

(*Paper No. 2125.*)

## “Wicklow Harbour Improvements.”

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As far as the Author has been able to learn, no satisfactory attempt has hitherto been made to construct sea-walls, in exposed places, by means of concrete entirely laid in position ; and the works carried out at the port of Wicklow are, he believes, the first instance where this system has been successfully adopted throughout, in a situation exposed to the open sea. The works, during their progress, were chiefly affected by storms ranging from south-east to north-east, being sheltered by land in other directions; the greatest waves come with storms from the south-east, as northerly storms do not raise heavy seas. A small rocky headland afforded some shelter to the mouth of the River Leitrim, which was encumbered by a bar across its entrance, having only about 18 inches of water over it at low-water spring-tides. As the range of spring-tides at Wicklow is about 9 feet, and of neaps  $6\frac{1}{2}$  feet, the small coasting vessels trading with the port, drawing 8 to 9 feet when loaded, could rarely enter or leave except at high-water spring-tides. The depth of the entrance channel has now been so improved that vessels drawing from 11 to 12 feet of water can enter and leave the port at any state of the tide.

Though a sum of £18,000 was expended between 1851 and 1871 in repairing the quay-walls, and in the attempt to obtain the depth of 8 feet at low-water, required by the Wicklow Harbour Act before the Harbour Commissioners could levy tolls, the works became impaired, owing to the absence of funds to continue the work and for maintenance ; so that the desired depth was not attained.

At the end of 1879, the Author submitted a comprehensive design for the improvement of the port, at an estimated cost of £40,000, to be raised by a public loan on the security of the rates of the neighbouring baronies ; and in August 1881, a contract was made with Mr. John Jackson, of Westminster, for the carrying out of the works. These consisted of a breakwater, protecting the entrance to the river and forming a prolongation of the rocky headland on the right bank ; a deep-water packet-pier

at the end of the opposite bank (Plate 5, Fig. 1); the rebuilding of 320 feet of river quay-walls, founded 6 feet below low-water; the repair of 600 feet of quay-walls; and dredging to obtain the requisite depth in the river. The breakwater projects far enough to protect the river entrance from northerly gales; and an ample opening is left for the easy entrance and exit of vessels. Higher up, the river expands into a wide estuary, affording considerable scour through the entrance channel at each tide; so that since the removal of the bar, this scour, aided by the position of the piers, has sufficed to keep the channel clear of silt without any dredging.

The breakwater has been formed of solid concrete throughout, so that it is much stronger than sea-walls constructed with outer and inner walls of large blocks with rubble hearting between, whilst the cost of construction is lessened by the large reduction in the amount of the materials. The breakwater is 750 feet long, and is founded for about two-thirds of its length on rock, and the remainder upon marl (Plate 5, Fig. 2). At 450 feet from the end, the depth attains 13 feet below low-water spring-tides, and increases gradually to the extremity which is founded at a depth of 18 feet; so that this portion of the breakwater can be used in ordinary weather as a quay for discharging vessels. The breakwater is 30 feet wide at the quay-level, and has a batter of 1 in 6 on the seaward side and 1 in 12 on the inner side. The quay-level is 5 feet above high-water spring-tides, and the top of the parapet wall  $13\frac{1}{2}$  feet higher; the breakwater, in a depth of 16 feet, contains about 40 cubic yards per lineal foot (Plate 5, Fig. 9). A small lighthouse, with a fifth-order dioptric apparatus, and lighted with oil, has been erected at the end. The total cost of the breakwater was £23,660, including the cost of the gravel and sand for concrete dredged from the river.

No special arrangements were required for the first portion of the breakwater, as the foundations were above low-water; but the concrete in position proved very advantageous in adapting itself to the very rugged rock at this part. When the depth increased, a staging was erected in front of the work, consisting of six or eight trestles of pitch-pine barks, placed 14 feet apart, and carrying two lines of railway as shown by Plate 5, Figs. 2 and 3. A Titan, mounted upon carriages running on both lines of railway, was placed on the advanced part of the staging: it turned upon a pivot exactly over the centre of the wall, and a pile-engine attached to one of its arms fixed the profile piles which subsequently served to keep the panelling in position. A 5-ton crane was employed

to deposit the concrete from skips; and a small locomotive with skips and wagons completed this portion of the plant. A strong rectangular barge, carrying a 5-ton steam-crane, and to which a B size Priestman digger was attached, was employed for dredging the harbour, and at the same time obtaining materials for concrete; and there were about six attendant barges, each capable of holding 40 or 50 cubic yards of dredged material.

The staging was secured at the bottom by depositing about 50 cubic yards of concrete round the feet of the piles of each trestle by a skip from the crane-barge. These shoes of concrete became hard enough in a few days to secure the staging thoroughly, and subsequently formed part of the mass of the wall. Each section of staging, consisting of six to eight trestles, occupied generally from a week to ten days to fix; concrete being simultaneously deposited in the rear portion of the breakwater.

In the early part of the work, under low-water level, long panelling was employed reaching to the bottom, and the concrete was carried up in layers inside it; but the operations were frequently stopped by storms, when the panelling got often damaged or destroyed. As the staging proved generally strong enough, by itself, to withstand storms, it was found desirable to make the panelling comparatively light, so that it might be the first to give way. Experience, indeed, showed the expediency of casting the panelling adrift on the approach of a storm, so as to avoid its breaking and damaging the face of the concrete, as it was found that so long as rubble was kept well away from the face, concrete only twenty-four hours old was very little injured by the waves, except in severe storms. On one occasion, in the early part of the work, a layer of concrete had been deposited in the morning, raising the wall from about 6 feet to 2 feet below low-water, and in the afternoon a storm suddenly arose, and, lasting for some days, carried away the panelling with a good deal of the freshly-laid concrete. On subsequent examination, it was found that a great wedge of the concrete had been detached on the outside down to the top of the older work, and, having slipped over the edge, had settled in the form of a hard sloping toe against the base of the work, so that it was necessary to cut the panelling away, in fitting it to the face, to clear the excrescence. This occurrence confirmed the idea, which had been suggested by the firmness of the concrete shoes, that concrete could be deposited successfully without the use of panelling, even without waiting for calm weather. The process of construction was accordingly modified; and the several steps in depositing the concrete on this system

are illustrated on the cross sections (Plate 5, Figs. 4 to 9). A large central mound was deposited along the whole length of the advanced section of the staging; the profile piles were then put in place, and the panelling was attached to them, but only brought up to 3 feet below low-water, when the comparatively small space was quickly filled with concrete; and afterwards, in favourable weather, fresh panelling was added, so as to bring the work above low-water level (Plate 5, Fig. 6). Though quite as stormy weather was experienced after the adoption of this system as before, no panelling was destroyed or lost; while the mound renders the staging far more secure for supporting the panelling. When the marl bottom was reached, some of the staging piles were driven into the ground; but it was found that no advantage was thereby gained, either in saving of time or stability, over the concrete shoes, so the same plan was continued throughout as on the rock foundation.

This system of depositing the concrete enabled very rapid progress to be made, so that frequently in favourable weather 250 cubic yards were deposited per day. The loss of fresh concrete in depositing the central mound, on the arrival of a sudden storm, was small; the surface was always found clean and hard, and the loose gravel and sand washed close to the inner toe of the mound. In laying the mound in deep water, a good deal of concrete was deposited with surface waves 2 to 3 feet high, which would have been impossible with long panelling. When the outside of the work had been raised high enough to afford shelter, the inside face and hearting were laid, after clearing away the loose gravel or sand from the inside toe of the mound.

The irregular cracks which occur in long continuous concrete walls, owing to variations of atmospheric temperature, were avoided by making vertical separations in the structure by means of cross panels, at intervals of about 40 feet, starting from low-water level upwards; a little higher up intermediate separations were introduced, and further subdivisions were made in the upper part. Thus the structure was parted by articulations, increasing in number in the upper part, which is subjected to the greatest variations in temperature. By this means, irregular cracking has been prevented; whilst the masses into which the work is divided are far larger than could be attempted in block construction. The only troublesome portion of the work was the face between low-water and 2 feet below, as waves only from 6 inches to 1 foot high squirt the water between the joints and around the end of the panelling, tending to wash out the cement before

the concrete has set. Stronger grooved and tongued panelling, and canvas lining inside and outside the panelling, were tried; but the most effective remedy consisted in adopting richer and finer concrete in the proportion of 4 parts of sand and gravel, and sometimes 3 parts to 1 part of cement, whereby a good face has been obtained. The faces were tested during the progress of the work by probing with steel-pointed bars, and no serious defects were ever found up to about 3 feet below low-water.

The average proportion of the concrete was 7 parts of gravel and sand to 1 part of cement, the gravel and sand being found very clean and good as dredged from the inside of the harbour where deepening was required. The Portland cement had an average strength of 384 lbs. per square inch, being tested with briquettes of  $2\frac{1}{4}$  square inches section after seven days' immersion in water; and 12 per cent. of the cement would not pass through a sieve of 50 meshes to the square inch. Quick-setting cement was used for the work under water, and slower setting cement for the upper work. The sand and gravel were mixed in a skip, containing a cubic yard, on one of the barges; and the proper proportion of cement was gradually added. The skip was then raised by a 5-ton steam derrick crane, and its contents were discharged into the hopper of the mixer. The mixer consisted of a stout timber box, 3 feet square inside, and 12 feet high, within which five diagonal shelves were fixed at an angle of  $45^\circ$ ; and at the bottom was a mouthpiece, 1 foot square, raised 10 feet above the ground, so that the empty skips could be run underneath it. The materials, falling through the mixer, were turned over from shelf to shelf in succession, and were discharged into the skip below perfectly mixed. The concrete to be deposited under water was mixed dry; but water was added to the concrete for the upper portions of the work, just when the materials had fallen into the hopper. The skips, full of concrete, were then conveyed by the locomotive on to the breakwater, and deposited as shown by Plate 5, Fig. 2.

Rubble was allowed to the extent of one-fifth part of the work; but it was found quite as economical, and more advantageous, to use no rubble under low-water. Above low-water level, about one-fourth part of rubble was placed in the hearting; but rubble was always kept well away from the face of the work. The largest pieces of rubble obtainable weighed only about 2 cwt.; and loss invariably resulted from its use with the concrete under water when exposed to wave disturbances before the concrete had set. Concrete alone formed a compact mass with a smooth surface,

over which the waves glided without injuring it; but when rubble was added, its projecting pieces presented irregular opposing surfaces to the waves, and, becoming loosened, caused an eddy all round them, resulting in the washing out of the cement, and the exposure and loosening of the adjoining stones. Though the Author has not used large rubble weighing several tons in a similar way, he believes that the large projections would set up eddies equally injurious to the adjacent concrete. An instance of the facility with which castings of concrete in position can be made was afforded by the construction of the parapet of the lighthouse.<sup>1</sup> The inside face of the breakwater is coped with granite; the two extreme corners are also protected by granite quoins, and granite steps are provided at each end.

The most severe storm to which the works were subjected occurred in the winter of 1883, with the wind ranging from south to east, raising waves about 15 feet in height. The shelter afforded by the breakwater was manifested by vessels being moored alongside the quay during the whole time. Occasionally the waves running along the breakwater rose above the parapet, momentarily almost hiding it from view. The waves did not strike the breakwater severely, but in receding they dashed violently against the incoming waves at a distance of some 60 or 70 feet in front; and though great masses of water fell with force upon the quay, no damage was done.

The progress of the works was a good deal interrupted by bad weather; but as the system of construction admitted of very

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<sup>1</sup> The Cupola of the lighthouse was formed by filling concrete into the space between two circular and concentric panels, at the top of which, and around the outside, a strong timber platform was erected, well propped from below; an iron spindle was accurately fixed vertically in the middle, and a strickle board, shaped to the form of the section to be given to the cap, was mounted to the spindle. A rough brickwork mould was then built on this platform in weak cement-mortar, outside but not quite touching the strickle when it was revolved round the vertical spindle; as soon as this had set hard enough, the inside was plastered with cement plaster, carefully smoothed all over, and brought to the required form by revolving the strickle board, so that a perfectly turned and accurate mould was prepared, much in the same manner as the loam moulds for iron castings are prepared in foundries. When the plaster coating to the mould was set, it was painted, to prevent the concrete adhering to it. The hand-railing, fixtures for the lantern, and such like, were suspended from above, and fine concrete, in the proportion of 4 parts of sand and gravel to 1 part of cement, was deposited inside. This was allowed to stand for a week, when the fragile brickwork mould was carefully removed, and the concrete casting of the Cap came out so clean and perfect as not to need any dressing afterwards. The weight of the concrete casting was about 10 tons.

rapid progress during fine weather, the important parts were completed in December, 1883, and the additional works were terminated at the close of 1884.

The breakwater and other concrete works have not, since their erection, entailed any outlay for maintenance or repairs.

The Steam-Packet Pier, or Deep-Water Quay, on the opposite side of the harbour, has a frontage of 300 lineal feet (Plate 5, Fig. 1); it was founded upon gravel and marl at a depth of 16 feet below low-water spring-tides, and has a total height of 30 feet. The quay-wall, 14 feet wide at the base, was constructed of concrete laid in position, within long panels, up to low-water level, like the early portion of the breakwater. The beach at this site, which was almost entirely dry at low-water, had to be excavated for the foundations, and for a berth for vessels alongside. This excavation was effected by a Priestman digger, attached to a 10-ton derrick crane with a 70-foot jib, and its pivot 50 feet back from the outer face of the quay. The cutting stood well at a slope of 1 to 1, and the bottom width of the excavation was about 18 feet. Piles were then driven outside the line of the wall, to which the panels were fastened; and the concrete was laid from skips by the crane. The fixing of the large semicircular panel for the outer end, 17 feet high, 27 feet in diameter at the bottom and 24 feet at the top, formed of vertical timbers attached to curved angle-irons, constituted the only difficulty experienced in this work. The circular end was faced with granite above low-water, and the wall is protected by fenders placed 20 feet apart. The wall is returned at an angle on the northern side; and the enclosed space was filled up with the surplus dredged material to form a quay. The exposed end of the northern wall has been protected by a deposit of 300 tons of granite boulders.

In addition to the above works, some of the river quay-walls were rebuilt in a similar manner, and others repaired, as previously mentioned, and a considerable quantity of dredging was satisfactorily executed by the Priestman digger. Several hundred yards of rock had to be removed in the upper part of the navigable portion of the river, to the extent in many places of 4 feet in depth, to obtain the statutable depth of 8 feet below low-water; and blasting by dynamite was tedious, owing to the flaky nature of the rock. The remainder of the works consisted of a roadway to the breakwater, mooring-buoys, boundary walls, and sundry minor works.

The total expenditure, including land, was a little less than the loan of £40,000; and the Commissioners, having more than fulfilled

the obligations under their Act, are empowered to levy tolls and rates. The port now affords accommodation for vessels of considerable size; several large foreign vessels have been discharged, and recently an Atlantic cargo steamer, 260 feet in length, and 14 feet draught, was afloat nearly the whole time it lay alongside the quay-wall being discharged.

The Author submitted a plan for a refuge harbour at Wicklow before the Harbour Accommodation Committee in 1884, having a depth at the entrance of  $4\frac{1}{4}$  fathoms at low-water spring-tides, and sheltering an area of 100 acres, of which 35 acres would be over  $3\frac{1}{2}$  fathoms deep; and the estimated cost was £150,000, if constructed on the system described above. The section of the proposed breakwater is shown by Plate 5, Fig. 10. A desire appears to have arisen amongst masters of vessels for a greater number of small refuge harbours, rather than large works similar to those which now exist; and for such a harbour, Wicklow is peculiarly suitable.

The important feature in the works described above is the method of depositing the concrete. Concrete in position is sometimes described as having been "poured in," an operation fatal to the concrete, as in its passage through the water nearly all the cement is washed away, and a mass of sand and gravel alone reaches the bottom. It is essential to convey the concrete in skips down to the bottom, allowing the skips to repose for a moment whilst the trigger is pulled, releasing the bottom of the skip; the skip must then be gently raised, when the mass of fresh unset concrete will settle quietly down and associate itself with the material previously deposited. The concrete should also be deposited as rapidly as possible during fine weather. The exceptionally good quality of the sand and gravel dredged at Wicklow enabled excellent concrete to be made with the average proportion of 7 of these to 1 of cement, quite equal to many instances of good work, which the Author has seen, where the proportion of 5 to 1 had been adopted. The Author, however, is not in favour of small proportions of cement, for, as cement can now be delivered for less than 40s. per ton, no advantage is gained by starving the concrete.

The great advantage of this method of construction is that no special appliances are needed, beyond the usual plant which contractors for such works have on hand, or can obtain without delay. The work, moreover, consists of blocks of prodigious size, stretching right across the breakwater, which the sea is impotent to affect or disturb, and which rest quite uniformly on the most irregular bottom. With proper precautions, sound and solid work is obtained;

and where defective work is liable to occur, it is easily detected and repaired.

The Author's experience at Wicklow shows that this system of construction is capable of advantageous application in many other places where exposed sea-walls are required, especially where the bottom is irregular and firm. It might be an improvement to form a larger mound, making a wall of the section shown on Plate 5, Fig. 10, with a long sloping toe, using panelling only from the summit of the mound upwards for the outside. As concrete can be deposited to stand in the mound at an angle of about  $45^\circ$ , the amount of material for such a sea-wall in deep water would still be comparatively small. Moreover, as the depositing in deep water is easily effected, there appears to be no practical limit of depth to the advantageous adoption of a system which affords a uniform bearing over the roughest bottom, and which forms such large and solid masses as to ensure the safety and permanence of the work.

The Paper is accompanied by three sheets of illustrations, from which Plate 5 has been prepared.

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Fig: 2.

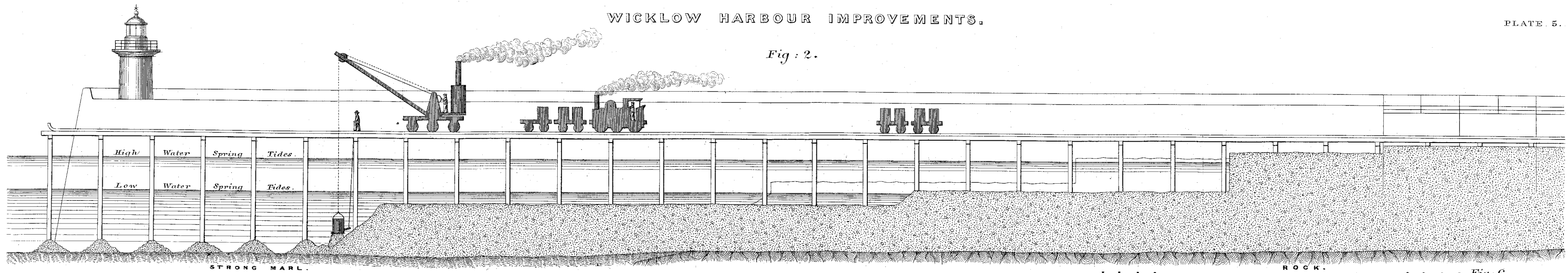
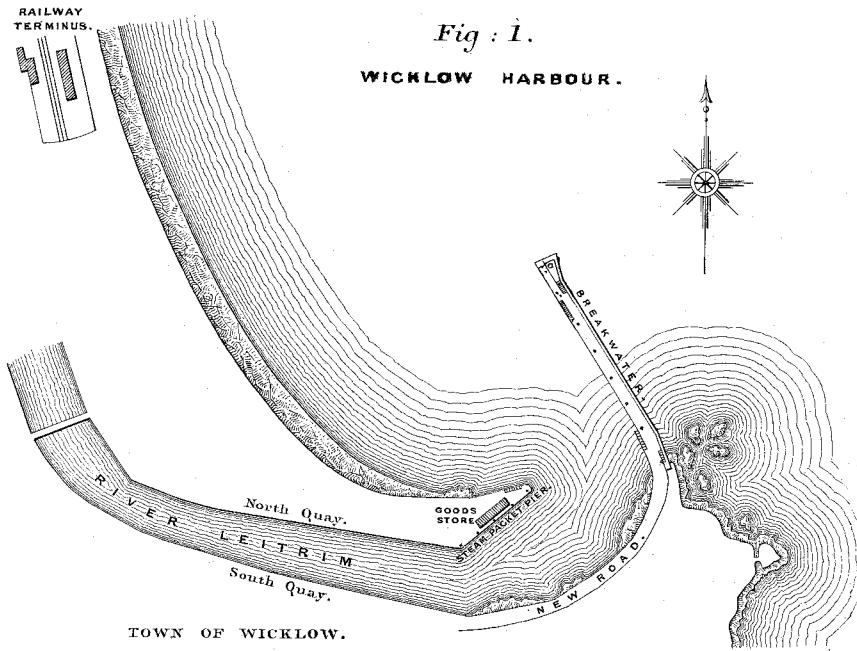


Fig: 1.

WICKLOW HARBOUR.



Scale: 600 Feet = 1 Inch.  
Feet 100 200 300 400 500 1000 Feet.

Fig: 3.

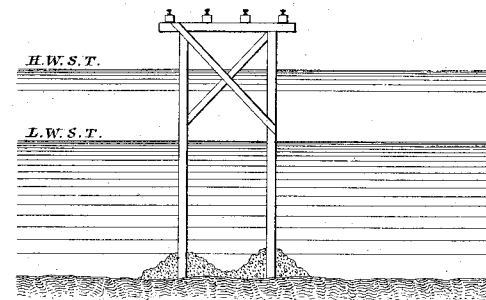


Fig: 4.

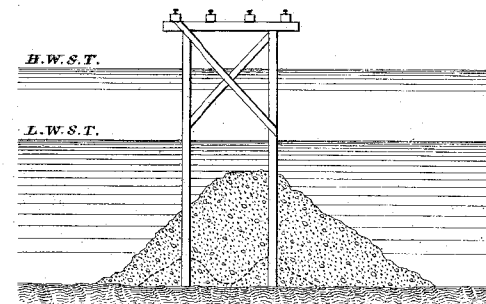


Fig: 7.

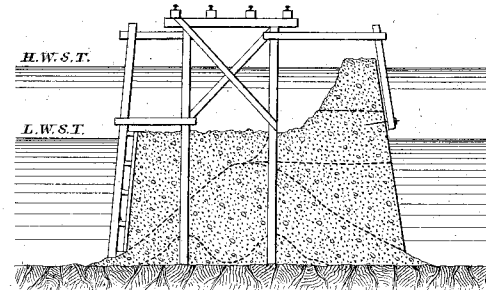


Fig: 8.

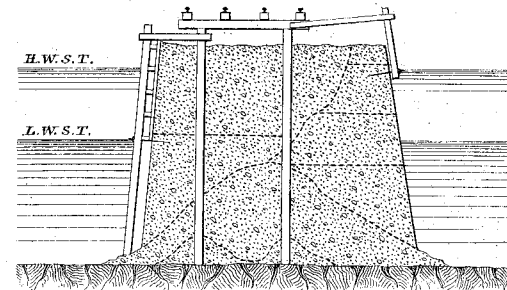


Fig: 5.

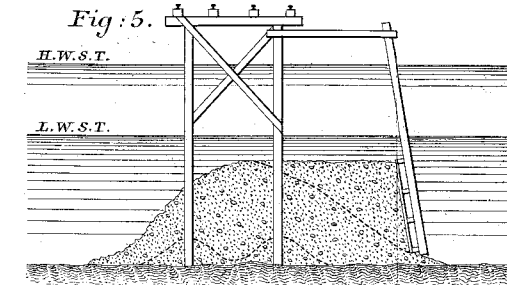


Fig: 6.

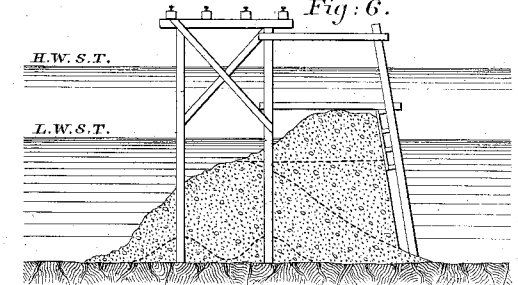


Fig: 9.

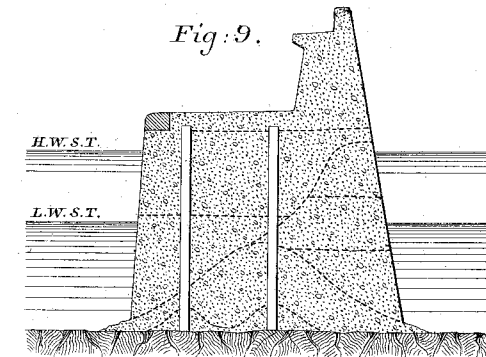
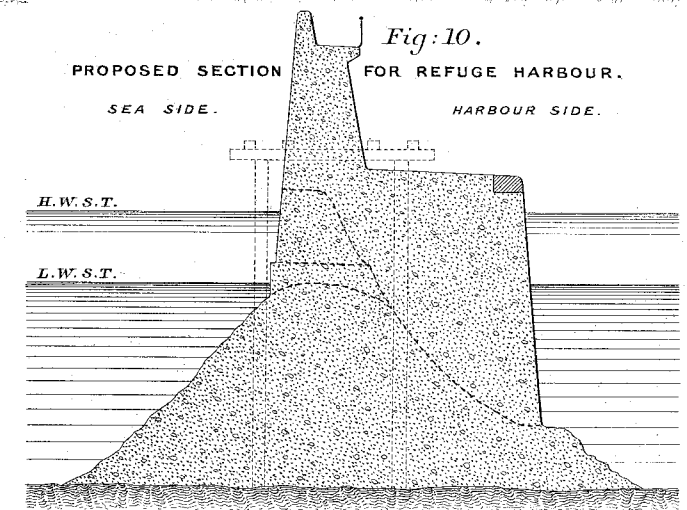


Fig: 10.

PROPOSED SECTION FOR REFUGE HARBOUR.

SEA SIDE. HARBOUR SIDE.



Scale: 24 Feet = 1 Inch.  
Feet 10 20 30 40 50 100 Feet.