variety of curves in the architrave and cornice, as ascertained by Mr. John Pennethorne,* was even still more extraordinary.

March 12, 1844.

The PRESIDENT in the Chair.

No. 663. "Account of the Town and Harbour of Pulteney-Town (Wick, Caithness), from their origin in 1803 to the year 1844." By James Bremner, M. Inst. C. E.

Pulteney Town Harbour.

Pulteney-Town and Harbour, situated in N. latitude 58° 26′ 45″ and W. longitude 3° 3′ 56″, are the property of the British Fisheries Society, which was established under Acts of Parliament, for the purposes of extending the fisheries, and improving the sea-coasts of North Britain. They were, under these Acts, empowered to construct this harbour, which, with the town, was planned by Mr. Telford in 1803; both are located upon the property of Sir George Dunbar of Hempriggs, and are separated from the burgh of Wick by the river, which is spanned by a stone bridge of three arches, with a clear water-way of 156 feet: it was built in 1805 by Mr. G. Burn, also from the designs of Mr. Telford.

In the same year, the old or north harbour (Fig. 1), was commenced. With the exception of the pier heads, which were founded by the author, for the contractor, at a depth of 4 feet below low-water mark, the outer walls were all constructed above that level, on a bed of blue clay mixed with stones. The works were of ordinary construction, having behind the face-walls clay puddle, within which, sand was used as hearting. A mass of boulders, whose tops reached the level of half tide, lay outside the pier heads, and protected them from the action of the sea. This harbour was finished in 1811 at an expense of £16,400.

The bed of Wick Bay is sand to a considerable depth; this sand, when disturbed by storms, is driven in great quantities to the head of the bay, where the river empties itself into the sea; with freshes, in easy weather, the river carries the sand thus lodged near its course, towards the harbour entrance.

The north harbour thus soon became nearly filled with sand, from the nature of its situation and the position of its entrance, and owing to this, and the very small rise of tide at this place, the depth of

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* Vide "Pennethorne's Topography of Athens," 2nd Edition, page 573.

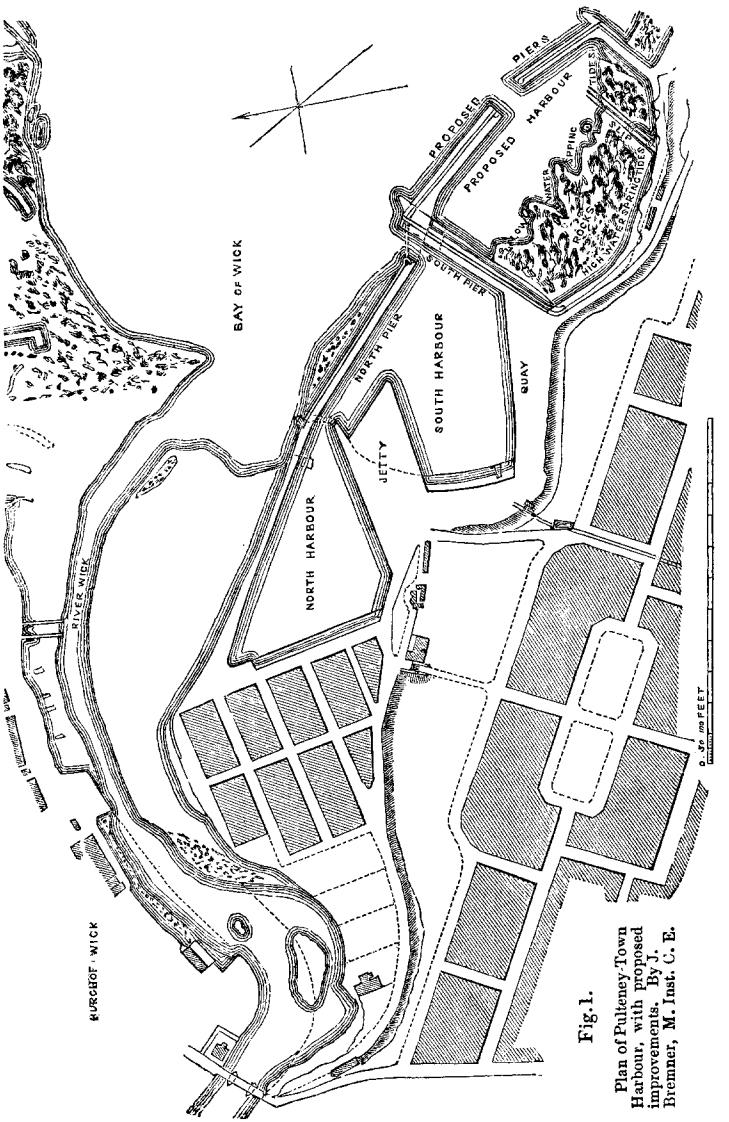
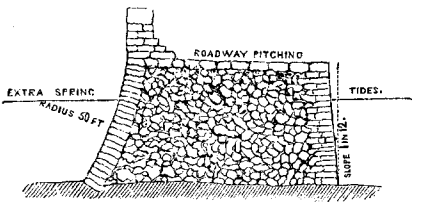


Fig. 1.
Plan of Pulteney Town Harbour, with proposed improvements. By J. Brenner, M. Inst. C. E.

water in the interior, with ordinary spring tides, did not exceed 8 feet 6 inches.

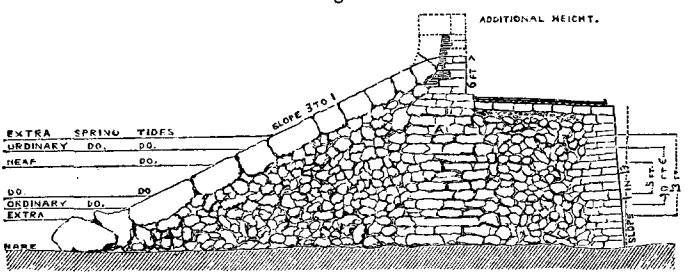
The rise of tide at Pulteney-Town, as shown in the accompanying sections (Figs. 2, 3, and 4), is, with neap-tides 5 feet; with ordi-

Fig. 2.



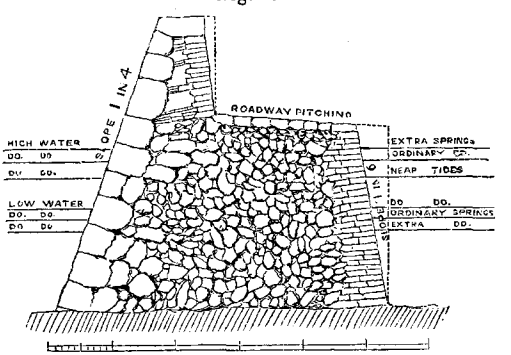
Cross Section of North Pier.

Fig. 3.



Cross Section of South Pier.

Fig. 4.



Cross Section of proposed Pier.

nary springs 9 feet 6 inches; and, with extraordinary springs, from

the point of the lowest ebb, to that of the highest flow, is 13 feet. From this some idea may be formed of the difficulty of making a harbour, sufficient for the ingress and egress of the ordinary size of vessels, even with spring tides; so that to obtain a sufficient depth of water, it was requisite that the piers should be formed under low-water mark.

To account for this limited rise of tide is not difficult. The Bay of Wick is only 17 miles from the east entrance of the Pentland Frith, which separates the Orkney Islands from the mainland. This frith, or strait, being only 7 miles wide, is quite inadequate to communicate each tide to the Moray Frith, the rise and fall of the North Atlantic ocean on its western side. From this source, the tide in it flows for 7½ hours at the rate of 11 miles an hour; while from the Moray Frith, at the north side of the mouth of which Pulteney-Town is situated, it ebbs only 4½ hours, on account of the barrier formed by the Orkney Islands; accordingly, vessels bound to the eastward find no difficulty in getting through this strait; while those proceeding westward having so limited a tide, are often put back from near Cape Wrath in attempting to get round it.

The north harbour was first used by coasting-vessels, which at that time were of a very small size, from freights being so high as to enable the smallest class of vessels to pay well. After the conclusion of the continental war, however, freights were lowered so that small vessels, for which this harbour was only fitted, could no longer be lucratively employed. This occasioned the use of vessels of a larger draught of water, which rendered the north harbour almost useless.

The practice of partially loading in the harbour, and finishing in the bay by means of boats, was not only attended with extra expense, but also, in many cases, with the loss of lives and property, owing to the very great exposure of Wick Bay. This, together with the cost of removing the sand that accumulated in the harbour, and the rising prosperity of the town, led to the erection of the south harbour in deeper water. This prosperity was chiefly induced by the success of the herring fishery, for which Pulteney-Town has always sustained a high reputation, and it is now perhaps the largest fishing-port of the kind in Great Britain.

The survey for the south harbour was made by Mr. J. Mitchell, and his plan for it, after being revised by Mr. Telford, was adopted in 1823. The contract, which embraced the present quay, and 175 lineal feet of the south pier from the inner angle, was let to the author, and in 1825 he was directed to extend this pier 100 feet further; in 1826 he was again called upon to construct an extension of the south pier to its present length, a great part of it being from 4

feet to 8 feet under the line of the lowest spring tides. In the same year, the author entered into a contract for building the north pier; building and embanking the jetty; making an opening from the south to the north harbour; and closing in the old entrance of it; and for completing the harbour as it remains at present.

In preparing to carry on these works, two powerful barges of 40 tons and 60 tons burthen respectively, were built; one of them having one crane, and the other two cranes on a new construction. By means of a double line of railroad to the quarry, a plentiful supply of stones was procured at all times. The barges were also, in good weather, enabled to carry stones from a part of the bay about a mile without the harbour, and were worked with safety and expedition, by means of track-lines laid out in the direction of the loading-place. The importance of having a large supply of materials for a work of such magnitude and hazard, will at once be seen, when it is stated, that only about 24 weeks in the year are fit for carrying on such works. Aware of this danger, and of the heavy nature of the work of forming the last 100 feet of the south pier, the author had a large number of masons, quarriers, lightermen, and other men employed night and day in the season of 1827, and had made rapid progress towards its completion. All would have been finished by the 20th of September of that year, but unfortunately on the 10th of that month a violent storm arose, and, notwithstanding the temporary blocking up, which was used as a precautionary measure, about 100 feet of the pier head were swept down in one tide, to the level of low water. From having to bond the last portion properly with the end of the former, this joining was laid open, and 20 feet within it was also laid in ruins by the next tide. The stones were carried to a distance of nearly 100 feet from the work, by the force of the sea, and chiefly into deep water.

To prevent the breach from spreading, and causing the destruction of the whole work, 50 shipwrights, and 300 masons and labourers were employed, in placing nearly 40 tons of chain cables round the open end, and upon the pitching of the roadway, and fastened them securely inwards; this was accomplished in two tides, although the storm did not abate. Very large stones were afterwards laid on the open end; this proceeding, with due attention to the chains, was the means of avoiding the destruction of the whole work, during the stormy winter that followed; as it was, the loss sustained in the two tides, amounted to £5000.

The cause of this failure, may justly be ascribed to the great slope and the low parapet, by which the sea was thrown bodily upon the roadway, the pitching of which first gave way; a portion of the

hearting then followed; afterwards the front wall fell, until at length all support was removed from the pitching stones of the slope, and they also were carried away.

In order to prevent such an occurrence in future, a wall of large rough stones was built under the parapet, as shown on the cross section of the south pier (Fig. 3); the roadway pitching was, in addition, wedged firmly with fir wedges, on which cills of 1½ inch boards, going along the roadway, were spiked down at intervals of 10 inches apart; on these cills, boards 1 inch in thickness were fixed and closely joined together, the outer ends laying to the foot of the parapet, while the inner ends reached half way over the coping of the front wall, so that the sea in falling from the parapet, was not allowed to touch the pitching.

Early in the spring of 1828, preparations were made for rebuilding the work which had been thrown down; so much difficulty was experienced in the erection of machinery and clearing out the old materials, that it was found easier to quarry most of the stones afresh, than to drag out of deep water, the stones which had been carried thither by the sea.

The machinery used by the author, consisted of four jib cranes, which were set in strong frames of timber, of sufficient height to build the front wall and the parapet. There were also two radiating beam-cranes, each 110 feet in length, working upon rails supported by posts built into the slope, moved round by a small rope tackle on each side, and having a travelling carriage on each for the crane chain. These cranes took in the whole range of slope, without being moved, and were very efficient.

The stones used for the construction, were of hard quality and naturally well shaped for the work; they varied in dimensions from 3 feet to 20 feet in length, by 3 feet to 8 feet in breadth, and 8 inches to 15 inches in thickness. In the slope they were set on edge, and the courses were placed diagonally; in the front wall they were laid flat, the beds being perpendicular to the line of face.

In laying the foundations under water, the two-crane lighter was particularly useful, one crane being used for clearing away the sand, by means of a bag and spoon, while the other set the stones in their places. The foundation course of the slope, consisted of large blocks of stone, each from 15 tons to 20 tons weight, and it was for floating these stones, that the author first used the casks, of which he presented the description to the Institution (No. 622).*

In the month of September in the same year, the whole length of

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* Vide page 122.

120 feet of pier was completed, and since that period, not a single stone has been removed by the sea.

The parapet of the south pier being only 6 feet in height, with a flat slope on the outside (Fig.3), was but ill adapted for affording a shelter on the inside of the pier in storms; in fact the sea broke over it at high water as over a half-tide rock. After many representations on the part of the author, it was resolved to raise the parapet to the present height of 14 feet (Fig. 3), which was done in the following year. The necessity for this, appears from the fact, that even now, during storms, the spray is carried a distance of 100 feet, after passing over the parapet. If the slope had been less, the force of the receding wave would have been increased, so as to counteract the force of the wave, on meeting it, before touching the slope; at its present inclination of 3 to 1, the receding wave only adds to the bulk and violence of the approaching wave.

During the year 1830, great progress was made with the north pier and the interior works. The harbour was excavated to the level of low water of ordinary spring tides, and the material obtained was used in the hearting of the jetty. A very slight batter was given to the back wall, because, the sea, in running along the face of the pier, at an angle of 45°, exerted but little force against it.

The south harbour was completed in 1830, and cost £20,900, including the opening connecting it with the north harbour, closing the old entrance, and all repairs for three years after its completion; the quarry was near, and labour was cheap, or nearly double the amount would have been expended.

The effect of the north pier, in contracting the bay, has led to a large accumulation of sand on the north side of the river, which is a proof, in the author's opinion, that if the sea be carried past the entrance of any harbour, the sand is, necessarily, carried past with it; in this case, great change was produced by the junction of the two harbours. The north harbour was rendered much more convenient and safe, and less liable to be sanded up; it was soon after deepened, and the pitching of its roadways partially relaid.

It is still to be regretted, that in stormy weather, the south harbour does not afford proper shelter, and considering that it is surrounded (excepting a slope of 300 feet in length), by perpendicular walls, which add to the recoil of the sea within, this is not to be wondered at. Besides this evil, it is liable to become partially sanded up, probably from the effects of the river running against the projection of the south pier, beyond the projection of the north pier; the removal of this sand has been attended with some cost and trouble.

Pulteney-Town covers a large space of ground, and is composed of

neatly built houses, two and three stories in height; the population is estimated at 3,200, entirely sprung up in thirty-eight years.

Ship and boat-building, and the rope and sail-cloth manufactures are extensively carried on, but the fishery forms the staple trade of the place, so that fish-curing and cooper-work are carried on to a great extent. The average quantity of herrings caught annually, exceeds 60,000 barrels; and about 12,000 persons, chiefly strangers, are employed during the fishing season, which extends usually from the middle of July to the early part of September: about 600 fishing boats, each of 20 tons burthen, enter and depart from Pulteney-Town when the weather permits. The shipping frequenting the port in 1843, amounted to 53,952 register tons, of which 5,460 tons were in the foreign trade.

An increase of harbour space, and of depth of water, has been so eagerly sought after, recently, that the British Fisheries Society applied to the author for a plan, comprising a low-water harbour, which should be altogether free from sand, the entrance being in deep water and away from the influence of the river, while the pier heads should be so placed as to throw the sand past them, along with the sea, and at the same time be easy of access, which would be important for a refuge harbour. A slope of 750 feet in length, with an inclination of 1 in 12, for expending the force of the sea, would be required. The south harbour also required to be freed from sand, and deepened. This plan is shown in Fig. 1, and an Act of Parliament has recently been obtained for its execution.

The paper is illustrated by two drawings, (Nos. 3592 and 3593,) giving the general plan of the harbour, with the proposed improvements, and the sections of the pier walls, with the sea slopes and the method of constructing them.

No. 662. " Description of the Casks used for floating large stones, to construct Sea Walls in deep water." By James Bremner, M. Inst. C. E.

Casks for floating Stones.

The ordinary mode of conveying stones for harbour work, is by means of two large boats, with baulks of timber lashed across them, from which rope tackles are suspended. These tackles are hooked on to 'lewises' inserted into the stones, and tightened at low water. When the tide flows, the stone floats, and it can be conveyed to the spot where it is intended to be laid. Stones weighing 40 tons each, have been thus transported several miles, without difficulty, in good weather; but it has been found, that the boats were soon strained,