types of construction adopted for the iron and steel superstructures.

The various forms of superstructure comprise lattice-girders of the “N” truss type, having pin connections made with bolts and gusset-plates, and plate-girder bridges having parallel flanges. The 60-metre and 75-metre spans were designed and built in the United States of America, and the rest in England. The live-load assumed in the calculations for these bridges was a train of six-wheeled coupled locomotives, the length of wheel base of each engine being 21 feet 4 inches, and the total weight $35\frac{1}{2}$ tons. *Fig. 1* gives the distribution of weight on the various wheels.

Fig. 1.

The smaller bridges on the line, up to spans of 5 metres, require little description, being of the ordinary type of plate-girder, with parallel flanges of plate- and angle-iron. The sleepers rest directly upon the top flanges, being secured to them by means of bolts. The girders, placed 4 feet 5 inches apart, from centre to centre, are united by horizontal wind-bracing and vertical cross-bracing.

The percentages added to the live-load for the effects of impact were as follows :—

ADDITIONS FOR IMPACT.

Span in Feet.	Amount to be added to Live-Load.	Span in Feet.	Amount to be added to Live-Load.
	Per Cent.		Per Cent.
75	10	20	50
50	20	15	60
40	30	10	70
30	40	5	80

Bearing-plates are riveted to the under side of the girders, and rest directly upon the abutments, to which the girders are secured by holding-down bolts, passing through oval holes, and allowing for a little adjustment or expansion of the girders.

DECK BRIDGE OF 10 METRES SPAN.

This type consists of a pair of plate-girders, having a uniform depth of 1 metre, placed 4 feet $7\frac{1}{2}$ inches apart, from centre to centre, and united by cross-bracing as well as by horizontal wind-bracing of flat bars riveted to the bottom boom. The sleepers rest directly upon the main girders, without the intervention of cross-girders and rail-bearers.

The bearing-plates, which are $\frac{1}{2}$ inch thick, rest upon planed cast-iron bed-plates, bolted down to the masonry with the usual allowance for expansion. The holes in the bearing-plates are covered by large wrought-iron washers, to prevent the access of dirt.

THROUGH BRIDGE OF 10 METRES SPAN.

This is very similar to the type last mentioned, except that the main girders are placed wider apart, and united by cross-girders at intervals of 10 feet $11\frac{1}{4}$ inches, connected by rail-bearers resting on their lower flanges. The sleepers are spaced at about 1 foot $9\frac{1}{8}$ inches from centre to centre, and are bolted down to the top flanges of the rail-bearers by $\frac{3}{4}$ -inch bolts.

THROUGH BRIDGE OF 15 METRES SPAN (FROM CENTRE TO CENTRE OF BEARINGS).

The main-girders of this bridge are of the Whipple-Murphy type, counterbraces being inserted where necessary (Fig. 1,

Plate 4). The connections of the braces with the booms are made with gusset-plates and rivets. The distance between the main girders is 12 feet $5\frac{1}{2}$ inches, from centre to centre, and the depth 6 feet, from centre to centre of booms. The booms are composed of four angle-irons connected together at frequent intervals by pieces of plate (Figs. 2 and 3). Plates are used to make up the required area where it exceeds that of the angle-irons. The depth of the booms is $7\frac{1}{2}$ inches over angle-irons, and the width 1 foot over plates. The posts are built up of four angle-irons, two of which are returned over the top of the cross-girder, and bolted to it as shown in Fig. 2, with a gusset-plate inserted between the pair of angle-irons. All the connections of the main girders are made with bolts.

The end posts are inclined, and are of the same construction as the booms, the connection with the lower boom being made as shown in Fig. 3. The tension braces are composed of two flat bars bolted on either side of the gusset-plates, which connect them with the booms, as shown in Fig. 3A. All rivets in the main girders are $\frac{7}{8}$ inch diameter, and 4 inches pitch, while in the covers the pitch is 3 inches. All rivets in cross-girders and rail-bearers are $\frac{3}{4}$ inch diameter, and 4 inches pitch. All bolts are turned, and all bolt-holes drilled. The weight of this bridge is very small, being only about $14\frac{1}{4}$ tons; and, although the cost of manufacture per ton was much higher than for some of the other bridges, it was more than compensated by the saving in freight.

SPANS OF 20 METRES.

The Mendoza Viaduct consists of six of these spans, which were designed by Messrs. James Livesey and Sons, and are illustrated in Figs. 4 to 7, Plate 4.

The girders are of the "N" truss type, the principal connections being made with steel pins. The sleepers are bolted down directly upon the top booms of the main girders, and their projecting ends are utilized for carrying a narrow footway on one side of the bridge. The girders are 5 feet 11 inches apart, between centres, and 5 feet 10 inches deep, from centre to centre of booms, and they are braced together by a system of angle-iron bracing (see Fig. 5). The footway is protected on the outer side by a wrought-iron hand-railing, composed of gas-tubing, carried by cast-iron standards.

The booms of the girders are of "trough" section, built up of channel-irons and plates, the top booms being stiffened at

intervals of about 2 feet 7 inches by internal diaphragms composed of angle-irons and plates. All posts and tension-members are carried inside the booms, at their junction with them. The posts are built up of two channel-irons placed front to front and connected by pieces of plate. The tension braces are composed of flat eye-bars with pin-connections.

In the four centre bays the bars composing each diagonal are bolted together with $\frac{5}{8}$ -inch diameter bolts, gas tube distance-pieces being used, thus making them sufficiently stiff to take compression, which they have to sustain in certain positions of the live-load. The wind-bracing is composed of flat bars connected to the bottom booms of the girders and to the cross-bracing struts by bolts and gusset-plates.

DECK BRIDGE OF 40 METRES = 130 FEET (FROM CENTRE TO CENTRE OF BEARINGS).

The main girders of this bridge are 14 feet deep, from centre to centre of booms, and the distance between them is 9 feet $10\frac{1}{8}$ inches from centre to centre. The design closely resembles that of the 45-metre spans.

DECK BRIDGE OF 45 METRES SPAN = 146 FEET 9 INCHES (FROM CENTRE TO CENTRE OF END PINS).

This bridge was designed by Messrs. J. E. and M. Clark and Co.

Figs. 8 to 11, Plate 4, illustrate the construction of the main girders, which are 16 feet in depth, and placed 11 feet $5\frac{3}{4}$ inches apart, from centre to centre.

The bracing is of the "N" type, with pin-connections, and inclined end-posts; the load is brought upon the joints of the upper boom by cross-girders placed directly over the pins, spaced at intervals of 12 feet $2\frac{3}{4}$ inches, from centre to centre. The booms are of trough section, built up of angle-irons and plates, the top boom being stiffened internally by diaphragms. The posts are built of two channel-irons set face to face, and connected together at frequent intervals by small pieces of plate, the pin-connections being made through the webs of the channel-irons.

The rail-bearers are placed 4 feet 5 inches apart, from centre to centre, and rest upon the bottom flanges of the cross-girders, except at the ends, where they are carried upon cast-iron bed-plates fixed to the abutments, and are braced together by frames of angle-iron.

The tension-braces are composed of flat eye-bars, the connections being made with steel pins $3\frac{3}{4}$ inches in diameter. The top horizontal bracing consists of flat bars connected to the bottom flanges of the cross-girders by bolts and gusset-plates, while the lower wind-bracing is composed of angle-irons.

The transverse bracing consists of top and bottom struts, built of angle-irons and plates, bolted to the inner sides of the posts, and braced by diagonals of T-iron, bolted to the webs of the struts. At the intersections of the braces and counter-braces, the bars are held together by means of clips, made of two pieces of plate, and drawn together by bolts. The inclined end-posts are formed with a trough section similar to that of the booms, and are connected to the upper booms by internal cover-plates $\frac{5}{8}$ inch thick, bolted to the vertical webs of the troughs in each member; while cover-plates are also bolted to the top tables of the inclined struts, and carried up to the top plates of the booms, to which they are united by angle-irons. The members are also connected outside by means of angle-irons bolted to the lower flanges of the booms. The connections with the lower booms are made in a similar manner.

As this bridge was to span a deep "quebrada" or ravine, it was decided that it would be best to launch it after erection upon one of the abutments. For this purpose, a special wrought-iron launching apparatus was constructed. The object of projecting the top and bottom booms of the girders beyond the end posts, was to afford means of connecting this special launching apparatus to the bridge. The expansion end rests upon roller-bearings, consisting of turned-steel rollers contained in wrought-iron frames, running upon cast-iron bed-plates.

THROUGH BRIDGE OF 60 METRES SPAN = 197 FEET $\frac{3}{8}$ INCH (FROM CENTRE
TO CENTRE OF BEARINGS).

This bridge is constructed principally of steel, and was designed and built by the Pencoyd Bridge and Construction Company of the United States of America. The main trusses are of the form shown in Fig. 12, Plate 4, and are placed 14 feet 9 inches apart, from centre to centre.

Each girder is divided into nine equal panels, and has a maximum depth of 30 feet from centre to centre of pins. This depth is maintained for the width of three panels at the centre of the span, but is reduced towards the ends as shown in the figure. The top booms and inclined end-posts are built of steel angle-

bars and plates, and are of trough section. The plates run all along the top, and lattice bars are riveted all along the bottom of the trough, the dimensions of which are $15\frac{1}{2}$ inches deep over angles, and 22 inches wide. The lower chords and the diagonal ties are composed of flat eye-bars with pin-connections.

The vertical posts are built of two steel channel-bars set face to face, and joined together at the sides by lattice-bracing. At the bottom, where the floor-beams are attached to the posts, the channel-bars are connected by steel web-plates and angle-bars. The webs are thickened at each end of the post by the addition of plates riveted to them, in order to obtain sufficient bearing area for the pins. The floor-beams or cross-girders are 2 feet $6\frac{1}{2}$ inches deep, and are built up of steel plates and angle-bars. Their ends rest upon angle-cleats, fixed upon the inside channels of the posts, to which they are fastened by turned bolts. The stringers, or rail-bearers, are small plate girders of ordinary construction, with a depth of 2 feet $\frac{1}{2}$ inch over angles. They rest upon angle-cleats riveted to the floor-beams, and are bolted to the webs of the floor-beams. The top wind-bracing is composed of struts and tension-rods, arranged as shown in Fig. 12A. The struts are built in the form of cross-girders with steel angle-bar flanges and lattice webs. The struts are connected to the top chords of the trusses by plates bent round the ends and riveted on, through which the main pins pass and are fastened by nuts (see Fig. 17).

The tension-members of the top-bracing are square bars, and are connected by wing-plates (see Fig. 16), through which also the main pins pass. The bars are screwed into clips, which are connected to the wing-plates by bolts. Thus all the members of the system of bracing are very simply connected to the trusses by means of the main pins; an objection to this plan, however, in the Author's opinion, is that it must cause a good deal of trouble in erecting the bridges. At each post, the main trusses are united by transverse bracing, consisting of a second horizontal strut (built of two channel-bars) attached to the posts below the upper strut, and united to the latter by diagonal tie-rods of square section, fitted with sleeve-nuts for adjusting their length (see cross sections A and B, Fig. 13). The inclined end-posts are united by portal-girders 5 feet 6 inches in depth, with angle-bar flanges and lattice-bracing; they are also united at the foot. The bottom horizontal bracing is composed of square bars connected to the bottom flanges of the floor-beams by gusset-plates and pins. Fig. 15 shows the junction of one of these rods with the end strut. The stringers, or rail-bearers, are braced together at their centres,

and the end stringers at both their centres and ends, by means of cross-frames, which fit between the inner flanges, and are bolted to the webs of the stringers. The stringers at the abutments have bearing-plates riveted to them, which rest upon bed-plates, and are bolted down to the masonry (Fig. 14). The trusses rest upon roller bearings at the expansion end of the bridge; each bearing consists of steel rollers held together in a frame. The rollers are $2\frac{1}{2}$ inches diameter and 2 feet $\frac{3}{8}$ inch long, and have grooves turned at their centres into which the guiding strip enters. They rest upon bed-plates which are held down to the masonry by foundation bolts. The trusses are carried upon the rollers by shoes, built up of angles and plates which are connected to the trusses by the end pins. At the fixed end of the bridge the trusses rest upon shoes, of a somewhat similar form, bolted down to the masonry.

THROUGH BRIDGE OF 75 METRES SPAN = 246 FEET (FROM CENTRE
TO CENTRE OF END PINS).

This is the longest span on the line, and it was designed and built by the Phoenix Bridge Company, of the United States of America, and is constructed almost entirely of steel. The main trusses are of the form shown in outline in Fig. 18, Plate 4, and are divided into nine equal panels of 27 feet 4 inches.

The depth of the trusses in the five middle panels is 35 feet from centre to centre of chords. The top chords and inclined end-posts are of trough section, constructed in the form already described, but with a width of 2 feet $5\frac{1}{2}$ inches at the bottom, and a depth of 2 feet $\frac{1}{2}$ inch over angles. The vertical posts consist of two channel-shaped sides united by lattice-bracing (Fig. 19), each channel being formed of a plate and two angle-bars. The dimensions of the posts are $12\frac{1}{2}$ inches by $14\frac{1}{4}$ inches. The lower chord consists of flat eye-bars with pin-connections, and the same form is adopted for some of the diagonal ties; others are of square section and are fitted with "sleeve nuts" for adjusting their lengths. The hangers at the ends of the trusses, B K and I R (Fig. 18), are composed of flat bars having an arrangement of angle-bars and plates at their lower ends, connected to them by pins, for carrying the cross girders or floor-beams. The floor-beams have a depth of 3 feet 3 inches over angles, and are carried by angle-bar brackets riveted to the posts and hangers, and are secured to the posts by means of bolts. The stringers or rail-

bearers are 2 feet 6 inches deep over angles, and rest upon brackets riveted to the floor-beams; they are also bolted to the webs of the floor-beams. The end stringers at the abutments rest upon wrought-iron bed-plates, and are braced together by cross-frames built of angles and plates. The lower horizontal bracing is composed of square rods, which are connected to the ends of the floor-beams by pins and gusset-plates.

The top chords are united by cross-stays and wind bracing as shown in Fig. 19. The cross-stays are of lattice-girder form, the flanges being composed of steel angle-bars united by the bracing. The wind-ties are composed of square rods, which are connected to the top chords of the trusses by means of brackets riveted to the tops of the upper chords, the rods being passed through the brackets and secured by nuts. The end-posts are united by portal girders 5 feet deep over the angles. The trusses are braced together at each post by vertical cross-bracing, composed of horizontal struts of angle-bars bolted to the inner sides of the posts, and two pairs of diagonal bracing-rods; these are attached on each side of the posts by angle-brackets riveted on, having drilled holes through which the rods pass and are secured by nuts. The sleepers are bolted down to the top flanges of the stringers, and are spaced at about 1 foot 11 $\frac{3}{8}$ inches from centre to centre.

The bridge rests at one end upon expansion-bearings, each consisting of a wrought-iron frame containing nine steel rollers having grooves turned in them to receive the guiding-strip. Upon the rollers is placed the pedestal, which is constructed of steel plates and angle-bars, and has a guiding-strip riveted to the under side and fitting into the grooves in the rollers. The pedestals are connected to the main trusses by 6-inch turned steel pins which pass through the bottom of the end-posts. The rollers are placed upon a steel bed-plate, which also has a guiding-strip upon it.

The centre rollers, instead of being held in the frame like the others by projecting ends turned upon them and fitting into the holes in the sides of the frame, are bored and tapped, and have $\frac{3}{4}$ -inch diameter iron tap-bolts screwed into them; thus enabling these rollers to serve as ties to the frame.

The following are the data used for calculating the stresses in this bridge:—

<i>Live-load</i>	Train of Transandine Railway Consolidation Engines.
<i>Dead-load</i> . . .	1,450 lbs. per lineal foot.
<i>Wind-pressure</i> .	150 " " " for top laterals
" " . . .	400 " " " " bottom laterals.

The bridges which were built in England were manufactured by the Horsehay and the Horseley Companies.

The weights of the several classes of bridge described in this Paper are given in the Appendix.

The communication is accompanied by fifteen tracings, from which Plate 4 has been compiled, and by a series of detailed specifications.

APPENDIX.

TRANSANDINE RAILWAY.

Weights of Bridges.

Span in Metres.	Description.	Designed by	—			
			Tons.	Cwts.	Qrs.	Lbs.
3·00	Deck Plate . .	Messrs. Clark & Co.	0	18	0	11
4·00	Ditto.	Ditto.	1	9	0	26
5·00	Ditto.	Ditto.	2	1	0	24
10·00	Ditto.	Ditto.	5	12	3	6
10·00	Through Plate .	Ditto.	8	12	0	11
15·00	{Through Lattice-} { Riveted . . . }	Ditto.	14	7	0	0
20·00	{Deck, Plate, Pin-} { Connection . . }	{Messrs. J. Livesey & Sons . . . }	22	3	3	22
40·00	Ditto.	..	95	5	0	0
40·00	Ditto.	Messrs. Clark & Co.	68	12	0	0
45·00	Ditto.	..	113	0	0	0
45·00	Ditto.	Ditto.	89	11	0	0
60·00	{Through Pin-Con- { nection . . . }	The Pencoyd Co. .	Approx.			
75·00	Ditto.	The Phoenix Co. .	156	5	0	0