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“On the Construction of a Lock and Weir in the River
Darenth, at Dartford.”

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THE River Darenth rises at Riverhead near Sevenoaks, and traverses the valley to which it gives its name, passing through the villages of Otford, Shoreham, Eynesford, Farningham, Sutton at Hone, Darenth, &c., until it reaches Dartford, whence it flows, through embanked marsh lands, to its junction with the River Thames at Crayford Ness. Its bed, for the greater portion of its length, lies in the chalk formation. It is fed by springs, yielding at all seasons a considerable volume of water, and the river supplies water-power to several mills on its banks. The total fall between Riverhead and Dartford, a distance of 13 miles, is 285 feet.

The head of the navigation is Dartford, where the upland waters are retained by a weir, to which point ordinary tides flow. Between Dartford and the River Thames, a distance of $2\frac{1}{4}$ miles, a considerable amount of traffic has been carried on for many years; and the navigation is controlled and regulated by the Dartford and Crayford Navigation Commissioners, who also have jurisdiction over the River Cray between its junction with the Darenth, about 1 mile below Dartford, and Crayford. The amount of the traffic may be appreciated from the revenue which in 1893 reached £700, the tolls being 1*d.* per ton on all classes of merchandise or goods in or out. By the Dartford and Crayford Navigation Act, the Commissioners have power to levy tolls, of a maximum of 3*d.* per ton, and are bound to keep the Rivers Darenth and Cray free for navigation by the removal of banks, shoals, &c. They are also required to expend on the improvement of the navigation any profits which may accrue. Prior to 1894, when the works described in this Paper were commenced, the navigation on the river, and more particularly the handling of the traffic when it arrived at Dartford, was restricted to a few hours on each tide; the bed of the river at that time being 3 feet above Ordnance datum, and the channel, but for the land-water flowing down, being dry for about

seven hours out of twelve. The chief inconvenience arising from this circumstance was that if a barge arrived at Dartford on the top of the tide and berthed alongside any of the wharfs, it was soon left high and dry; and if, as was frequently the case, there were goods to be delivered at other wharves, an entire tide would be lost at each. The same difficulty had to be encountered in loading, the loss of much time resulting. In 1893, the Commissioners, having a considerable sum of money available, determined to expend it in constructing a lock and weir to hold up the water, at and near Dartford, at a uniform level, sufficiently deep to allow barges to move about at any time—in fact, to form a floating harbour. For several reasons it was found unadvisable to place the lock lower down the river than the point at which it has been constructed. Its position being practically determined by local circumstances, the Author was in 1893 requested to advise on the mode of construction of the proposed works, which were in 1894 and 1895 carried out under his superintendence.

The lock is constructed on the right or east side of the river, where the bank was at a slope of about $1\frac{1}{2}$ to 1, and pitched with Kentish rag stone; the east wall of the lock was erected within the slope, and retaining walls about 210 feet long at each end were built to direct the channel. The weir was constructed between the west wall of the lock and the left-hand bank. The lock is 150 feet long, the gates being 25 feet wide in the clear, and the depth of water retained above the sill being 9 feet 6 inches. The weir is 90 feet long on the crest, which is fixed at 10 feet 6 inches above Ordnance datum—about 2 feet below ordinary spring-tides, but the top of the gate is 12 feet above datum; and this height was decided upon to allow of the weir being raised and the water being retained to that level if hereafter it should be found advisable. At high spring-tides the gates are submerged. The invert and walls of the lock and the retaining walls are constructed entirely of Portland-cement concrete, with the exception of the gate floors and chambers, which are faced with stock bricks. As it was anticipated that most of the concrete would have to be placed in the winter months, and would also at once be exposed to the action of the tide, it was made of exceptional richness, the ratio being from 4 to 1 to 6 to 1, according to the position in the work. The concrete in the invert and gate floors was gauged 4 to 1, the back wall 6 to 1, with a facing of 4 to 1, 12 inches thick; and the west wall, which was exposed on both faces, was gauged 5 to 1, the matrix being in every case clean gravel, most of which was obtained from the excavation, only

about 800 cubic yards of Thames ballast being used for the purpose. The pointing sills and hollow quoins are of cast-iron, the former being in three pieces, faced and bolted together, bedded and backed up with the concrete of the invert, and an oak sill for the gates to close against bolted on their face. The hollow quoins are in one length, and are moulded to fit the heel-posts. Cast-iron was adopted for these parts of the work, with a view to expedite the work, and each sill, with its hollow quoins, was placed, bolted and bedded in a single tide.

It was originally contemplated to construct the lock in a whole-tide cofferdam consisting of a single row of timber sawn on all sides; but when the work was commenced, great difficulty was experienced in driving the guide-piles true, and the contractor obtained permission to adopt a method of construction which had previously been found successful, viz., dredging a trench 3 feet deep and placing in it 3-inch planks which are carried up on the outside of the piling, the trench being filled, and the planking backed up for a height of about 3 feet above the river-bed with good clay puddle. A long time was occupied in completing the dam, and when it was finished the water was allowed to rise on the outside. After about 6 feet head had been attained, the water poured in beneath the planking in such volume that it was found necessary to open the sluice to prevent a blow; and throughout the subsequent work, until the invert was complete, the water was let in when the tide had risen 3 feet and was allowed to run out through the sluice as the tide fell. The consequent delay, however, was not serious, as there is dead low-water for about seven hours every tide, so that eight hours' to nine hours' work was made out of the twelve hours, and the work was proceeded with night and day. The amount of pumping also was moderate, an 8-inch pump would clear the water after the tide left the work in less than half an hour, and when once clear it had only to be worked for a few minutes at intervals to entirely clear the sump, which was sunk 7 feet below the bottom of invert in the centre of the lock. The bottom was inserted in lengths varying between 15 feet and 25 feet, extending the full width of the work to the back of the walls; and the concreting of each length was usually completed in a couple of tides, the surface being carefully covered with boards, weighted down, before the water was admitted. As the latter came in slowly the cement was never washed out of the work. The 4 to 1 concrete set so hard in thirty-six hours that a pick would make little impression on it. Under the invert, 9-inch pipes led from the sump to the working faces, and these were thoroughly

grouted with thinly mixed concrete before the sump was finally filled. The brick facing was carried up simultaneously with the concrete walls. The width between the walls is 26 feet, but oak rubbing-pieces are inserted at intervals of 12 feet which project 6 inches, reducing the net width to 25 feet, corresponding with the gate openings. Copings of Roach Portland stone 3 feet by 1 foot, roughly hammer-dressed, are fixed on the top of all walls. The anchor-stones are of Portland, and are fine tooled to the radius of the heel-posts.

The gates are of oak framed with red wood, with wrought-iron sheathing 3 inches thick caulked with oakum and pitched. The mitre- and heel-posts measure 15 inches by 12 inches, and the rails as follows:—Bottom rail 12 inches square, second 12 inches by 9 inches, third 10 inches by 9 inches, fourth 9 inches by 9 inches, top out of 12 inches by 16 inches. The posts and top and bottom rails are rebated to receive sheathing.

There are two cast-iron sluices in each gate, one above the other, the bottom one being slung by wrought-iron slings from the upper one, so that both are lifted simultaneously by one set of gearing; their dimensions are, bottom 3 feet by 1 foot 9 inches, top 3 feet by 2 feet. The edges are planed, and they work in planed cast-iron guides. The heel-post pins are of steel, turned and fitted into holes bored in the pointing-sills, and on the heel of the heel-post a cast-iron socket is fixed with a brass bearing for the top of the pin. Cast-iron racers and rollers are provided, and a wrought-iron turned hoop is fitted to the heads of heel-posts, which are embraced by the wrought-iron anchor straps.

The situation did not admit of levers for opening and closing the gates, so cast-iron toothed segments were securely bolted to the top rail of the gate, into which pinions, worked by bevel gearing, engage. One man can easily open either of the gates in about forty seconds, though they weigh about 4 tons each. As it was necessary to avoid interference with the traffic on the river, the lock was first constructed and the gates and other works were completed while the traffic passed on the west side of the river. The cofferdam was then removed, and, the gates being kept permanently open, the vessels were passed through the lock while the weir was proceeded with.

The weir is of L shape in plan, to give sufficient length of crest to take the heaviest estimated land floods; but to guard against possible contingencies, four shuttles or sluices are provided, each 4 feet square, which can be lifted in pairs by machinery worked from a stage above high-water level. The weir consists of

two rows of piling 15 feet apart, the front being composed of guide-piles, 13 inches square, at 5 feet centres, filled in with 6-inch sheet piles grooved and tongued with steel, the back 10-inch square piles being spaced similarly and covered with 5-inch sheeting. Double rakers 9 inches by 6 inches connect the heads of the front and back row of piles, and these form joists for the apron of 3-inch close laid planking. The front row of sheeting is backed up with concrete, 4 feet wide at bottom, 2 feet at top and 3 feet high, and the space between piling is filled with heavy stones taken from the bank and closely hand-packed. The timber for the weir was subjected to the Gardenerizing preservative process.

The total cost of the lock was £4,016, and of the weir £410, or a total of £4,426. The price of the concrete was, it must be noticed, abnormally low, being, for 4 to 1 concrete below Ordnance datum, constructed to the curve of the invert, 10s. 6d. per yard; for 5 to 1, and 6 to 1, in walls built between shutters and planking, 10s. per yard, and 9s. 6d. per yard respectively. Nearly all the ballast was found in the ground, and the Portland-cement was supplied by the Dartford Portland Cement Company, whose works were connected with the lock by a narrow-gauge tramway. The cement was specified to stand a tensile stress of 380 lbs. per square inch at seven days; but from tests made constantly as the work proceeded, the average strength was 490 lbs. per square inch, and only in two cases was it as low as 400 lbs. The average strength at fourteen days was 568 lbs. per square inch, and in a few instances the strength at thirty-one days was 674 lbs. per square inch. All the castings and machinery were made at Dartford. Notwithstanding the advantages resulting from the works to craft-owners and owners of property and merchants at Dartford no additional tolls have been exacted by the Commissioners on account of the outlay entailed by the construction of the lock.