

(Paper No. 2880.)

## “Low-Level Bridges in Queensland.”

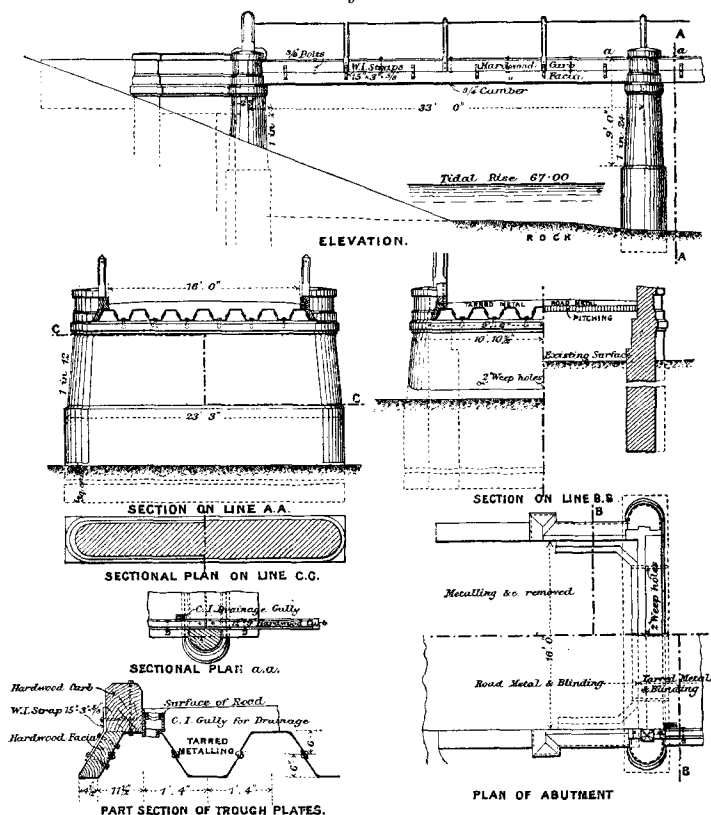
By ALFRED BARTON BRADY, M. Inst. C.E.

IN Queensland and in other parts of Australia where heavy floods are frequent, low-level bridges are necessary for carrying the main stock-routes and roads for mail-coaches, carriers' teams, cattle and sheep over the rivers and creeks in the interior. High-level bridges, above the reach of all floods, would be too costly; and even if constructed would in many instances be unapproachable during the wet seasons, on account of the low-lying country on each side being submerged. Low-level bridges are found to be much less liable to be carried away by floods than semi-high-level structures; and are frequently built even where the higher bridge would, on account of being near to centres of population, be more desirable. Floating logs and driftwood cannot accumulate against a low-level bridge, for débris is not usually carried down-stream in considerable quantity until the bridge is entirely submerged, and then all trees, logs and rubbish can float harmlessly over it. A high-level bridge to be perfectly safe, must be above the level of the highest possible flood, and must admit of the free passage of logs underneath the superstructure. In some instances, during the floods of January, 1887, March, 1890, and February, 1893, high-level bridges have been destroyed, through no defect in the design or fault in construction, but solely on account of the water reaching such a height that the superstructure was subjected to great lateral pressure from the accumulated drift, to resist which they had not been designed. Bridges built at a low level must, however, be of strong and in some localities of exceptional construction, to successfully resist the repeated strains to which they are subjected every year during the flood-season.

The four bridges to be described are typical examples of low-level bridges which have recently been erected in Queensland.

## HERBERT RIVER BRIDGE, GAIRLOCH.

The level of the decking of this bridge, *Figs. 1*, is 10 feet above high water of ordinary spring-tide, or 29 feet below the highest flood-mark. The bridge has a total length over the abutments

*Figs. 1.*Scale,  $\frac{1}{16}$  inch to 1 foot.

## HERBERT RIVER BRIDGE, GAIRLOCH.

of 481 feet 3 inches; and consists of fourteen spans of 33 feet each, the clear width of roadway between the curbs being 16 feet.

*Piers and Abutments.*—The piers, thirteen in number, together with the abutments and wing-walls, are built of Portland-cement concrete composed of one part of cement, three parts of clean

sharp river-sand, and six parts of hardstone broken to 2-inch gauge. The string-courses under the steel superstructure were formed of a stronger concrete composed of one part of cement, two parts of sand, and three parts of hardstone broken to  $1\frac{1}{2}$ -inch gauge. The pier foundations were laid on rock at depths varying between 4 feet 6 inches and 6 feet below high water, temporary wrought-iron caissons, constructed in sections bolted together, having been used. The maximum depth of sand overlying the rock-bottom was 4 feet 6 inches; and the maximum depth of sinking in the rock 1 foot 6 inches. Each pier has semicircular ends with a batter of 1 in 12 above the plinths; the batter of the sides, between the splayed plinth and the underside of string-course, being 1 in 24. All exposed faces of the concrete in the piers and abutments were floated with a mixture of one part of Portland cement to two parts of sand.

*Superstructure.*—The superstructure or decking of the bridge was formed of mild-steel trough-plates 12 inches in depth, weighing 25·82 lbs. per square foot of area covered. The plates were cambered to the extent of  $\frac{3}{4}$  inch at the centre of each span, and the sections riveted together with  $\frac{5}{8}$ -inch rivets at 6-inch pitch throughout. The trough form of superstructure possesses many advantages for short spans, as girders may be entirely dispensed with, and, in the case of low-level bridges, the small depth of the troughs offers but little resistance to the passage of flood-waters during the wet seasons. The whole of the steel-work received three coats of tar. For securing the steel superstructure to the piers and abutments, 1-inch lewis-bolts were fixed in the concrete string-courses, the upper surfaces of which were trowelled smooth and level, to form a uniform bearing for the steel-trough decking. The bolt-holes at one end of each trough were slotted to allow for expansion of the decking.

*Roadway.*—The road- or carriage-way was formed of metalling broken to 2-inch and 1-inch gauges in equal proportions, mixed with boiling coal-tar. The troughs were completely filled with tarred metal, and were covered to a depth of 7 inches at the crown and 5 inches at the curbs, being well punned and afterwards rolled and covered with sand. Drainage from the surface of the roadway is provided for by thirty gullies having outlets through holes cut in the trough decking. The curbs are of Moreton Bay ash, 12 inches by 9 inches, bolted to the steel decking; and the hand-railing is of hard-wood posts and iron chains easily removable.

*Approaches.*—The approaches were made in cutting through the sandy formation of the banks, the cutting for the south approach

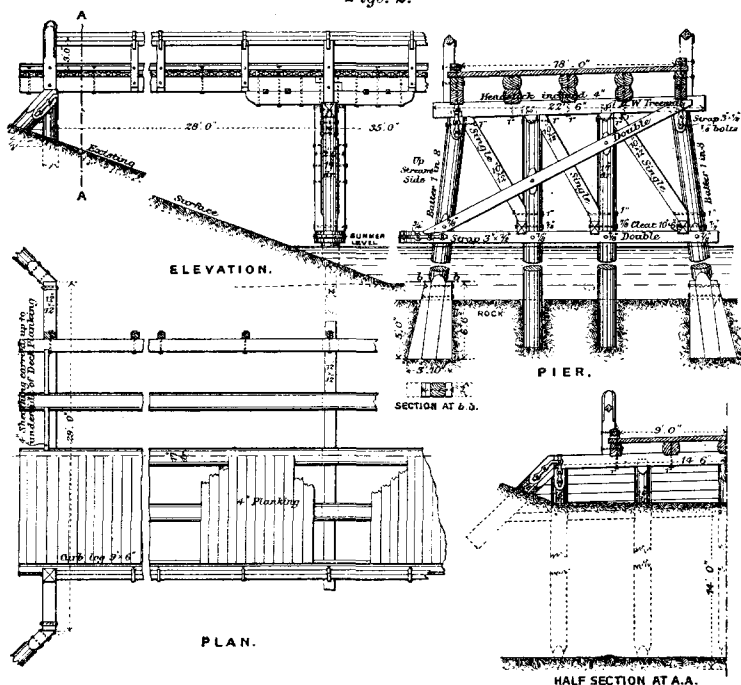
having a maximum depth of 17 feet. The slopes were faced with bricks laid in cement; and concrete water-tables were constructed at the foot of the slopes.

*Flood Tests and Repairs.*—During the construction of this bridge exceptionally bad weather was experienced; and two of the highest floods known in the locality occurred, resulting in considerable delays, loss of plant and materials, and damage to the approaches. In April, 1894, two and a half years after the bridge was opened for traffic, the Herbert river was visited by the most disastrous flood that has ever been recorded in the district, considerable damage occurring to the tarred metal or asphalt roadway on the bridge, necessitating its entire renewal. In repairing the roadway the quantity of tarred metalling, which, on account of its depth in the troughs of the decking, required a long time to set sufficiently hard for traffic, was reduced by filling the troughs to a depth of 12 inches, and forming a surface over the decking, with Portland-cement concrete, upon which tarred metalling or asphalt was laid to a depth of 6 inches, and reduced by rolling to 5 inches. The concrete was composed of one part of Portland-cement, one part of river sand, and six parts of stones from the river, of 2-inch, 1-inch, and  $\frac{1}{4}$ -inch gauges in equal quantities. The asphalt was formed of broken river-metal of 2-inch and 1-inch gauges in equal quantities, mixed with  $\frac{1}{4}$ -inch screened river-gravel, in the ratio of six parts of stone to one of screened gravel. After being thoroughly dried, heated, and well mixed with the required quantity of boiling coal-tar, it was stacked to allow the superfluous tar to drain off, and then laid on the surface of the concrete and rammed and rolled. The surface was finished with 1 inch of tarred sand and screenings, composed of four parts of coarse sand and two parts of fine gravel, screened, dried, heated and mixed with boiling coal-tar as before. After finishing, the entire surface was covered with clean sharp river-sand to a depth of  $\frac{1}{2}$  inch; and, to give sufficient time for the asphalt to harden, a month was allowed to elapse before the bridge was re-opened for traffic.

*Cost.*—The contract for the construction of this bridge was let in January, 1890, and it was completed and opened for traffic on the 4th of November, 1891, the total cost of the bridge and approaches amounting to £7,737 16s. 7d. The cost of the bridge, exclusive of approaches, amounted to £5,704 4s. 0d., or £11 17s. 0d. per lineal foot. The cost of the concrete and asphalt work, together with some other necessary repairs, amounted to £684; the total cost of the bridge being thus increased to £13 3s. 6d. per lineal foot.

## BALONNE RIVER BRIDGE, ST. GEORGE.

This bridge, *Figs. 2*, is wholly of bloodwood (*Eucalyptus corymbosa*), and consists of twelve spans of 35 feet each, with two end-spans of 28 feet each; the total length over the decking being 481 feet, and the width of roadway between the curbs, 18 feet. The height of the bridge above the lowest or dry-weather level of the river is 15 feet, the highest flood having reached a level of 16 feet

*Figs. 2.*Scale,  $\frac{1}{16}$  inch to 1 foot.

BALONNE RIVER BRIDGE.

above the bridge decking. The bed of the river consists entirely of hard rock.

*Piers.*—Each pier has four piles spaced at 6-foot 2-inch centres at the level of the headstock; the two outer piles having a batter of 1 in 8, and the two intermediate piles being planted vertically. The diameter of the piles, exclusive of sapwood, is 17 inches, the butt-end being placed downwards in every case. Each of the

outer or battered piles was lewised to the rock-bed of the river, each hole being cut to a depth of 5 feet, the dimensions at the bottom being 46 inches long by 14 inches wide. The sides and one end were cut vertically, and the opposite end tapered so 'as to reduce the length of the hole at the surface to 26 inches. The sides and ends of each hole were carefully rough-tooled to exact lines; and properly-shaped wedges of seasoned bloodwood were then inserted, and made to bear evenly against the rock. The feet of the piles were squared for a length of 6 feet 6 inches; they were then inserted in position between the wedges, and firmly driven home; the whole being securely bolted together above the surface of the rock. The wedges and the feet of the piles before being fixed were twice coated with Stockholm tar; and, after fixing, the interstices were completely filled in with strong-cement grout. The two intermediate piles in each pier, and also the abutment piles, were planted in rock, the holes for which, 24 inches in diameter, were jumped or excavated to a depth of 4 feet. The feet of the piles were freed from sapwood, and twice coated with Stockholm tar; they were then planted in the rock, the space round each pile being completely filled with cement concrete. The sites of eight of the twelve piers were above the summer level of the river, but the first four piers from the St. George side of the river were in water, necessitating the provision of a cofferdam for each pier, to admit of the holes in the rock being cut without the aid of divers. Each pier was capped with a 12-inch by 12-inch headstock inclined 4 inches in its length towards the upstream side of the bridge, and provided with double 10-inch by 6-inch walings above water- or rock-level, three 10-inch by 12-inch struts between the piles, and double 10-inch by 6-inch diagonal braces. The waling and braces were coggled on to the piles, and the whole well bolted together. The upstream ends of each pair of walings were shaped and blocked solid to form a cutwater, and were well secured with wrought-iron straps and bolts.

*Superstructure.*—Each span consists of five girders or stringers scarf-jointed over the piers, and carried upon single corbels, 14 feet long, through which the girders were bolted. The corbels were coggled on to the pier headstocks; and, in addition to being bolted, the girders were keyed to the corbels with well-seasoned wedge-keys tightly driven, working 3 inches square, and having a 4-inch projection on each side for tightening. The superstructure is secured to the piers by through-bolts and anchor-bolts. The decking consists of 9-inch by 4-inch planks laid

transversely over the girders in one length from side to side, and spiked down with 8-inch by  $\frac{1}{2}$ -inch spikes. The outer girders and corbels exposed to view are of hewn timber 14 inches by 12 inches; the inner girders and corbels being of round timber 17 inches in diameter, exclusive of sapwood, adzed flat to a thickness of 14 inches over all bearings and for the planks of the decking. The entire superstructure is built with an inclination of 4 inches towards the upstream side to prevent lodgment of driftwood under the bridge decking in time of flood. The abutments were sheathed at the back of the piles with 4-inch planking, carried also along the wings of the abutments. The curbs measure 9 inches by 6 inches, and are rounded on one edge and bolted through the decking and girders; the curb on the upstream or lower side of the bridge being raised  $1\frac{1}{2}$  inch to allow for drainage from the surface of the decking. The handrails, 6 inches square, are placed diagonally on 9-inch by 6-inch intermediate posts, and 9-inch by 9-inch main posts over the piers, terminating at the ends of the bridge in 12-inch by 12-inch guard-posts securely fixed to the girders of the end spans and tenoned into the abutment headstocks. The handrailing is only 3 feet above the decking, and of exceptional strength, without intermediate rails and wires, so as to offer as little resistance as possible during floods, and to enable it to withstand the pressure due to the accumulation of flood débris. Strong permanent handrails are to be preferred to movable handrails, which are troublesome and expensive, and their removal at the vital moment is often neglected.

*Painting and Tarring.*—The whole of the timber-work received three coats of oxide paint, with the exception of the decking, which was covered with three coats of Stockholm tar.

*Flood Tests.*—Since it was opened for traffic, this bridge has been several times submerged by floods without sustaining injury.

*Cost.*—The construction of the bridge was commenced in October, 1890, and it was opened for traffic in June, 1892, after many troublesome delays in consequence of wet weather and floods. The total cost amounted to £4,467 16s. 4d., inclusive of approaches, which alone cost £419 10s. 0d., the cost of the bridge per lineal foot amounting to £8 8s. 4d.

#### MARY RIVER BRIDGE, TIARO.

This bridge was built to replace that washed away by floods in July, 1889. Its total length is 306 feet, and it consists of seven 35-foot spans and two 28-foot end-spans; the entire work, with the

exception of the pier foundations, having been constructed of Queensland grey ironbark.

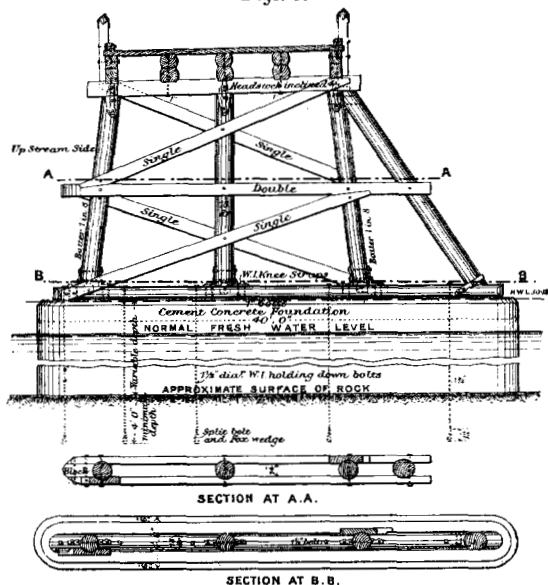
*Foundations.*—The concrete work in the foundations for the piers was built within timber framing sheeted down to the rock-level. The bottom was sealed with a layer of concrete, after which the water was pumped out and the concreting completed in layers 12 inches thick well rammed. The concrete was composed of six parts of broken stone, of 2-inch gauge, three parts of river-sand and one part of Portland-cement. Each foundation is 40 feet in length and 4 feet 6 inches in breadth, and is built to a level of 3 inches above high water.

*Piers.*—Each pier consists of three piles 18 inches in diameter, free from sapwood, spaced 9 feet 3 inches from centre to centre at the headstock level, and placed with the butt end downwards. The centre pile is vertical and the two outer piles have a batter of 1 in 8. A strut, 18 inches in diameter, is provided on the downstream side of each pier with a batter of 1 in  $1\frac{1}{2}$  to further increase the base and to assist in resisting the overturning tendency during floods. The piles and struts are tenoned into the headstocks and sills, and secured to the latter by wrought-iron knee-straps and bolts. The sills are 37 feet 6 inches long and 18 inches in diameter, squared on the top and bottom to a depth of 12 inches, and bedded in cement. They are secured by five wrought-iron anchor or holding-down bolts passing through the concrete foundations, and to a depth of 4 feet into the solid rock, where each bolt is fox-wedged. Holes for the bolts were drilled in the rock to the required depth, through 4-inch tubes driven through the sand where it overlay the rock. Wrought-iron bolts  $1\frac{1}{2}$  inch in diameter, with the lower end of each split for a length of 12 inches, and having wrought-iron fox-wedges inserted, were then put in place and firmly driven so as to fill each hole tightly at the bottom. The tubes were left in position and afterwards completely filled with strong cement grout. The bolts were increased to 2 inches in diameter at the screwed end, and over the sills they were provided with strong cast-iron washers and double nuts. The bolts vary in length between 9 feet 6 inches and 13 feet; and they are spaced at intervals of 5 feet, 6 feet, 11 feet and 10 feet respectively in each pier foundation, three being on the upstream side of the central pile, and two on the downstream side, *Fig. 3*, the greater lifting or overturning force being exerted at the upstream end of each pier when the floods reach the level of the underside of the superstructure. After the bridge has become completely submerged, its liability to injury



from flood-pressure or floating logs and *débris* ceases, until the water during subsidence reaches the level of the decking, when this element of danger to the structure again manifests itself. Each head-stock to the piers is of 14-inch by 14-inch squared timber and 22 feet 6 inches in length, inclined 4 inches from the downstream to the upstream pile to give the required inclination to the superstructure. Each pier is well braced and stiffened with 12-inch by 6-inch walings and braces coggled and bolted to the piles, the upstream end of each pair of walings being filled solid

Figs. 3.

Scale,  $\frac{1}{4}$  inch to 1 foot.

PIER OF MARY RIVER BRIDGE, TIARO.

and rounded to form a cut-water and prevent floating driftwood being caught between the walings.

*Superstructure.*—The decking of the bridge is at a level of 21 feet above high water, and 31 feet below the level of the highest known flood; the width of the roadway between the curbs is 18 feet. The design of the superstructure and abutments is similar to that of the Balonne river bridge at St. George, *Figs. 2*, the decking and girders being inclined or canted over in an upstream direction to the extent of 4 inches.

*Flood Tests.*—This bridge has been severely tested since its erection, several floods having passed over it, that of February,

1893, being the highest and most disastrous on record in the valley of the Mary, but no injury was sustained by the structure.

*Cost.*—The contract for the bridge was signed on the 9th September, 1890, and, with approaches, completed and opened for traffic on the 23rd of February, 1891; the total cost, exclusive of supervision, amounted to £2,913 3s. 2d., the cost of the bridge, exclusive of approaches, being £9 5s. 2d. per lineal foot.

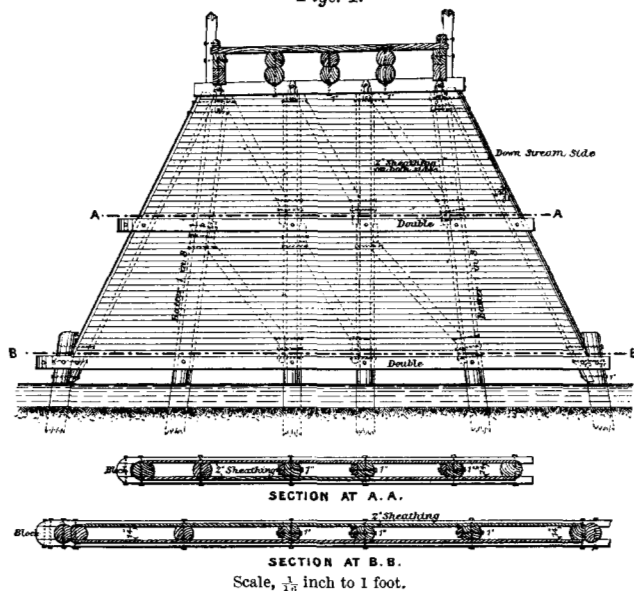
#### MARY RIVER BRIDGE, GYMPIE.

The old Channon Street bridge over the Mary River at Gympie was destroyed by heavy floods in July, 1892. Plans were prepared towards the end of that year for a timber bridge to be erected on the original site and at the same height as the old structure, 28½ feet above the summer-level of the river, or about 45 feet below the highest known flood-level. Tenders were invited for the work in January, 1893, and a contract let early in March. There are seven spans, one 40 feet, two 38 feet, two 30 feet, and two 20 feet long; the total length of the decking is 221 feet, and the width of roadway between the curbs 18 feet. The bridge is built of ironbark, blue gum, and spotted gum; and in design the superstructure is similar—excepting as to length of spans—to the St. George and Tiaro Bridges.

*Piers.*—The piers are of a design not previously adopted in low-level timber bridges, the piles being close sheathed on both sides of the pier with planking, *Figs. 4*, to prevent floating logs, branches of trees, and other débris becoming locked or entangled in the bracings during floods, and thereby endangering the safety of the bridge. This new feature in timber bridge-piers has since been adopted in several other bridges, and has given satisfactory results. Each pier of the Gympie bridge consists of four main or bearing piles and two strut piles, 18 inches in diameter at the head and 12 inches in diameter at the toe, and driven to a hard foundation. The outer main piles have a batter of 1 in 8, the two intermediate piles being vertical; whilst the two struts, from the headstock to the strut piles, have a batter of 1 in 2, the pier-base being 46 feet. The piles were driven to an average depth of 21 feet, with a 25-cwt. monkey falling 8 feet, each pile being shod with a wrought-iron shoe weighing 28 lbs. The headstocks of the piers are 12 inches square and 22 feet 6 inches long, and are inclined 4 inches in their length in an upstream direction. The walings are double 12-inch by 6-inch timbers, and are cogged and bolted to the piles, the usual diagonal bracings being omitted; but diagonal struts 12 inches by 10 inches between the piles are substituted, each

strut being bolted at each end to the piles, and abut upon chocks or cleats checked on to the walings and bolted to the piles. All the piles are squared or adzed to a thickness of 12 inches above the level of the bottom walings to receive the plank sheathing. The sheathing consists of 6-inch by 2-inch hard-wood planking, laid parallel to the walings in long lengths flush and close, and secured to the piles and squared struts with three  $\frac{3}{8}$ -inch spikes 5 inches long. The whole of the timberwork in the piers of this bridge was coated three times with Stockholm tar, and the superstructure

Figs. 4.



PIER OF MARY RIVER BRIDGE, GYMPIE.

received three coats of red-oxide paint. These are found to be the best preservatives for timber in the climate of Queensland.

*Cost.*—The bridge was opened for traffic on the 11th October, 1893, the total cost, inclusive of approaches, amounting to £1,500 8s. 6d., the cost of the bridge alone being £1,443 3s. 6d., or equal to £6 11s. 6d. per lineal foot.

The bridges described in the Paper were designed by the Author, who also supervised their construction.

The Paper is accompanied by four sheets of drawings, from which the *Figs.* in the text have been prepared.

[APPENDIX.

## APPENDIX.

## COST OF THE MATERIALS USED IN THE CONSTRUCTION OF THE FOUR BRIDGES DESCRIBED IN THE PAPER.

*Herbert River Bridge.*

	£	s.	d.	
Excavation for foundations of piers and abutments . . . . .	1	5	0	per cubic yard.
Portland cement concrete (6, 3 and 1) . . . . .	3	5	0	„ „ „
Steel-trough superstructure . . . . .	24	0	0	„ ton.
Wrought-iron in bolts, &c. . . . .		4	„	lb.
Sawn or squared timber . . . . .		4	0	„ cubic foot.
Tarred metalling on decking . . . . .	11	0	„	„ yard.

*Balonne River Bridge.*

Bloodwood piles, 17 inches diameter . . . . .	3	6	„	lineal foot.
Round timber in girders and corbels 17 inches diameter . . . . .	4	9	„	„ „
Sawn or squared timber . . . . .	4	9	„	cubic „
Wrought timber in handrails, &c. . . . .	6	6	„	„
Wrought-iron in bolts, &c. . . . .	7	„	lb.	

*Mary River Bridge, Tiaro.*

Ironbark piles, 18 inches diameter . . . . .	4	3	„	lineal foot.
„ „ 17 „ „ . . . . .	4	0	„	„ „
Sawn or squared timber . . . . .	4	0	„	cubic „
Round timber in girders and corbels, 17 inches diameter . . . . .	4	3	„	lineal „
Wrought timber in handrails, &c. . . . .	7	0	„	cubic „
Wrought-iron in bolts, &c. . . . .	4	„	lb.	
Excavation to rock for pier foundations . . . . .	10	0	„	cubic yard.
Sinking holes in rock for lewis-bolts . . . . .	1	0	0	each.
Portland cement concrete in foundation . . . . .	2	10	0	per cubic yard.

*Mary River Bridge, Gympie.*

Ironbark piles 16, 17 and 18 inches diameter . . . . .	3	1	„	lineal foot.
Round timber in girders and corbels, 16, 17, and 18 inches diameter . . . . .	3	0	„	„ „
Sawn or squared timber . . . . .	2	10	„	cubic „
Wrought timber in handrails, &c. . . . .	3	2	„	„ „
Wrought-iron in bolts, &c. . . . .	5	„	lb.	