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THE CONSTRUCTION OF A CONCRETE MASS AND BLOCK-WORK QUAY WALL BY HELMET DIVERS IN OPEN WATER.

By John Taylor, A.M. Can. Soc. C.E.

(To be read before General Section, April 29th, 1909.)

The quay wall, which is described in this paper, was built at Portland Harbour, England, in the years 1904-1906. It formed part of an extensive scheme of the British Admiralty to extend and increase the efficiency of the coaling facilities for the fleet at that port.

Portland Naval Harbour, since the completion of the enclosing breakwaters, having been made the headquarters of both the Channel Fleet and a destroyer flotilla, and also an important rendezvous during speed and gun trials, manoeuvres, etc., the existing coaling accommodation and storage proved inadequate for modern requirements. To meet this change, the work of which the wall herein described forms a part, was constructed.

The outstanding features of the scheme were a deep-water wharf backed by coal storage grounds equipped with railroad tracks, coal handling machinery, and fuel oil plant.

For obvious official reasons the writer proposes to limit his remarks and confine the scope of this article and illustrative drawings simply to the quay wall which formed the wharf frontage of the work.

This wall, as will be seen from the cross section shown on the accompanying drawing, is built of Portland cement concrete mass-work, faced with concrete blocks. The foundation of the wall up to 33½ feet below low water level of spring tides is built of mass-concrete. Above this point the wall is faced with 8-ton blocks backed with masswork to the level of 2½ feet above low water level.

From this level to quay level the wall is finished of mass-concrete faced with a 12-inch layer of granolithic concrete. A coping of dressed Devonshire granite completes the wall.

Attached to the front of the wall by wrought iron holdfasts are 12″ x 12″ creosoted pitch pine fenders at 10 feet centres, with 9″ x 4½″ creosoted American elm renewable rubbing pieces attached by 12″ x 1¼″ compressed oak trenails to the fender piles. Floating movable crib fenders to keep vessels well clear of the wall are also provided.

Cast steel mooring bollards and also the necessary hooks and rings for mooring purposes, with fairleads and electric winches for warping vessels into position were also installed. A double track railroad runs behind the wall with the coal storage tank in the rear parallel to the wall. Three electrically operated Temperley coal transporters 30′ gauge, 130 feet high, with 180 feet booms for the coal grab runways overhanging the coal pile and the water front, run with one track on the main wall and the other on the coal tank wall behind.

There are three hydraulic coal tips for handling coal cars, and on the old work there are six hydraulic 1½-ton coaling cranes.

This work was constructed within the comparatively sheltered area of the harbour. Portland Harbour, which is the largest artificial harbour in the world of its class, has an area of about 3,000 acres, with a deep water area of between 30 and 60 feet deep at low water of about 2,000 acres. It is enclosed by three miles of breakwaters, which are provided with three entrances.

These breakwaters enclose the Eastern Bay formed by the Island of Portland and its connecting link to the mainland, the Chesil Beach.

The geological formation of this island and beach are extremely interesting both to geologists and harbour designers, but is beyond the scope of this paper.

The longest water fetch inside the harbour tending to inconvenience the work was only three miles, but considerable trouble was encountered from the heavy swell which entered the south entrance, which faces the open sea. Under unfavourable weather conditions this made it difficult to secure the temporary work and floating plant. On account of the depth of water and comparative exposure of the work, the more ordinary and easier methods of construction within cofferdams could not be taken advantage of. It is doubtful if a dam could have been made sufficiently strong to keep watertight and withstand the swell and the inevitable bumping from floating plant and passing craft, at anything like a reasonable cost.

It was therefore decided to build the work entirely in open water by the aid of helmet divers. The first work undertaken was, of course, the dredging of the foundation trench and the deepening of the berth in front of the wall. This work was done by the ladder dredge "Cornwall," a vessel owned by the contractors, and built to dredge to 50 feet below her full load line.

As the wall runs at an angle to the general shore line, guide signals could be set up on shore and lights fixed to guide the work at night. The dredged material was towed to sea in hopper barges with opening bottoms and deposited in deep water. Certain small portions of the work which this dredge could not reach were excavated by means of a Priestman crane grab, mounted on a barge, but the cost per yard was very high compared to the ladder dredge, as it encountered some hard shale, which is not the class of excavation these grabs can handle economically.

The material proved easy for the ladder dredge to excavate, being mostly clay and mud, no large boulders or hard rock being encountered.

The shale rock scaled off easily in layers with the ladder dredge, without blasting, but the grab had to be assisted by a diver occasionally to clear away some obstinate piece.

The foundation was dredged until the hard shale and a satisfactory foundation was reached, borings having been taken which established the presence of shale rock at a considerable depth below the mud line.

The trench was excavated well clear of the back and front of the wall to provide room to work in and allow for the mud silting down the bank and filling up the angle at the bottom of the trench before concreting could commence. However, very little trouble was experienced from silting, the small amount which did find its way into the trench being easily removed by a grab immediately before the laying of the foundation concrete.

The water at this point, though often considerably agitated on the surface and for a few feet down, was practically motionless thirty feet down, there being practically no currents of any kind to move the mud. The bottom of the foundation trench left by the dredge was found to be remarkably level, requiring no levelling by the divers before commencing on the concreting.

Two 120-ton steel hopper barges, fitted up with a half-yard Koppel concrete mixer and a three-ton Bedford crane on each, were used for mixing the concrete *in situ* for the work.

These barges and the diving boats were moored along the line of the work to buoys securely attached to anchors and large stone blocks sunk in the mud.

The concrete material was brought alongside the mixer in forty-ton wooden barges, which were loaded at the harbour works pier from the stock piles. This pier had been fitted up primarily for the construction of the breakwaters previously mentioned, and was afterwards used for this work. It was equipped with four 20-ton Stothert and Pitt car tipping cranes for loading and unloading material. Several millions of tons of construction material for the breakwaters and this work were handled in this way.

The concrete shuttering for the quay wall was made in 20 ft. x 4 ft. panels of 3" planking, strongly braced with 9" x 4½" stuff, ballast consisting of old rails being attached to the bottom of the panels on the outside in sufficient quantity to sink them into position.

The panels were stored on a barge alongside the mixer and handled by the mixer cranes.

They were set up in the foundation in parallel lines back and front of the wall and strutted on the outside with light rails and timbers.

Small buoys were attached by lines to the corners of each section to guide the craneman in depositing the concrete.

In order to set out the line of the work a barge was securely moored over the work so as to practically eliminate movement, and the line was given by a transit from fixed points on shore. A 30-lb. plumb-bob, suspended by thin piano wire, was used to continue the line from the point on the barge down to the diver. This method proved to be quite satisfactory in ordinary weather.

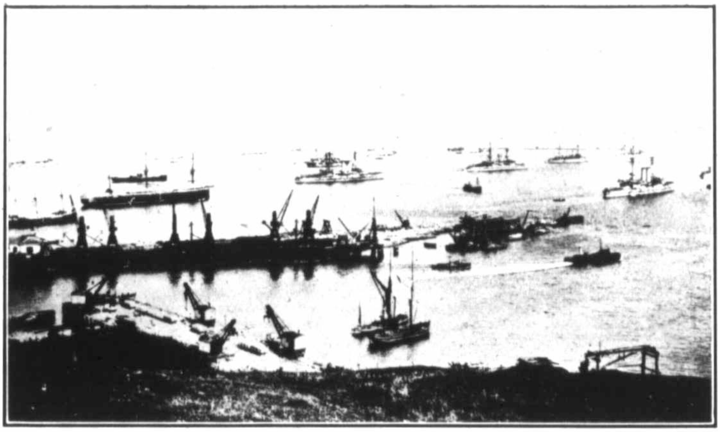
Afterwards, when the gantry was erected, line was given from the overhanging boom of the blocksetting cranes.

In the lower part of the work the divers experienced some difficulty from the partial darkness in the foundation trench and the cement particles floating in the water which obstructed the light. Electric lights under water were tried to overcome this difficulty, but were not very successful, and were abandoned by the divers when they had accustomed themselves to the layout of the work. When a one hundred-foot length of the bottom 4 ft. layer had been put in, the shuttering was stripped, the trench filled in with stone to the level of the top of the concrete, and the shuttering reset for another layer.

As soon as the blockwork level was reached, the concrete was levelled off to receive the blocks and careful line and level given from the gantry, which was erected as soon as the trench behind the wall had been filled up.

A light section steel rail was used by the diver to level off the

Fleet in Portland Roads.



Portland Harbour, from Verne Fort.

concrete for the blocks. The temporary block-setting crane, to be described later, was then erected, and a length of the first row of blocks set and backed up with mass-concrete. Wrought iron skips, containing one cubic yard of concrete, the bottoms of which opened automatically, were used to deposit the concrete.

The same class of shuttering was used for the back of the wall under water as for the foundation work, but slightly modified to enable it to be attached to the crane gantry piles for support. The method employed was simple and satisfactory, and is shown on the drawing, which also shows the shuttering for the rest of the work.

The blocks were laid with dry joints, Flemish bond, and bonded in addition with 12" diar. concrete-in-bag joggles. The top of the masswork backing was levelled off sufficiently wide to take the next course of blocks. The blocks were easily handled by the divers, the cranes working smoothly by means of an arranged code of signals.

A force of twelve divers was kept going, the foreman diver and an assistant setting the blocks, and the others setting and stripping shuttering and erecting the gantry, the two mixers following up with the mass concrete. The divers were housed in boats, with plenty of room in them for small stores.

Much expense was saved in the purchase of new diving suits by the employment of a skilled repairer. Many divers insist on throwing away, as unsafe, dresses which have become frayed and leaky. This soon happens to the exposed parts of the dress on work where blocks and timber have to be pushed around, and this renewal, on a work of any magnitude, adds considerably to the labour cost. Rubber and jute canvas patches can easily be put on the dresses with repairing solution. A good plan is to cover the more exposed parts of a new dress with protecting patches of this material, and renew them, before the dress itself is attacked. Detachable guards are sometimes used, but are troublesome to the wearer, as the addition of any unnecessary equipment outside of the ballast, piping and signal lines, hinders free movement, and, of course reduces the working efficiency of the diver and adds to the cost of the work.

In work which is difficult of access the fewer lines a diver has to look after the better. The more common accident happens through a diver getting his equipment mixed up and being unable to extricate himself. Each diver should have an intelligent attendant who can see ahead and get the material, tools, etc., on the spot at the right moment, and so avoid delays and the necessity of the diver's ascent to give verbal instructions. Much of the often abnormally high cost of diver construction is caused by the lack of system. A portable telephone is a very useful adjunct, but is a convenience more than a necessity to the work.

The concrete in the wall varied in its proportion to suit the position and exposure in the work, from that of one part Portland cement to five parts of aggregate in the foundation and masswork behind the blockwork, to one to six in the blocks and above-water work.

Stone broken in the works quarries by a crusher plant, sand brought by rail, and sea sand and shingle from the Isle of Wight were used. The Chesil Beach, previously mentioned, consists of millions of tons of excellent concreting material, but on account of danger from erosion of the adjacent coast, it is forbidden to use it. The average cost per cubic yard of concrete in the wall was about five dollars for materials and labour. The average output of the mixers was 80 cu. yards each per day, but their output was limited by difficulties inseparable from diver work. The cost of the wall was approximately 500 dollars per foot run contract price.

For the purpose of comparison with American work, the following labour and material costs are given. They are much lower than on this side, owing to the different standard and cost of living:

Diver, 50 cents per hour.
Divers' crew, 3 men, 10c. per hour.
Carpenters, 16 cents per hour.
Crane and mixer drivers, 14 cents per hour.
Ordinary labour, 10 cents per hour.
Cement, $7.65 per ton, delivered.
Mixed sea sand and shingle, 84 cents per cubic yard.
Sand, $1.50 per cubic yard.
Broken stone, 65 cents (exclusive of plant) per cubic yard.
Granite chippings, $1.20 per ton of 22 ft. delivered.
Timber for shuttering, $20 per thousand.

The shuttering was repaired and re-used as often as possible. The costs for shuttering was about 12 cents per square foot of underwater wall surface, and about 9 cents per square foot for above-water work.

This latter may seem high when diver and carpenter costs are compared, but is due to the smaller section of the wall above water.

When the last exposed course of blocks was set, they were carefully aligned, any error being adjusted. A complete 120 ft. length of shuttering for the work above block level was made in 20 ft. x 4 ft. movable panels, double braced in front, and made in panels to suit the counterforts in the wall behind, all held together by 1" diar. bolts and braced with removable struts of 4" x 2" stuff inside. Coach screws from the outside were used to secure the lagging to avoid bolt heads in the wall face of the shuttering.

The shuttering for the first layer above blocklevel was placed in position on the ebb tide and at once concreted up.

The existence of the counterforts provided assistance in studying the shuttering and preventing movement. The shuttering was then placed in position to quay level and foundation bolts, etc., set in position and concreted up.

It will be noted from the drawing that the shuttering for the back of the wall below the water line was attached to the crane gantry uprights. It was not possible to do this for the upper exposed work, as the gantry, although very steady for a temporary structure, vibrated sufficiently to have injured the alignment of the wall where it showed above the water line, although this movement was of no account lower down behind the wall.

The upper course of blocks, coming as it did well clear of the low water line, enabled the most difficult part of such work, namely, that around the low water line, to be done easily on the ebb, the two feet or so of a fall and rise of the water below the block line giving sufficient time to concrete up ahead of the incoming tide. Care was taken to make the shutters as nearly watertight as possible at this part to prevent the sea from sucking out the green concrete and pitting the face of the wall.

The lower layer of shutters was weighted down with rails to prevent flotation when the concrete was still new, and no trouble at all was experienced from movement of this part of the shuttering.

The lagging for the shutters was of pine, special care being taken to carefully plane and align the exposed face. The whole surface of the shuttering was well rubbed with a coating of soft soap to prevent adhesion of the concrete. The tie bolts were well oiled, and were slightly drifted after the concrete had partially set to loosen them from the concrete and facilitate their removal. By this means they were removed and re-used without injury to the wall.

The concreting progressed continuously with but few delays, the lower panels being removed after three days, reset on a new length, and replaned where any slight warping of the face had taken place. A very good surface was thus obtained. Unfortunately for the use of wood lagging, the warping takes place shortly after the concrete is placed in position, and while it is yet green enough to take the impression of the swollen joints. A thin covering of steel plate on the face of the lagging, the joints of which should be left slightly open to provide for swelling of the timber, overcomes this trouble where a perfect concrete surface is a desideratum without resorting to plastering or acid treatment. All-steel shutters are not sufficiently resilient for sea work; lacking resilience they have to be made unreasonably heavy and costly to resist the rough handling they have to undergo.

The writer has seen massive shutters used in breakwater construction, braced with steel T's, irreparably twisted out of recognition, whereas all timber shutters, though perhaps badly damaged, could, at least, be repaired and re-used.

The exposed facing of this wall, consisting of 1 part cement and 3 parts granite chippings, was deposited simultaneously with the backing to form a homogeneous mass, the facing during placing being kept separate from the poorer quality concrete behind by a 6-ft. x 1-ft. steel plate, with handles on one edge, and held the necessary distance from the face of the wall by thin plates rivetted on the face. One man moved this plate up as the work progressed, and deposited and carefully rammed the facing material, and the result, with careful shutter repairs, and the liberal use of the soft soap, was very satisfactory.

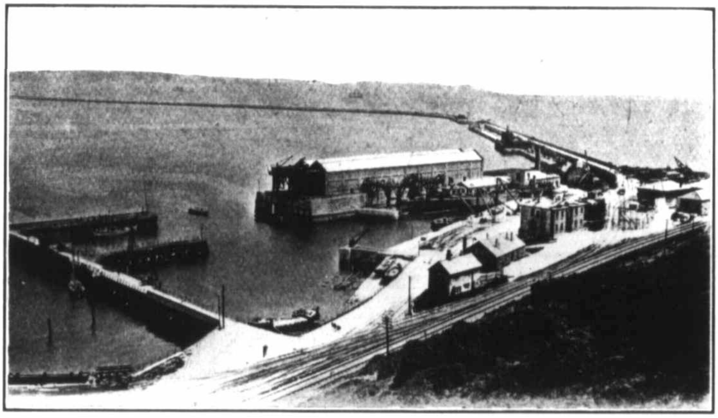
Openings were left for the fender pile attachments, and these were afterwards grouted in, and the shutter tie bolt holes neatly stopped up.

The small ratio of width to total height is a feature in this wall, particularly noticeable at the lower block line, and also the great height of the vertical back of the wall, totalling 68 ft., differing from the usual conception of a non-reinforced quay wall in British practice, in that the usual series of offsets or steps are omitted.

This was made possible by the high angles of repose of the material forming the backing of the wall. This backing is of large rubble, with the interstices filled with smaller spalls, and would stand with but slight support to within a few degrees of vertical. Making allowance for quay loading and strain from moorings it is much lighter in section than usual, the design being doubtless influenced by the quality of the backing. The writer has seen walls of similar general design, notably at Liverpool, Bristol, and Leith, with twice the ratio of width of foundation to height that is used in this wall, but the backing employed was of softer dredged or other material, which flattens down to a comparatively small angle with the horizontal on exposure to water action.

No signs of weakness whatever have appeared in this wall.

Possibly the introduction of a reinforced offset at the base of



Portland Harbour, South Entrance.

Twenty-foot Wave on Chesil Beach.

the back, and the use of a few old rails placed vertically near the back of the lower half of the wall at the point where the tensile stress is greatest would have increased the sense of security, though not necessarily the stability of the wall.

With the high angle of repose of the backing the resultant of the overturning moments of the wall comes well within the middle third of the foundation width, this being the usually accepted rule for a plain retaining wall without any indeterminate exterior strain, such as a quay wall is subjected to. The accurate design of this class of work for varying places and conditions is much hampered by the lack of designing data other than walls actually built which have stood successfully. No doubt many walls are made needlessly heavy simply for the reason that the average British engineer has a confirmed and very pardonable dislike to his structures coming down about his ears, even though the original cost may be somewhat high. Still, when the structure stands, the original cost is soon forgotten if the work proves stable and costs little for maintenance. Most of the British ports have arrived by a process of elimination and experience at some approximately standard design of wall to suit local conditions, but many designs are the result of individual caprice.

In this wall the cement used was of the finest quality and of high proportion in the concrete, and the aggregate clean and sharp and carefully proportioned. The different classes of aggregate were tested for voids. Sand in sufficient quantity was added to the stone to rather more than fill up the interstices, and cement added to the poorest quality of concrete, at least a little in excess of the quantity required to bond the sand particles. Every ounce of cement added to a concrete beyond the minimum, of course, represents a gain in strength.

Cements used in Britain, similar to that used in this work, have so far successfully withstood the action of salt water, with, of course, the inevitable exceptions sometimes due to bad workmanship, and in several of the earlier examples of concrete in sea water, to an insufficient knowledge of cement.

One precaution should always be taken in depositing concrete under water, namely, to raise the skips slowly and carefully for the first foot or two to allow the concrete to fall away easily and not be stirred up unnecessarily. Of course a small percentage of cement was unavoidably lost, but with careful manipulation of the depositing skips the amount was negligible. After each layer had set, and before another was deposited on top of it, the whole surface was brushed and cleaned. From two to three inches of slime, precipitated by the action of the cement on the sea water, always accumulated on the wall under water after concreting. Failure to remove this deposit on the concrete in sea water has been the fruitful course of wall failures. The cement particles in green concrete coming into contact with the sea water produce a chemical change in the cement and precipitates magnesia from the water.

This process takes place most easily before the concrete has set, and to a lesser degree after it has set. In sea water concrete which has not set should, therefore, be protected until the cement has had time to crystallize and set, and the part of a wall where work has been left off under water and another layer has to be placed later, should be thoroughly scrubbed with wire brushes to remove any particles of the cement which have been damaged by contact with the sea water in an unset state. The particles in most hydraulic cements develop a certain amount of heat during the process of hydration, and tend to rise like an effervescence from the surface of the wall. It can be readily understood that the process of depositing and levelling concrete in the water aggravates the deposit of this precipitate. Possibly the fact that the geological formation of this particular district is of limestone and chalk, and consequent impregnation of the sea water may account for the unusually large amount of the precipitate in this particular case. The writer simply states the case as he personally observed it. The writer dried and tested this slime and found it to have absolutely no setting properties whatever, simply drying up into a fine powder when mixed into testing blocks, so that its introduction in the wall in layers would have prevented bond and made a horizontal joint of non-cementing material, probably half an inch thick when compresed right through the wall at every four-foot layer, which would have caused lateral weakness in the wall. Although this is a gravity wall, and is calculated to have sufficient deadweight to resist lateral thrust, nevertheless the introduction of what would have been a series of joints on the tension face of a comparatively thin wall like this would not in view of mooring stresses have been a desirable feature, although dry joints in the blockwork face do not matter as they are under compression on that side of the wall.

The writer is of opinion that many cases of failure of concrete in the sea is due to a hot cement being used which swells during the process of hydration and setting in the work, producing holes and cracks which remain in the work after hydration is complete. These afterwards fill up with this same precipitate deposited by the salt water action on the cement, which, having no cementing value, rots away the wall, and the latter finally bursts off in large pieces. The writer has examined walls where pieces have broken away in this manner, and has detected the presence of a coating of this slimy material in the cracks. If the wall were perfectly solid the sea water could not find its way in and so cause this material to be deposited. The same occurrence in a milder form is to be seen in the efflorescence, which shows on ordinary concrete buildings in the form of white blotches and streaks of powdery material. A concrete which is not solid, and allows the water to freeze and expand in the cracks, is also undoubtedly the cause of failure of concrete in many cases, in water subject to frost and variations of water level.

The use of too much neat cement on the surface of a wall also tends, from the different exposure and ratio of expansion and contraction it bears to the inner concrete where more aggregate is used, to scale off the outer layer and produce hair cracks.

To avoid this particular defect on the face of a wall, the aggregate should be worked out against the shuttering and the wall covered with damp sacking while the concrete is maturing.

One insuperable difficulty in mass concrete in water with variations in level caused by the tide is the difference in the expansion and contraction of the concrete above water and that under the water. Blockwork is not so much affected by this as the joints allow free movement. The constantly alternating water levels and consequent changes in expansion and contraction of the material in the wall is very trying to good work, and soon shows its effect on poor concrete around the water line, and when this is coupled with any of the above-mentioned causes of decay, soon results in total failure.

A breakwater in Scotland, of which the writer has knowledge, having been engaged upon it on extension work, built in the pioneer days of concrete in sea work, presents an appearance which clearly indicates a failure to appreciate the importance of thorough aeration of the cement and removal of the salt water — cement precipitate from the top of the layers as deposited, and has been the immediate cause of numerous and costly repairs. At that period, of course, concrete in sea water was in a more experimental stage, and many, though not all, of the difficulties then encountered, both in the chemical composition and constructional use of cement for sea work, have been overcome. This breakwater shows joints of soft material, presumably this same precipitate, at every place where concreting had been stopped, and innumerable small hair cracks and holes in the body of the wall, filled with the same material. It has also, in parts, a spongy appearance, even where it is not exposed to wave action, which indicates a tendency for the cementing material to gradually eat away. This is the case in these earlier works, and age only can prove whether modern works will outlast this trouble, which would seem to be a gradual decomposition induced chemically. Vibration in the concrete, caused by the continual pounding from waves, might cause fatigue and consequent failure of the cementing material in a wall exposed to wave action, and has done so, but could not be the cause with sheltered work.

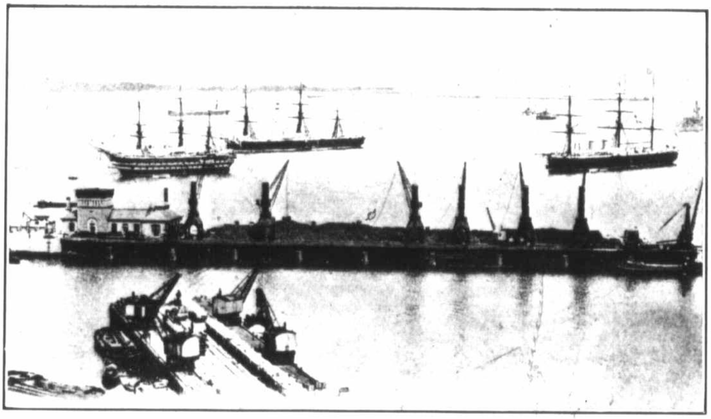
Perhaps we expect too much of nature when we think that our building materials are too short lived.

The every-day process of weathering and levelling down of rocks and all forms of erosion indicate that it is somewhat vain on the part of any man to hope to produce an everlasting material, a thing which is not found even in nature itself. The only thing we can do is to use those which last the longest and then replace them.

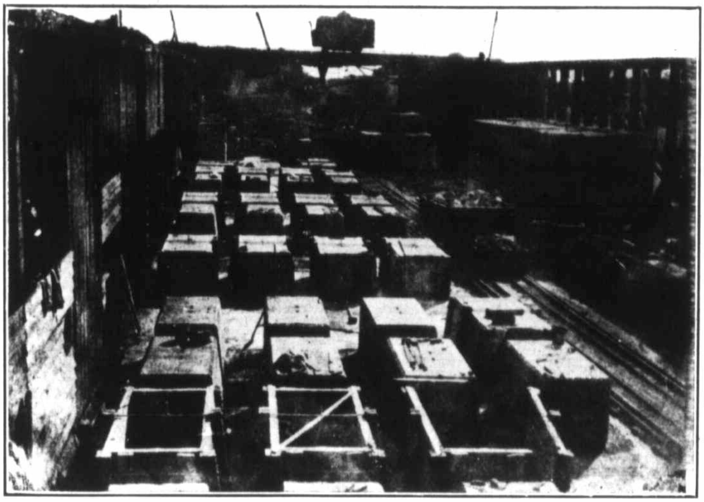
Many failures are traceable to some departure from the strict wording of the cement specifications on the part of the makers or the use of hot or dead cement.

The writer does not propose to wander into the realms of chemical science relating to the compositions of cements suitable for salt water, but from personal experience he would advocate the use of a first-class brand of Portland cement, with rigid and unbending inspection as to its guaranteed chemical constituents, age, tensile strength, fineness of grinding and calcination. Manufacturers, and especially middlemen, are occasionally not averse to rushing in a few carloads of insufficiently calcined and aerated cement, under pressure of output, or to dump a few loads of a dead cement in sufficient quantity to ruin a wall and trust to having it accepted in the rush of the work. Several hundreds of tons of cement, which many users would have accepted without remarks, were very rightly rejected on this work, although the concern supplying the cement was of a highly reputable standing in the trade. All cement should be shipped direct from the factory to the site to ensure actual delivery of the proper article ordered, and should be carefully stored on delivery. Attention to these practical details are essential in order to ensure good work. Some users accept cement which has been peddled and rejected round the country, and throw it around in sacks on the work in all weathers, and innocently wonder what can be wrong with it when the concrete shows signs of early decay, when their own treatment of it has probably been the cause.

A cement which requires to be aerated before use, or one which is partially hydrated, and so rendered practically valueless as a



Coaling Wharf, Portland, showing commencement of work.



Portland Naval Harbourworks Blockyard, 1905.

cement, should be rejected without compromise. Its acceptance tends to encourage general laxness in manufacture and distribution.

A cement which begins to set before the concrete can be deposited and rammed in position ought to be avoided. Not only do the set particles lose their cementing power when moved during placing in position, but many of these cements, with a high initial setting strength and speed, afterwards deteriorate in strength. An ordinary Portland cement concrete should not set very much under half an hour, giving ample time to deposit it.

At Portland the temperature is never sufficiently low to cause freezing, sufficient to affect concrete exposed to tidal action in sea water, but the writer has seen cases where the alternate wetting and drying of sea walls, and consequent freezing of the concrete around the water line, has caused the concrete to scale and burst off in large pieces, presenting a very unsightly appearance. Breakwaters which are wetted by spray or waves above the water line also sometimes present this appearance when subjected to frost. Probably the introduction of some waterproofing material in the outer facing of a concrete wall would improve matters, but although several compositions are on the market, the writer is not aware of any case where waterproofing of concrete has been tried successfully in sea water, if at all necessary. Proper protection of the face of a quay wall from damage by shipping is very desirable, as it is a difficult and costly operation to repair it effectively.

The stone and sand aggregate in a concrete ought to be clean and sharp. Neither the stone or sand particles should be too uniform in size.

A sand, the grains of which vary in size, makes a more solid concrete, and this also applies to the stone, because the smaller pieces fill up the interstices in the larger. Where no artificial coloring is used, it is necessary to use concrete materials of a uniform color if evenness of finish is desired. Nothing looks worse on a concrete wall than a patchy appearance, caused by using different makes of cement and changing the aggregate.

For the manufacture of the concrete facing blocks of this wall, a blockyard was constructed with a ten-ton gantry traveller running the whole length of the yard.

A large area of level concrete flooring, on which to build the blocks, was placed at one end, with two Baxter jaw stone crushers arranged in series, and a one cubic yard Taylor concrete mixer driven by a 20-H.P. engine.

The cement storage building was placed at one end next the mixer in a convenient position. The stone to be crushed was brought from the contractors' quarries in cars, thrown by hand straight from the cars into the crushers, and these deposited the screened stone into skips running on a narrow gauge road, which were hauled, also filled with the cement and sand, up an incline by an endless rope run by a winch and dumped in the mixer.

The concrete was dropped from the mixer into skips with opening bottoms handled by the gantry crane. The blocks were stripped and stacked along one end of the yard, down which ran car tracks for loading.

Four days were allowed for the blocks to set before the removal of the casing, and they were then numbered and dated and stacked, a few days later, to mature. The shuttering panels for the blocks were made of 3" pine, strongly braced, planed smooth, and well rubbed with soft soap before use. Provision was made for means to stack and set the blocks by leaving openings down the centre of the block to take two inclined lewis bolts in such a position as to be easy to withdraw and balance the block in a level position convenient for setting when being handled by the divers. Several of the blocks, which were afterwards used in the mass concrete, were split up to test the proportioning of the aggregate, and found to be perfectly solid. Three months were allowed to elapse before the blocks were permitted to be set in the quay wall.

For the purpose of setting the blocks two gantry cranes were set up in the centre of the length of the wall, and worked away from each other towards the ends of the wall. A 240-feet length of gantry framing was erected, and when the blockwork reached the top in the centre, the gantry was broken in the middle and removed and extended towards each end. Each part of the gantry was built in a slip on shore and towed to the site, where the foundation blocks of roughly-squared stone were attached to the bottom of the vertical piles and the section sunk into position. These blocks were made sufficiently heavy to overcome the buoyancy of the timber, and were left behind on the removal of each section. The foundations for the stone blocks were levelled off with spalls by divers at levels to suit the length of the pile, and the erection was cheaply and quickly done.

There were no accidents of any kind, either in the erection, working or removal of the cranes, and there was no trouble from wave action. Indeed, the whole work was remarkably free from accidents.

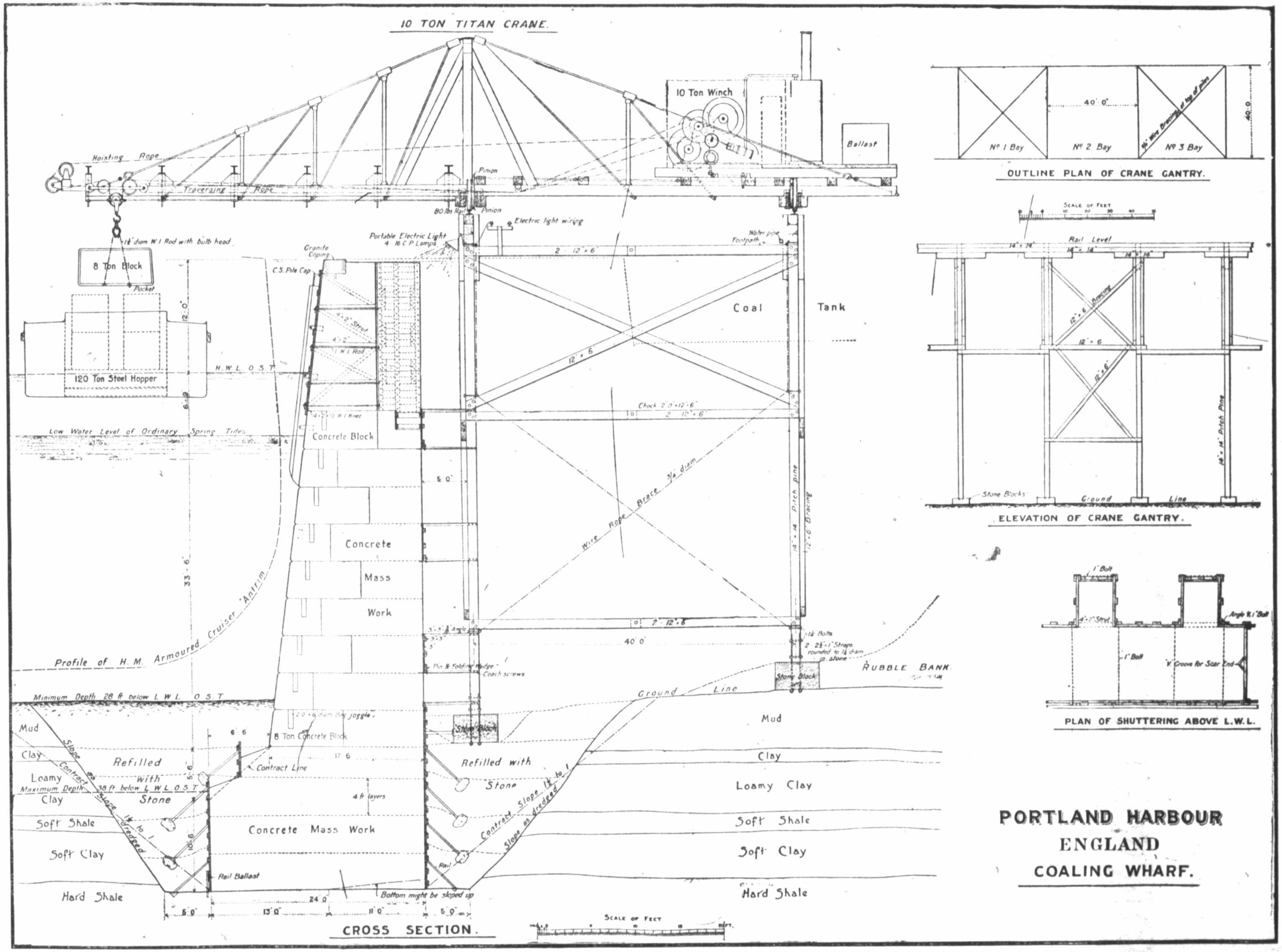
A ten-ton crane, mounted on a large steel barge, was tried for setting a few blocks in a position which the gantry crane could not easily reach, and though the work was accomplished, the wave action and heave of the vessel, caused by the manipulation of the block, rendered it extremely difficult, and even dangerous, for the diver to set it. In calm water, with a large barge, blocks of large dimensions can be set successfully by this method, and, consequently, more cheaply if suitable floating plant is available for a moderate-sized work, for which the construction of new plant would not be justified.

After completion of the wall, and removal of the gantry, the space in front at the base of the wall was levelled up, and also the filling placed behind the wall. The stone used was deposited from 120-ton steel barges with opening bottoms.

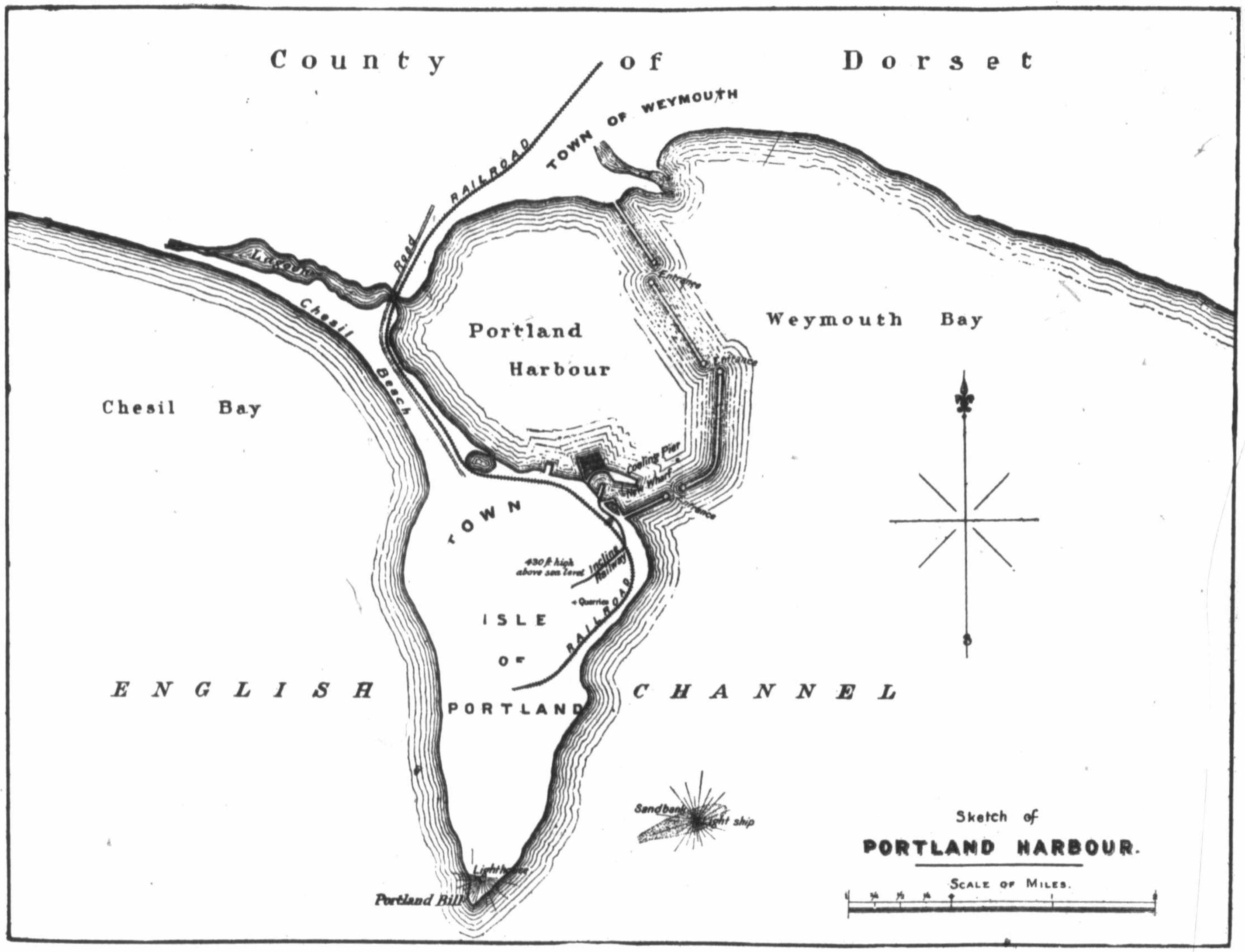
Above the water level, in the reclamation work behind the wall, the material was deposited from end tipping stone wagons spread in layers and rammed. A double track railroad of 80-lb. flat-bottomed rails on 9 ft. by 10 inch by 5 inch creosoted pitch pine ties, with crossovers and wagon turntables, was laid on the quay behind the main wall.

The roadway was finished off with granite setts set in cement, after the backing had settled sufficiently.

The contractors for the whole of the work were Messrs. W. Hill & Co., of Westminster, London, the writer being their chief assistant engineer, with outside charge on the work.



PORTLAND HARBOUR
ENGLAND
COALING WHARF.


County of Dorset
TOWN OF WEYMOUTH
RAILROAD
Road
Chesil Beach
Portland Harbour
Weymouth Bay
Chesil Bay
Coaling Pier
New Wharf
TOWN
430 ft high above sea level
Incline Railway
Quarries
ISLE OF PORTLAND
RAILROAD
ENGLISH CHANNEL
Sandbank
Light ship
Lighthouse
Portland Bill
Sketch of
PORTLAND HARBOUR.
SCALE OF MILES.