

arguments and we can only indicate, at present, the general course of examination, with the hope that others may assist in its proper conclusion.

*Method of Building under Water.* By JOHN MOFFAT, C. E.

From the Lond. Civ. Eng. and Arch. Journal, Mar., 1865.

[Read at the Institution of Engineers, in Scotland.]

Quay walls are the principal objects of subaqueous construction; and these have hitherto been made of wooden or iron framing, or of stone or brick masonry. In the former case they depend for their stability chiefly on the strength given by cohesion, and in the latter on that afforded by their weight. The security and durability of masonry, as compared with any description of framing, in every kind of harbor construction, are so great, that it would be invariably adopted, were it not for the consideration of time and expense. A pier can always be made of wood or iron much quicker and cheaper than of stone; and on this account they are frequently resorted to in cases where the time or the money at the disposal of the engineer render the superior structure unattainable.

About ten years ago I had an extension of the outer quay and break-water at Ardrossan Harbor to execute, which had to be completed in one summer, and for a limited sum. All the works at that harbor have hitherto been executed in stone, except a small pier of timber, which, though cheap at first, turned out in the long run to be the dearest work we had, on account of its being destroyed by the *Teredo navalis* in about ten years. We had also found that cast iron is corroded so rapidly, as to render an iron structure nearly as objectionable as a wooden one. And I was thus induced to turn my attention, to devising a plan for executing the building in masonry, within the limits assigned to me. And I succeeded in doing so, by the plan which I shall now proceed to describe.

In a stone pier, the portion which consumes most time and money, is that under low water. Hitherto this portion has been built in separate masses in wooden caissons, and floated to its position when completed, the sides of the caisson being disengaged when the mass of masonry had been set. Or it has been formed entirely of large squared ashlar, dropped into its place by means of water lewis, or set by means of the diving bell. At Ardrossan the masonry under water has been built entirely of ashlar, set partly in the first way, and partly in the second. Where set by the water lewis, the stones are laid so that the beds are not horizontal, but at an angle of 45°. After the first row of stones has been laid, and which must be done with very great care, the remainder are lowered so as to catch the upper edge of the inclined bed, and are slipped along it until they reach their position, when the lewis is disengaged in the usual way. Where set by the diving bell, the courses are horizontal, and form a solid mass of ashlar of the ordinary construction.

I found by calculation that with the plant at my command, I could

not complete the extension, by either of these methods, in less than two seasons, and that the cost would exceed the sum at my disposal. It then occurred to me, that I could attain my end by forming the masonry under low water of large hollow masses of brickwork, constructed in the graving dock, and floated to their position in the quay, after reaching which they could be filled with concrete. And on trial I found that this plan could be easily carried out, and furnished a method of submarine masonry much cheaper and quicker than any I had yet tried.

The average depth at low water was nearly 20 feet ; and I leveled out the foundation, and laid three courses of ashlar with the diving bell in the usual way, so that the upper bed was about 15 feet from low water. The hollow brick masses were made 15 feet long, 15 feet deep, and 11 feet thick. The bottoms were of cast iron plates  $\frac{3}{4}$ -inch thick, strengthened with projecting feathers along the edges. The walls were 20 inches thick, formed of large bricks 20 inches long, 10 inches broad, and 5 inches thick, set in Roman cement, and strengthened by horizontal strips of hoop-iron laid along the courses. When finished they were nearly water-tight, and their specific gravity was a little less than sea water. They were floated to their positions by being attached to one of the harbor punts, set at low water, and then filled with concrete. The ends were formed with alternate salient and re-entering angles, so as to lock into each other. The wall above low water was built of ashlar and rubble in the usual way ; and the work was finished in a satisfactory and substantial manner in the summer of 1855. The length of the pier was fully 300 feet, the average breadth 70 feet, and the cost was under £10,000. The average cost of the brick masonry under low water was 7*d.* per cubic foot, or about one-half the cost of solid ashlar.

The work has now stood for nine years exposed to a rough sea and a heavy traffic, and is as perfect as when completed. Four years ago I had occasion to cut down the masonry to low water, in order to erect a 20-ton steam crane, which I constructed on the top of one of the brick masses as a foundation ; and I found it then to be in the same condition as when set.

I had recently occasion to extend another of the quay walls, in water about 10 feet deep at low water ; and this extension I resolved to construct in a similar way to the previous one, but in a cheaper manner. The bottoms were made of wood instead of iron, and the bricks were of two sizes, at the ordinary price, instead of the large size previously used, which cost nearly twice as much. I originally made the brick masses only 15 feet long, from a fear that larger sizes would be unmanageable. But having found them to be very easily handled, I resolved to make them on this occasion double the length, or about 30 feet long.

This extension was also successfully constructed in a very short time ; and the drawings on the wall are intended to show the construction in detail. From the ground plan it will be seen that the extension is about 110 feet long, 35 feet broad, and the walls 27 feet deep.

The bottoms of the brick masses, which varied in length from 29 to 33 feet, were formed of a light wooden framing, formed of two beams of yellow pine 9 inches square, to which was spiked a platform of 3-inch white pine battens. These were caulked so as to be water-tight, and set on four logs on the bottom of the graving dock, as a foundation on which the brick caissons were to be built. The outer walls were formed of common bricks of two sizes—the one  $9\frac{1}{2}$  inches long,  $4\frac{1}{4}$  inches broad, and  $3\frac{1}{2}$  inches thick; and the other 13 inches long,  $6\frac{1}{2}$  inches broad, and  $3\frac{1}{2}$  inches thick. These were laid in alternate courses—the small bricks in one course, and the large ones in another, header and stretcher alternately, so as to give proper bond. The outer walls were thus 20 inches thick all round, and the front and back walls were connected by three cross walls one brick thick. The whole was set in Roman cement, and strengthened with hoop-iron laid along the bed of the courses. The weight was adjusted, so that when finished they floated, with the top about one foot above the surface of the water.

The size was determined by the length of the logs from which the longitudinal timbers of the bottoms were cut. For these I selected logs varying from 29 to 33 feet long, and nearly 18 inches square, which were cut into four timbers, the full length of the log, so as to avoid any waste. The average size of the caissons was 32 feet long, 13 feet deep, and 10 feet thick. When the brickwork was finished, a small beam of timber was laid along the top, and connected with the bottom by means of two long bolts of wrought iron 2 inches in diameter. The water was then let into the graving dock, the brick masses or caissons were floated, and attached to the diving bell barge, or to a crane punt, and towed to the place where they were to be set. They could be raised about 4 inches above the line of flotation by means of the crane on the punt, and were suspended at this level above the bottom, by means of the long bolts above described, until they were brought to their exact position in the work, when they were at once lowered on to the bottom, and filled with concrete. When they were set in their places, the top beam and bolts by which they were suspended were removed and used again. The concrete used to fill them was formed with a mixture of good hydraulic mortar and cement, and large gravel, in the proportion of 1 of the mortar to 2 of gravel, which I found to set in a short time into a very hard compact mass. All the brick caissons were of an oblong form, with square ends, except the closing one across the end of the quay, which was formed with rounded corners to a radius of 13 feet. I found that forming the ends with salient and re-entering angles caused a great deal of trouble both in building and setting, and was of very little use.

These operations were all carried on without the slightest difficulty. As a proof of which, I may mention that on one occasion I built four of the caissons in the graving dock at once, and floated them into their places in two tides, thus completing 126 feet of wall in twenty-four hours. When the brickwork was finished the masonry was begun on the top, and completed with a facing of ashlar and a backing of rub-

ble in the usual way ; and the space between the walls was filled with stones.

The cost of the work was £1881, or £51 per running yard, being less than the cost of open timber piling, which would have been great inferior both in efficiency and durability. The cost of the porting under low water was 4d. per cubic foot, concrete included.

I may mention that I am at present constructing another wall in a similar way, and that I have made some of the brick caissons even larger than I have stated. But from what I have seen, I think that about 40 feet long is the largest size which admits of their being easily handled.

Of course the possession of a graving dock offers great facilities for the construction of these floating masses of brickwork. But there is nothing to prevent them from being built on the beach in sheltered places by tide-work, and floated off at high water when finished ; they may be constructed on the ground above the level of high water and launched on slip-ways like a ship.

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### *Steel Bridges.*

From the London Mechanics' Magazine, February, 1865.

At the meeting of the Literary and Philosophical Society on the 24th ult., Mr. S. B. Worthington, C. E., stated that he had lately constructed a swing bridge for carrying a railway over the Sankey canal in which the girders are made of Bessemer steel plate. The object in using steel instead of wrought iron, was to reduce the weight of the girders. The girders are four in number, about 56 feet long, with bearings varying from 30 to 40 feet, and two feet deep. They were manufactured by Messrs. Benjamin Hick and Sons, of Bolton, from steel tubes made by the Bolton Steel and Iron Company ; and were tested with loads of a ton to the foot, or more than double the weight which they could possibly be called upon to bear. The deflection varied from  $\frac{1}{2}$  inch to 1 inch according to the length of the girder, and there was no permanent set on removal of the testing load.

The plates used varied from  $\frac{1}{4}$ -inch to  $\frac{7}{8}$  in thickness ; and the average tensile strength of a considerable number of plates tested, upwards of 36 tons to a square inch. The weight of the girders was about  $\frac{5}{8}$  of the weight which they would have been if wrought iron had been used. The contract for this bridge was made in November, 1864, and the bridge was erected during the past summer.

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### *Bursting of a Reservoir.*

From the London Mechanics' Magazine, Dec., 1864.

On the 31st ult., a catastrophe occurred at the seaport town of Irington, Cumberland, similar in some respects to that which produced such devastation around Sheffield in the early part of this year, though upon a much smaller scale, and fortunately unattended with any loss of life. About 11 o'clock on that day a reservoir, three acres in