Sydney University Engineering Society.

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Opening Bridges of New South Wales.

By H. HARVEY DARE, M.E.; Assoc. M. Inst. C. E.

(Read before the Sydney University Engineering Society, November 25th, 1896.)

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THE navigable waters of New South Wales may be divided into three classes, viz. :—

(i.) The harbours and estuaries of the coast line, and the lower reaches of the tidal rivers, which are open for deep sea traffic ;

(ii.) Such portions of the coastal rivers of the eastern slope as are available for vessels of light draught ; and

(iii.) The western river system, made up of the Darling, Murray, and Murrumbidgee Rivers, with their tributaries.

In waters of the first class, sailing ships with masts up to 200 feet in height are by no means infrequent, a Return furnished in July, 1896, showing that 15 sailing ships with height of masts exceeding 165 feet had visited the port of Sydney during the previous twelve months, and that 11 more were then expected to arrive ; while in a first-class port, such as Sydney or Newcastle, steamers with beam up to 45 feet are constant visitors, so that any opening structure erected across such waters should be of the most modern type, speedy of operation and providing ample waterway.

The traffic on rivers of the second class is confined to ketches and schooners with masts up to and exceeding 100 feet in height, and beam up to about 25 feet, droghers, cane-punts, etc., the conditions for the design of any opening span being unlimited headway with comparatively small opening. In such places, where the importance of the river traffic does not justify the expense of a swing bridge, traversing bridges, bascule bridges, or hinged leaf bridges may be adopted, with provision, where there is any probability of dredging above the bridge, of an opening of not less than 30 feet, in order to pass a dredge or sand-pump through, if required. With the ordinary small craft, forming the bulk of the traffic, it is not usual to open such bridges to their full extent, the span being opened for a portion of its width or height only.

On the western rivers steamers and barges constitute the only traffic The former are of the paddle-wheel or stern-wheel type; the top of the funnel or "tow-post" is thus the highest point for which clearance has to be provided. On the Murrumbidgee River (at Hay), the maximum tonnage of the steamers is 102 tons, the greatest width of beam 35 feet overall, and the maximum height above water 20 feet ; whilst the following are the dimensions of some of the largest steamers and barges on the Murray River, as shown in the accompanying photographs (by Mr. D.W. Armstrong, Res. Eng., Swan Hill).

Steamers :

	Length. Ft.	Gross Tonnage.	Max. Height above water Ft.	Beam. Ft.
S.S. Trafalgar † ..	106	228	27	33 overall
„ Bantam ...	92	—	26	39 „
„ Gem* ...	134	228	36	20·7 not over p'ddles
„ Nellie* ...	80	66	34	20·4 „ „
„ Ellen* ...	120	324	—	18·9 „ „
„ Pearl* ...	110	213	—	24·2 stern wheel
„ Corowa ...	95	210	30	20 „

* Three tiers of Cabins. † Highest trading above Swan Hill.

Barges :

Shamrock ...	112	300	17 loaded	28 overall
Echuca ...	120	178	17 „	28 „
Monarch ...	123	191	17 „	26 „

The overall width of the barges is sometimes increased by logs of timber slung from the sides, but the small headway required allows of their passing under the side spans of the bridges in such cases.

It is to be remembered in designing any opening structure for these waters, that there is a considerable variation between the summer, or ordinary, level of the river and the flood level, and provision has to be made for giving clearance at all practicable heights ; the steel lift bridges, which have been the only type hitherto adopted, are designed to give a clear headway above the highest known flood level, varying from 23 to 30 feet.

It may be noticed in passing that in waters of the two latter classes, where a bridge has to be opened on an average only from one to six times per week, the time of opening is not so much an object as economy in working, so that if the span can be raised, or opened, to its full extent by one man in 10 minutes, the result may be considered satisfactory.

Turning now to a description of the opening bridges of the colony, they may for convenience be classified in four divisions, viz. :—

Division 1.—Traversing bridges, *i.e.*, bridges where the opening span rolls back, either over an adjacent span, or over an abutment.

Division 2.—Swing bridges.

Division 3.—Hinged bridges ; these first three giving unlimited headway, and

Division 4.—Lift bridges, giving a limited headway clear of flood.

A summary of the bridges of various types is given in the appendix.

Division 1.—Traversing Bridges.

Four types are illustrated. Type 1 is that adopted first of all in the Dunmore Bridge, Paterson River, erected 1864, and subsequently, with modifications, in the bridges over the Lansdowne River at Coopernook, and over Erina Creek at Gosford, erected in 1884 and 1885 respectively, the latter being the one shown in the plate. In this bridge the opening span consists of two plate girders, 2 ft. 7½ in. deep, 14 ft. apart centres, between the webs of which are riveted light cross girders carrying the deck planking, which is 12 ft. wide between kerbs. At the centre of the span are a pair of towers secured to the top flanges of main girders, and connected overhead by a lattice girder, from the tops of which a 2½ in. x ⅝ in. rod is brought down and secured to the top flange of each main girder, midway on each side, to stiffen the girders when the span is being opened. On each side of the bridge are four cast-iron wheels, 23 in. diameter, running on an ordinary flanged rail, and worked by worm gearing operated from the deck. In Coopernook Bridge the rails extend over adjacent spans, but at Erina Creek they are carried back along the embanked approach; this latter arrangement has the disadvantage that the rails are apt to become choked with earth, though since the span is rarely opened beyond about 20 feet, this is not so serious a drawback as it might otherwise prove. At the tail end of the span is a flap which is raised during opening, the weight of the moving parts, including flap, being about 40 tons. Two men can work the span, but the operation of opening and closing is slow and laborious —due to want of stiffness in the main girders, and to the style of traversing gear adopted. It has been observed at Erina Creek that when the end A of the span leaves its bearings there is a deflection of about ¾ in. at the overhung end, with a corresponding lift at B, due to which the wheel at B is raised fully ½ in. clear of the rail, and may be spun round with the hand; the bulk of the weight is thus thrown on the two wheels on each side at the centre, and the rolling friction is correspondingly excessive.

Type 2, which represents the Lismore Bridge, opened June, 1884, is similar in the principle of the operating machinery to Type 1, worm gearing being used, the worm working a worm wheel on rear shaft of the centre bogie. The lattice traversing girders are 6 feet deep at the short end, which is made of heavier section in order to act as a counterbalance; they stand 15 ft. 9 in. apart centres, and travel inside the girders on the side spans. The deck on the opening span is of timber, 14 feet wide between kerbs, and the weight of the span is between 40 and 50 tons. This bridge has not been opened for some years.

There is a bridge with a traversing span over the Lake Macquarie entrance at Swansea (Type 3), working on a somewhat different principle to those described above, inasmuch as the flap at the tail end is done away with, and the deck of the opening span, when the bridge is closed, is at the same level as that on the side spans. The opening span, designed about 1871, was originally used in a bridge at Blackwattle Bay, and when no longer required there, owing to the reclamation of that area, was transferred to Lake Macquarie, and strengthened to carry a locomotive which ran across it, drawing stone for the harbour works.

The two plate main girders in this span have a tower at the centre, with rods on each side as in Type 1, but instead of having the flanges parallel, these are curved as shown, so that, when the bridge is closed, the tail end of each main girder projects above the deck level of the side span, being held in that position by means of a chain and screw gearing. On each of these projecting ends there is a counterbalance weight, and on slacking off the screw gearing the tail end drops and allows a pair of rack pinions, worked by a winch at the end of the span, to engage with a rack on the underside of each main girder. The span runs on a pair of wheels on each side at the centre, travelling on a rail as in Type 1, giving a clear opening of about 30 feet, but the operation of opening is heavy and tedious.

The traversing span shown in Type 4 is that used in a small timber bridge over Cook's River at Botany, over which runs a light locomotive drawing trucks, employed in conveying the refuse from the straining chamber at the sewage inlet house over to the sewage farm. The opening span is formed of two rolled girders 12 in. x $6\frac{1}{4}$ in. x 65 lb. per foot, spaced 3 ft. 11 in. apart centres, carrying the deck planking, on which is laid a pair of rails 4 ft. $8\frac{1}{2}$ in. gauge. Near the centre the longitudinal girders are supported by two 12 in. x $6\frac{1}{4}$ in. rolled girder struts, which have a jaw on their upper ends, bearing on a wrought-iron shaft passing through the webs of the longitudinal girders; the lower ends of the struts are provided each with a turned cast-iron wheel working on a vertical rail secured to the piles of pier. Both girders and struts are securely braced, and the struts are connected by diagonal suspension links from their centres to pins passing through the girders of the side span over pier. The process of working is as follows:—An endless Manilla rope, connected to the tail end of the opening span, is laid along the deck of the side span at the rear, passing over guide pulleys on the deck, and sheaves on the capsill, and is worked from a winch on the platform below; this supplies the pull on the span. As the span travels the cast-iron wheels, referred to above, run down the vertical rail, and the rolled girder struts attain a vertical position when the bridge stands about half opened. Up to this point the end of the span has travelled on two turned cast-iron wheels, running on wrought-iron plates, spiked to the deck of the side span, and forming a track curved upwards in the vertical plane, but when the struts are approximately vertical, and the wheels A have been raised to the level of the rails on the side span, the jaws on the struts then disengage from the transverse shaft, and the span runs for the rest of the distance supported on the wheels A, and the wheels at the end of the span only.

This span is easy of operation, and well fulfils the purpose for which it was designed; it was erected in 1887.

Division 2.—Swing Bridges.

The earliest swing bridges in the colony were those erected over branches of Sydney Harbour at Pyrmont and Glebe Island, in 1857 and

1862 respectively. These are both of small span, moving on a ring of cast-iron rollers, and operated by hand.

Pyrmont Bridge, which has a swing span of the deck lattice type, carried on a central pile pier, gives two openings, one of 51 ft. 6 in., and the other of 35 ft. 6 in. in the clear; while in Glebe Island Bridge, which works over an abutment, there are two shallow plate girders, connected at their centres by rods back and front to a wrought-iron tower, and affording one clear opening of 34 ft. As both these bridges will probably be shortly replaced by structures of a more modern type, it is only necessary to refer to them here.

Hay Bridge, over the Murrumbidgee River, opened in 1873, has a swing span similar in the design of the superstructure to that shown in Type 5, though somewhat smaller. In this case the span revolves on a single central cylinder 12 ft. in diameter, formed of wrought and cast-iron, the opening on each side being 49 ft. 6 in. in the clear. The main girders, four in number, are 5 ft. deep over L irons, 121 ft. long overall, spaced 3 ft. $6\frac{5}{8}$ in. apart centres, carrying a timber deck 15 ft. wide on their upper flanges, the ends of the planking being supported by T iron cantilevers secured to the outer main girders. At every bay the girders are braced together in the lower horizontal, and also in the vertical plane by diagonal angle irons, except at the centre, where these are replaced by four plate diaphragms, running the whole depth of the girders, and forming a stiff connection over the pier. The weight is taken partly on a central wrought-iron pivot, and partly on 12 cast-iron rollers, 12 in. diameter, 6 in. face, working on a cast-iron track carried on top of the pier. Motion is imparted by means of a pinion working in a cast-iron rack secured to the L iron of the cylinder; the pinion is operated by hand gearing from a platform on the side of main girder and travelling with the bridge. Mr. G. S. Mullen, Resident Engineer at Hay, has informed the writer that this bridge has been opened during the past six years on an average 106 times per annum, the river being too low for navigation during about seven months of the year. One man can open the span to its full extent in four minutes, and the working is very satisfactory.

The swing-span in the Parramatta River Bridge, shewn in Type 5, has a timber deck 24 feet 2 inches wide between kerbs, carried on top of four wrought-iron lattice girders 6 feet 5 inches deep over angle irons 144 feet long overall, the ends of the planking being carried on cantilevers secured to the outer main girders. The superstructure is braced in a similar manner to that described for Hay Bridge, the girders bearing over the pier on a circular wrought-iron girder 1 foot 6 inches deep, 18 feet 6 inches in diameter, to the underside of which is bolted the upper wrought-iron roller-track. The weight of the span, approximately 220 tons, is carried on a central pivot of wrought iron 8 inches in diameter, and 20 cast-iron rollers, 18 inches diameter, 6-inch face, rolling on a cast iron track secured to the top flange of the lower circular girder, which is seated on the top of four 6-feet cylinders, forming a square of 14 feet side, and braced to the central 6-feet cylinder carrying the pivot. One end of the span swings over a stone abutment, the other over a pair of cylinders, 12 feet diameter, sunk round the original 6-feet cylincers which were damaged by a collision soon after erection ; the clear opening on either side is 54 feet 1 inch. The ends of the span are raised when the bridge is closed by means of cams, one under each main girder, working on a transverse shaft operated by a hand-wheel at the centre of the bridge. The clear headway under the fixed spans, 20 feet above high water mark, is sufficient for the ordinary ferry traffic on the river, but the bridge is frequently opened for larger vessels, and in spite of the damage done it by various collisions, works very satisfactorily, one man being able to open the span to its full extent in three minutes. Up and downstream of the central pier there are timber-protecting platforms, while on each side of the pier guide piles and walings serve to direct the river traffic through the bridge when open ; the timberwork in these (except piles) below high water mark has been recently renewed. This bridge, which has five 150-feet lattice girder spans in addition to the swing-span, was opened in 1881, the cost of the superstructure of the swing-span being about £4,300.

The Lane Cove Bridge at Figtree, completed in 1885, consists of four plate-girder side spans, with a swing span, working over an abutment, and giving one clear opening of 47 feet 7 inches, as shewn in Type 6. The two main girders of swing-span are of the plate type, with curved upper flange, 6 feet deep over pivot, diminishing to 2 feet 9 inches and 2 feet at the short and long ends respectively, and spaced 16 feet apart centres. On the lower flanges are seated wrought-iron cross girders, 4 feet 6 inches apart, carrying a buckled plate and tarred metal deck 16 feet 3 inches wide, with two 4-feet footpaths. The span, which is heavily counterweighted at the short end, works on a 10-inch wrought-iron pivot and 16 cast-iron rollers, 25-inch diameter, 12-inch face, the roller-tracks, top and bottom, being of cast-iron ; steel carry-wheels, 26 inches in diameter, are also provided at the tail end of span. Motion is imparted by gearing worked by a handle from the deck and actuating a pinion on a vertical shaft ; this engages with a cast-iron rack secured to the abutment at the short end, one man being able to open the bridge in six minutes.

Division 3.—Hinged Leaf Bridges.

The bridges over the Belmore and Camden Haven Rivers, Kinchela Creek, and Shea's Creek Canal are of this type, consisting in each case of a timber leaf span giving 40 feet clear opening, with timber side spans ; the first two bridges were completed in 1891, Shea's Creek in 1892, and Kinchela Creek in 1893. In the hinged span, Type 2, there are two 15in. x 10in. outer girders, and one 15in. x 15in. inner girder, connected each at one end to a hinge working on a $2\frac{3}{4}$in. transverse shaft ; the deck is 10 feet 6 inches wide on the hinged span, splaying out to 15 feet on the side spans. To the other end of the span are secured two $1\frac{1}{4}$in. lifting chains, which pass over chain wheels on top of a pair of towers, and are connected to a series of cast iron balance weights filled with lead, motion being imparted by means of a vertical shaft operated by gearing, worked from a platform at the