

(*Paper No. 4006.*)

“Natal Harbour-Works.”

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IN August, 1895, the Author was called upon by the Natal Government to take charge of the harbour-works at Durban; he had previously been engaged as Assistant Engineer since May, 1884, and while holding this office had served for a period of 13 months (July, 1887, to August, 1888) as Acting Engineer.

This Paper is confined to a description of the works actually carried out during the Author's periods of control, and no allusion will be made in it to the many controversies which took place concerning various proposals for improvement.

Early in 1888 a detailed survey of the bed of the entrance-channel was made, in order to ascertain whether the bottom really consisted of solid rock, as supposed. The survey comprised not only a close examination in diving-dress, but also systematic probing, the position of each probing being accurately laid down on the chart.

The probings were taken from a punt having a central well 18 inches wide extending for about half its length—an arrangement which enabled the workmen to get all round the probing-rod. The rod, the nose of which was softened so that if hard rock were encountered a burr would result, consisted of a $1\frac{1}{8}$ -inch octagonal bar of steel. This was first jumped down as far as practicable, and was subsequently driven with 7-lb. hammers, until its point reached a depth of 21 feet below low water. The nature of the material through which the rod was being driven could be judged fairly well by the ring of the blows and by the rate of progress. The greatest depth of probing was 12 feet (the average being 9 feet 6 inches), and the time for each hole ranged from 5 to

8½ minutes. At first the withdrawal of the rod was effected by the send of the punt, but subsequently a tackle hanging from sheer-legs was introduced.

From this survey it was ascertained that what had previously been regarded as rock was nothing more than consolidated shingle with occasional small boulders; and, with the exception of some blasting on the south side of the channel out of the fairway, the existing depths of 33 feet and upwards at low water of ordinary spring-tides were obtained by dredging alone.

Fig. 1, Plate 2, is a plan of the harbour in 1907.

BREAKWATER¹ AND NORTH PIER.

A section of the south breakwater at the seaward end, as completed in 1903, is shown in Fig. 2, Plate 2. The staging and crane for making up the aprons are indicated in dotted lines: the former had an overall width of 70 feet, and was supported on 16-inch square pitch-pine piles. Four of these piles, which in some cases were of lengths up to 55 feet, served for each transverse frame, and the frames were pitched 15 feet apart longitudinally.

As soon as the piles of each frame were driven, the crossheads and longitudinals for carrying the pile-engine roads and the intermediate lines for the stone-trucks were fixed. Large rubble was then without delay heaped round the piles to prevent scour, which in bad weather would otherwise have been very great.

The depth of the sea-bed was subject to sudden variation; indeed, at a point one bay (15 feet) seaward of the frame last driven, an alteration of 10 to 15 feet in 48 hours was frequent, and on one occasion a change of 20 feet was recorded.

The four pile-engines were originally connected, but during a bad storm, which lasted from the 8th to the 11th May, 1889, the whole machine was lifted clear of the rails, and would have been destroyed had not the flanges of the wheels become embedded in the way-beams. It was then decided to cut the machine in two, so that it could be run back to a place of safety. A crossover road to a radius of 300 feet was laid on the staging, and no difficulty was found in getting the two sections round the curve.

In some cases it was necessary to renew the pitch-pine piles owing to the ravages of the limnoria (the life of a 16-inch square pile cannot be taken at more than 3 years). This was done by

¹ Innes's breakwater, begun in 1883.

driving the new pile, fitted with a special shoe having a long tapering nose, into the centre of the old stump previously cut off square as near the level of the foundations as possible. A few light blows were first given to bury the nose of the shoe, and when this had been done the ordinary drop of about 8 feet with a 30-cwt. monkey was resorted to. In some cases driving was thus carried to a depth of 20 feet through old pile, surrounded as it was by rubble and boulders.

As soon as the piles forming a bay of staging had been made secure, another bay was driven, the deposition of rubble and boulders going on simultaneously until low-water level was reached.

After allowing a reasonable period for settlement, the foundations were levelled up with concrete in bags, double bags being used, to prevent the cement from being washed out. The bottom-course block on the weather side was then built in situ at low water, the timber mould being covered, when filled, with iron plates and a gridiron of old railway metals, and the whole was secured to the piles with heavy chains and union screws. The building of the remaining portion of the superstructure in situ was comparatively easy, as the work was more or less sheltered from the sea.

The weather apron was composed of 7-ton and 5-ton concrete blocks, principally the latter, which, in the first instance, were tipped from the staging into the water, but were subsequently lowered by the staging traveller. In practice it was found best to use blocks rather green, so that they might cut into each other, and thus be less likely to move in bad weather. Very little trouble was experienced even in the worst weather from this cause, notwithstanding the small size of the blocks. An advantage of small blocks deposited at random is that they expose a number of cutting edges to the waves, and thus break the intensity of the stroke, which otherwise would be exerted on the superstructure. The 5-ton blocks were built in the Bluff work-yard in nests of four, principally by convict labour, and twenty blocks constituted a day's work for fifty men.

The concrete was invariably gauged with salt water, and the mixture generally used consisted of 1 part of cement, 2 parts of coarse beach-sand, and 4 of broken stone. The cost worked out at 18s. per cubic yard. The concrete used in the central portion of the breakwater was much weaker than this.

The superstructure, which had been allowed to stand unfinished since 1894, was completed in 1901, and a tunnel in the parapet, to provide safe access to the light in all weathers, was put in hand.

A length of 1,320 feet of breakwater, together with concrete decking and permanent rails for the 7-ton locomotive steam-crane working at a radius of 50 feet, was finished early in 1903. A tramway was laid in the tunnel for the conveyance of stores to the lighthouse.

The construction of the north pier was similar to that of the breakwater, but being sheltered it presented fewer difficulties.

The last extension of this work, to the extent of 705 lineal feet, was recommended by Sir Charles Hartley, K.C.M.G., M. Inst. C.E., and Sir John Wolfe Barry, K.C.B., Past-President Inst. C.E., in their joint report, dated 1897. The width of the entrance is now 600 feet, and the maximum tidal velocity about 18 months ago was 1·9 knot per hour, with float submerged 12 feet, and 1·758 knot with float submerged 20 feet.¹

The outer 370 feet was built entirely of concrete, the core being a weaker mixture (Fig. 3, Plate 2). Landward of this portion the top course of the core is of rubble, a material which still nearer the root is used for the lower course also. Permanent rails were laid for a steam-crane of similar capacity to that employed on the breakwater.

The time taken to complete this extension, inclusive of superstructure, parapet-walls, and lighthouse, was 4 years, but it must be remembered that considerable time had to be allowed for the rubble foundations to consolidate before the superstructure could be added.

Whenever this work has been stopped for any length of time, a hole has formed around the end, up to 50 feet in depth; and on one occasion a bay of staging, the piles of which had been driven in 38 feet of water, was washed away, the scouring in one night being 10 feet. Before redriving, this hole was filled with spoil deposited by the dredgers and hoppers.

FLOATING PLANT.

Dredging has played such an important part in the history of Durban that the Author believes the following particulars will be of interest to engineers having control of sand-bar harbours. The Table on p. 36 shows the amount of dredging, both outside the piers and in the extreme outer end of the entrance-channel, and the available depths are tabulated alongside. The gross amounts, exclusive of the work done by the stationary dredgers engaged in land-reclamation, are also given.

¹ These figures have been kindly furnished by Mr. L. H. A. Shadwell, Assoc. M. Inst. C.E., the present Harbour Engineer to the Natal Province, South African Union.—C. J. C.

Year.	Depths in Entrance-Channel.			Month in which		No. of Days on which entrance was		Amount of Dredging done, in Tons.			Remarks.
	Maximum.	Minimum.	Yearly Average.	Greatest Depth Occurred.	Least Depth Occurred.	Dangerous.	Impassable.	Outside Pierheads.	In Section A.	Inside and Outside.	
	Ft. Ins.	Ft. Ins.	Ft. Ins.								
1895	15 0 $\frac{1}{2}$	10 0 $\frac{1}{2}$	12 1	Jan.	Aug.	45-00	21-00	137,955	193,750	1,070,705	500-ton hopper suction dredger "Beaver" employed.
1896	18 5	10 9 $\frac{1}{2}$	15 11 $\frac{1}{2}$	May	Jan.	29-75	19-75	373,050	631,950	2,070,240	1,200-ton hopper suction dredger "Octopus" started work in January.
1897	20 2	14 0	17 3	Nov.	March	32-66	18-50	337,950	229,750	2,041,715	1,200-ton hopper suction dredger "Walrus" started in October.
1898	20 7	15 8 $\frac{3}{4}$	18 7	Sept.	July	30-75	19-50	624,600	151,200	3,063,445	700 feet extension of north pier fully effective in November.
1899	20 5	18 8 $\frac{1}{4}$	19 7 $\frac{1}{2}$	Feb.	May	23-00	7-66	255,800	97,900	2,794,865	1,200-ton hopper suction dredger "Grampus" started work in October.
1900	21 9 $\frac{1}{2}$	17 4	19 8 $\frac{1}{2}$	May	Oct.	23-50	8-00	260,900	113,050	2,543,445	2,500-ton hopper suction dredger "Nautilus" started work in April.
1901	20 6 $\frac{3}{4}$	18 1	19 1 $\frac{1}{2}$	April	Oct.	25-66	8-12	458,000	226,550	2,765,370	3,000-ton hopper suction dredger "Cetus" started work in September.
1902	20 3	16 7 $\frac{1}{2}$	18 5	Dec.	April	21-50	13-66	523,000	183,400	3,683,775	Total amount of dredging done exclusive of land-reclamation.
1903	23 8 $\frac{1}{2}$	18 0	21 3 $\frac{1}{2}$	Dec.	April	14-66	7-50	934,750	188,900	5,553,637	
1904	27 0	23 10 $\frac{1}{2}$	25 9	June and Dec.	Aug.	3-66	2-33	833,500	187,500	8,839,413	
1905	30 6	26 5	28 8	Dec.	June	2-75	1-75	995,000	71,000	8,102,405	
1906	31 11	30 5	31 0	Dec.	Oct.	0-50	0-00	625,500	81,000	5,223,141	
1907	34 6	30 0	32 8	Nov.	April	0-00	0-00	669,500	115,500	5,221,602	
						A "cone-day" is a day of 12 hours.				52,973,758	

It will be noticed that the only actual set-backs in depth occurred in 1901 and 1902. The extension of the north pier in order to bring it level with the breakwater was fully effective in November, 1900, and the weather in 1901 was normal, while the amount of dredging done outside the heads was nearly doubled. In 1902 the entrance was dangerous on $21\frac{1}{2}$ days, and impassable on 13·66 days, the former being 15 per cent. below and the latter 75 per cent. above the average of the previous 3 years. It is very noticeable how the number of bad-weather days decreased as the depths at the entrance increased.

The sand is of course deposited outside the entrance during bad weather from the south and south-west, and in order to prevent the work of the port from being interfered with after such weather, the dredgers were employed in deepening the area a little south of the entrance to 40 feet, i.e., below the general depth, so as to form a trap for the sand before it reached the channel.

The entrance depths could undoubtedly have been increased more rapidly had the dredgers been employed outside the heads whenever they could work; it was necessary, however, that the depths in the neighbourhood of the wharves should be brought into line.

In 1904 and 1905 nearly 17 million tons of spoil were removed, and a year later it was found possible to lay up, and afterwards to dispose of, several dredgers.

A cubic foot of wet sand was found to weigh almost exactly 1 cwt.; thus the spoil removed from the harbour by dredging during the 12 years under review, exclusive of that used for reclamation, would be represented approximately by a cut 2 feet 1 inch in thickness, taken over the whole area of the bay ($7\frac{1}{2}$ square miles).

The Table on p. 38 gives some particulars of the dredgers and of their rates of working.

The records of the "Nautilus" and the "Cetus," of pumping clean sand at the rate of 7,894 and 6,000 tons per hour respectively, were of course made under very favourable circumstances, and the contract-speed for each was only 3,000 tons per hour.

The Congella channel, from opposite the west end of Salisbury Island to a point near the Albert Park (Fig. 1, Plate 2), was dredged very rapidly to an approximate depth of 12 feet below L.W.O.S.T. by the suction dredgers, so as to enable them to reach the site for the proposed Congella Wharf. The sand in this case was pumped over the side of the dredgers, and comparatively little shoaling took place in this channel subsequently.

The dredging of the Esplanade channel to a depth of 25 feet

PARTICULARS OF DREDGERS IN USE AT PORT NATAL, 1895 TO 1907.

Name of Dredger.	Descrip- tion.	Capacity of Hopper.	Dia- meter of Suction Pipe.	Capacity of Pumps In Clean Sand.		Average Output per Annum.	No. of Years Aver- aged.	No. of Days Laid Up.	Average Cost per Ton, including Repairs.	Date of Starting Work.	
		Tons.	Inches.	Contract.	Record.	Tons.			Pence.		
Water Rat .	Suction	..	12	300	..	..	5	49	..	July, 1886	Employed at reclamation work and dredging for quay wall.
Sandpiper .	"	..	12	250	81	..	May, 1890		Approximate cost of work- ing, £1,700.
Beaver .	"	500	..	500	625	464,680	5	45	2-39	29 Aug. 1889	Sold 4th Jan. 1910.
Octopus .	"	1,200	42	3,000	..	930,991	4	72	3-73	Jan. 1897	Sold in Aug. 1906.
Walrus .	"	1,200	42	3,000	..	989,375	4	73	3-07	12 Oct. 1898	Sold in Aug. 1906.
Grampus .	"	1,200	42	3,000	..	1,325,850	4	40	2-23	20 Oct. 1902	Sold in Dec. 1907.
Nautilus .	"	2,500	42	3,000	7,894	2,424,700	4	44	1-59	17 April, 1903	
Cetus .	"	3,000	42	3,000	6,000	2,482,750	2	37½	0-30	4 Sept. 1905	Pumping ashore. Sections taken of work done.
Snipe .	"	200	12	300	340	169,303	2	26	2-53	19 Aug. 1903	
Curlew .	"	..	15	400	Employed almost entirely in land- reclamation, the output being governed by the length of delivery- pipe and time lost in shifting pipes and dredgers						25 June, 1902
Ibis .	"	..	15	400							15 Dec. 1902
Pelican .	"	..	18	500	10 Nov. 1905						Fitted with cutting gear for hard material. Erected and launched on harbour works.
Penguin .	"	..	18	500	11 Dec. 1905						Erected and launched by (Natal contract.
Platypus .	Bucket	..	..	150	150	107,742	5	43	3-65	1884	(Principally employed on hard material.
Otter .		500	..	500	545	222,387	5	66	5-44	16 Dec. 1889	
Teredo .		800	..	800	640	569,505	6	44½	3-52	31 Dec. 1901	
Peter Pat- erson		450	about	29 July, 1902	Sold in Aug. 1906.
Wm. Ball	hoppers	350	..	..	..	293,783	3	30	3-1	27 Feb. 1891	Annual cost of working, £2,500 approximately.
John Milne	steam	350	..	..	..	235,450	2	16	..	8 Jan. 1892	

below low water was much more difficult, as heavy clay was encountered, and gellignite had frequently to be employed to break down the face.

The stationary dredger "Pelican" was fitted with a revolving cutter in order to deal with hard material, but although she did good work she was not powerful enough to keep pace with the progress of the wharf and had to be supplemented by the large dredgers. The reclamation-work done by the dredgers is described later on.

The suction dredgers were employed in the harbour for many different purposes, such as the baring of wrecks which had to be removed, the putting down of dolphins and screw-moorings, etc., and the deepening of the site for the floating dock to 40 feet below L.W.O.S.T.

With regard to the floating dock shown in Fig. 1, the necessity of having some means of laying dry vessels of larger tonnage than could be handled on the patent slip had long been recognized. A floating dock was therefore ordered, capable of raising a vessel having a keel-length of 320 feet and a dead weight of 4,500 tons. This dock was unfortunately wrecked off Mossel Bay while being towed to its destination, and tenders were invited for a larger one capable of raising a vessel of 8,500 tons and having the following dimensions:—

Length over pontoons	425 feet.
Length over platforms	475 "
Extreme beam	96·2 "
Width of entrance between fenders	70 "
Water over keel-blocks	23 "
Time for lifting vessel displacing 8,500 tons	2½ hours.

The dock arrived safely after a voyage of 145 days. Both this and the wrecked dock were constructed on the self-docking principle, i.e., the forward and after pontoons can be uncoupled and docked on the middle one. At the official trial the S.S. "Kent" was raised in a little more than 2 hours, her estimated weight being 7,100 tons. The dock was used for repairing the S.S. "Main," which was brought into the harbour (after striking the Aliwal shoal) in a sinking condition. Her weight was at least 8,500 tons. The dock cost £95,715.

A floating workshop was brought out on the floating dock, and has proved of great service in effecting small repairs to the dock, the dredgers, etc. It is self-propelled and is fitted with the following appliances driven by electric motors:—Planing-, drilling-, punching-, shearing-, and angle-cutting-machines; lathe, blower, and grindstone, also a steam-hammer and two forges.

A 15-ton steam-crane, having a radius of 35 feet, is also provided, and is capable of depositing its load on the workshop floor, a hatch-way being left in the roof. The crane has been frequently used for removing heavy weights from vessels which were unable to get a berth under the 50-ton crane. Some of the copings of the repairing-quay and concrete blocks in the groyne at the Bluff were set by this appliance, the cost of which was £16,000.

An electric launch was obtained in 1902, and was used for surveying and for the general service of the officials.

INNER WORKS AT THE BLUFF.

In 1899 it was decided to build 700 lineal feet of timber wharf on the harbour side of the Bluff, a length which was subsequently increased to 1,050 feet. The depth of water alongside is 25 feet.

This work was begun in 1900, and by the end of that year 650 lineal feet had been completed. The remaining 400 feet was not finished until much later, as the ship bringing the necessary timber was wrecked.

The section of the wharf is shown in Fig. 7, Plate 2, and in order to test the relative merits of locally-grown blue-gum and Australian jarrah, piles of these two timbers were driven alternately in the first 700 feet. As the Author had little hope that the blue-gum would withstand the ravages of the teredo, the wharf was so constructed that piles could easily be replaced. In less than 5 years many of the blue-gum piles had been eaten completely through between wind and water, while for comparative purposes it may be stated that some of the round jarrah piles driven in 1879 at the Point were quite sound after 20 years' use. The largest teredo bore the Author has seen was fully an inch in diameter.

A coal-shed and three timber-sheds, each 96 feet by 48 feet, were built at the back of this wharf, and two 3-ton locomotive steam-cranes were placed on the wharf for discharging timber-laden vessels.

A position to the south-west of the work last referred to was selected for a coaling-wharf, but the site had to be reclaimed, as at this point the high-water mark lay at the foot of the Bluff. The work was put in hand in 1902, a single line of staging, composed principally of old timber and rail bracings from the breakwater staging, being run out. From this staging a rubble mound was deposited to form a retaining bank for the sand filling to be pumped in by the dredgers, which when employed upon this work were kept far enough out in the bay to obviate any danger of undermining the mound. The average depth over the area reclaimed was 7 feet at

L.W.O.S.T., and the finished level was 12 feet above the same datum.

As many as four sand-pump dredgers were employed simultaneously on this work, the progress being slow by reason of the large quantity of shingle encountered. In rough weather, when it was dangerous for these dredgers to go outside to deposit their load, they discharged it alongside the dredgers engaged in the reclamation-work, whence it was repumped ashore.

By the end of 1904, $33\frac{1}{2}$ acres had been reclaimed in this manner, exclusive of that between quay-wall and sloping rubble bank.

The aggregate length of the quay-wall co-extensive with the reclamation is 1,585 feet: alongside 1,005 feet of this the depth is 30 feet at L.W.O.S.T., and alongside the remainder the depth is 34 feet. A section of the deepest wall is shown in Fig. 4, Plate 2.

The method of constructing the quay-wall was similar to that adopted by the Author's predecessor for the wall on the Point side providing for a 23-foot depth, so that the existing plant could be utilized. As it was very desirable that this coaling-quay should be finished as soon as possible, an approach-staging was run out from the reclaimed ground to the proposed quay-line at each end. The piles for this staging were pitched 20 feet apart longitudinally and 34 feet transversely, the structure being made strong enough to carry a light locomotive, the locomotive goliath, and the loaded block-wagons. The heaviest block weighed a little less than 20 tons, and all the blocks were built in a yard 1,400 feet by 200 feet, situated on levelled sand dunes at the foot of the Bluff (Fig. 1, Plate 2). Steam gantry-cranes of 20 tons capacity were used for lifting, stacking, and loading the blocks.

In the case of the deeper wall the foundation-trench was dredged as nearly as possible to the required depth, namely, 39 feet at low water. The piles were then driven to such a depth that a slot cut in each was at a constant and predetermined level. This slot was used for regulating the position of a straight-edge from which the divers could work. If too much dredging had been done, the deficit was made up with clean sand delivered to the divers by means of a tube; if, on the other hand, too little had been done, or silting had taken place, the superfluous spoil was removed by one of the small suction dredgers, the bonnet of the suction-pipe being directed by the divers. A thin layer of quarry-refuse formed the bed for the foundation-blocks, and the line of the work was fixed by using heavy plumb-bobs suspended by piano-wire.

As soon as a sufficient length of work had been built in this manner, the joints between the blocks were stopped with stiff clay

and the work was grouted up. The grout was conveyed through a 4-inch pipe from the staging, and before it was introduced the vertical grout-cavities were filled with quarry-chippings. The lewis-holes were treated in the same manner. The upper surface of each block was provided with seatings standing $\frac{3}{4}$ inch above the general surface, so as to leave a space in the bed-joints for the grout. For grouting, neat cement was used at first, but after making careful experiments $1\frac{1}{2}$ of sand to 1 of cement was eventually substituted, and this effected a saving of about 55 per cent.

The top block, in which the tunnel for water-pipes, electric wires, etc., is placed, was built in situ. Rubble, carefully hand-packed by divers, was laid as a toe for the foundation-blocks.

By working from each end with two independent gangs, 700 feet of completed wall were built in 12 months.

The costs of the 30-foot and 34-foot sections were not kept separately, but the average price was £59 per lineal foot. As soon as a sufficient length of wall had been built, the suction dredgers were again employed to fill the space between the sloping mound and the back of the wall. The stone from the retaining mound was removed as far as possible as the filling by the dredgers progressed.

In 1905 tenders were invited for the mechanical equipment of the coaling-quay, it being specified that the appliances should be capable of loading coal at the rate of 200 tons per hour, the coal being delivered in the largest wagons used on the Natal Government Railways, which are about 37 feet long by 7 feet 9 inches wide by 5 feet 6 inches deep, and can carry 35 tons of coal. The order was placed in August, 1905.

The plant is driven electrically from a sub-station on the Bluff which is fed from the main station through a high-tension submarine cable. The sub-station is built of brickwork, and the transformers, which have a capacity of 300 kilowatts, reduce from 6,600 volts alternating to 500-550 volts continuous current, the transformed supply feeding the arc-lights as well as the motors.

The loaded wagons run by gravitation to a point from which they are picked up by an electrically-driven "pig," housed under ground, and are thus drawn on to the L-shaped tipping-cradle of a large hoist. The wagon is then raised, and, on reaching the required level, is tipped sideways into a shoot, whence it is discharged into six dump-buckets: each of these buckets has a capacity of 6 tons, so that in the aggregate they take the whole of the 35-ton wagon-load, with a margin of 1 ton to spare. These buckets, while being loaded, rest

on trollies, and when loaded they are taken by a locomotive under one of the transporters, which lifts the buckets one at a time and transfers them on board the vessel, the buckets being so arranged as to open automatically on being lowered.

When it is not desired to transfer direct from wagon to vessel, the transporters can discharge the 6-ton dump-buckets into a storage-bin, whence the coal can be again discharged, through doors in the bottom of the bin, into the dump-buckets. The capacity of the storage-bins is 10,000 tons, and they are divided into units of 1,000, 500, and 250 tons. Two transporters are provided, each travelling along the wharf by its own power, and as the outer overhanging arm can be raised into a vertical position, there is no necessity to move the ship when it is desired to load into another hatch.

At the tests in April, 1907, when the plant was provisionally taken over, 1,500 tons were loaded direct and 1,000 tons from the storage-bins at a rate slightly exceeding that laid down in the contract. Since then vessels have been coaled by the two transporters at the rate of 500 tons per hour.

The length of tracks laid was about 8 miles, and the whole of the wharf and yard is lighted electrically. The cost of the coaling-plant was approximately £70,000.

In 1901 the quantity of bunker coal loaded at Durban was 265,240 tons, and in 1907 566,830 tons, while the corresponding figures relating to export coal were 55,757 and 324,425 tons.

INNER WORKS AT THE POINT.

The following lengths of quay-wall were completed at the Point between August, 1895, and December, 1907:—

600 lineal feet with a depth of 22·0 feet at low water.					
2,875	"	"	"	23·0	"
900	"	"	"	27·0	"
700	"	"	"	30·0	"
170	"	"	"	34·6	"

The sections of the 23-foot, 27-foot, and 34-foot 6-inch walls are shown in Figs. 5, Plate 2. The sections giving depths of 27 feet and 30 feet were built without widening the base adopted for a depth of 23 feet, and even with the section giving a depth of 34 feet 6 inches the widening of the base is only slight. The number of blocks was greatly reduced, thereby increasing the rate of progress, as it takes as long to lay a block 3 feet in depth as one 4 feet; and had it not been that the goliaths were only capable

of lifting 20 tons, a still larger block, with a corresponding diminution in the number used, would have been introduced. The reason for using blocks of different thicknesses in some sections was that some were built in advance and had to be worked in.

The construction of the quay-wall, a considerable length of which was built outside the old timber wharves, was carried on under great difficulty, as the constantly increasing trade prevented a long length being given up at a time. For economy it is essential that the staging should be carried well in advance of the work: then the two diving-gangs—the one preparing the bed and laying the foundation-course, and the other completing the block-setting up to low-water level—do not interfere with each other.

The first 620 feet of the section, providing for 23 feet depth, occupied 2 years and 7 months, four divers being employed, working in two shifts. Subsequently, however, the number of divers was doubled, and although the deep section was being dealt with, the rate of progress increased to 700 feet per annum.

The method of construction was, generally speaking, similar to that employed before the Author took charge, as shown in Fig. 9, Plate 2. By this means the plant, such as cranes, divers'-houses, moulds, etc., could be utilized.

A concrete boat-dock was formed at the angle of the wharf, and in this three small stepped jetties were built to accommodate ships' boats, the Harbour Department craft, and private ferry-boats. The piles for these jetties were of old double-headed rails.

In the old block-yard, which was served by four hand-power gantry-cranes, it was found impossible to build blocks with sufficient rapidity to keep pace with the progress of the quay-wall; and in 1904 the total length of the yard was increased to 1,500 feet, and a 20-ton electric gantry-crane, having a span of 135 feet 8½ inches, was ordered. This crane was brought into use in July, 1905, and has entirely replaced the hand-cranes, thus effecting a great saving. The travelling-speed is about 500 feet per minute.

The concrete was hand-mixed on a travelling bunker raised to a sufficient height to clear the tops of the moulds. Two stone-crushers were employed, discharging into wagons running in a sunk way. The salt water for gauging was pumped into a tank on the roof of the engine-house, and the coarse sea-sand used was brought by rail from the south or outer side of the Bluff.

Additional accommodation being urgently required for imported timber, it was decided to construct some temporary timber jetties. For these, blue-gum piles would have been used had they been

procurable in time, but as this was not the case, the stock of jarrah and turpentine-wood was drawn upon.

The position of these jetties is shown in Fig. 1, Plate 2. Nos. 2 and 4 are arranged for end-on discharge, dolphins being put down in prolongation for convenience in mooring the vessels, and the ends being ramped. These jetties are respectively 350 feet by 50 feet, 150 feet by 68 feet, 400 feet by 68 feet, and 150 feet by 68 feet, and the depth of water alongside in all cases is 21 feet.

A jetty 350 feet by 20 feet, with 15 feet of water alongside, has also been built to accommodate the local fishing-industry, and a ferry-jetty with wind-screen and waiting-room has been built at the corner of the wharf.

Opposite sheds H and I, six dolphins, each consisting of five turpentine-wood piles 55 feet long, were driven for the convenience of vessels waiting for a berth at the wharf. In driving these dolphins it was necessary, owing to the length of the piles and the small headroom under the engine, to dredge a deep hole, but this was filled in when the piles had been driven. A general section of the wharf-equipment, showing the positions of the sheds, rails, cranes, etc., in relation to the wharf-face, is shown in Fig. 6, Plate 2.

Each of the five new sheds constructed in connection with the wharf is 405 feet long and 90 feet wide, while a space of 300 feet is left between them. The floors are either of asphalt or of wood blocks, and each shed is provided with fixed hydraulic cranes and with a dock at each end, for convenience in loading railway-wagons. The concrete blocks forming the bases of the shed-columns were in many instances built on the sand immediately after it had been deposited by the dredgers, but no settlement occurred, the pumped sand having been consolidated by the continuous flow of water.

Hydraulic power has been used exclusively on the wharf for working the cranes, and the following additions to these have been made:—

Eight 30-cwt. fixed shed-cranes.

Thirty 3-ton travelling wharf-cranes.

One 10-ton travelling wharf-crane.

One 50-ton fixed crane.

The 3-ton travelling wharf-cranes vary in character, some having luffing jibs admitting of a maximum radius of 50 feet; but all are capable of depositing their loads on the shed-platforms, thus avoiding interference with the wagons and locomotives feeding the wharf.

The 10-ton travelling crane is similar in design to the 3-ton type. The 50-ton crane is supported on an arched pedestal, which allows wagons to pass underneath; its radius is 50 feet, and it is capable of lifting the 3-ton cranes whole, and thus transferring them from one side of itself to the other. To facilitate slinging, the 3-ton cranes are furnished with lifting-rings. Sixteen hydraulic railway-capstans, with the necessary number of snatch-heads, were also installed.

The hydraulic plant having thus been so considerably augmented, it became necessary to build a new pumping-station, and the following is a general description of the machinery installed therein:—

There are two horizontal, compound, surface-condensing engines having a stroke of 38 inches, with cylinder-diameters of $19\frac{3}{4}$ inches and 37 inches respectively. The rams of the force-pumps are 6.363 inches and the pistons 9 inches in diameter. Steam is provided by two Lancashire boilers, each 7 feet 6 inches in diameter by 30 feet long, working at a pressure of 120 lbs. per square inch. A 10-ton overhead traveller was provided in the engine-room for facilitating repairs.

The accumulator, the ram of which is 20 inches in diameter with a stroke of 35 feet, is housed in a steel-framed tower, and is loaded for a pressure of 750 lbs. per square inch. The pressure and return mains are 6 inches and 7 inches in diameter respectively, and the diameter of the branches to the wharf-cranes is 2 inches. The length of additional lines laid on and in the neighbourhood of the new wharves and sheds was about 12 miles.

In 1898 it was found necessary to make large additions to the central station for electric light and power. A new building, having a length of 110 feet and a width of 40 feet, was accordingly constructed, and in it was housed the following plant:—

Two horizontal compound engines of 105 B.H.P., running at 90 revolutions per minute and using steam provided by three locomotive-type boilers at a pressure of 140 lbs. per square inch. These engines, one of which was spare to enable the plant to run all night and every night throughout the year, drive, through a countershaft, three dynamos, each capable of feeding thirty arc-lamps of 2,000 candle-power. In addition to these, two direct-driven sets were also installed, one for lighting the hospital and the other for feeding the glow-lamp main and charging the accumulators. A 4-ton overhead crane travelling the whole length of the building was also provided.

In 1902 further generators were put down, and a year later a fourth boiler and a 75-kilowatt generator were also added.

In 1904 a 300-kilowatt direct-coupled machine, generating continuous current at 500 volts, was laid down, two upright water-tube boilers with mechanical stokers being supplied to provide the requisite steam.

From the foregoing it will be seen that each addition was only sufficient for the immediate needs, but financial considerations precluded any other course.

The whole of the cables were laid underground in cast-iron pipes, and the arc-lights were erected on latticed standards.

Power was supplied to eight private firms for lifts; and all the private offices and buildings at the Point, as well as the harbour-office, official dwellings, custom-house, etc., were supplied with current for lighting.

A new scintillating light, visible for 5 miles, was installed on the beach to help vessels in finding the anchorage. This was necessary, as the arc lighting of the town rendered the old fixed light useless.

Electric light was also added to the dredgers, steam-turbines being used to supply the motive power.

A two-story bonded warehouse was provided, and was so designed that a third story could be added later if required. Most of this building was let by contract, but the sinking of the concrete cylinder required for the ram of a hoist capable of transferring the 35-ton wagon from floor to floor was carried out departmentally. This cylinder was built of concrete in sections, upon a heavy jarrah ring provided with a cutting edge, and was sunk by pumping out the sand with a 12-inch centrifugal pump. At a depth of 33 feet some hard material was encountered which canted and strained the cylinder; eventually, however, it was righted, and the sinking was completed to the full depth of 54 feet. The inflow of water through the sides and bottom of the cylinder caused considerable trouble, and a diver was employed to stop the leaks and put in the concrete bottom. The hoist worked well, the deflection of the tracks inside the warehouse, when supporting a loaded wagon, being hardly capable of detection.

The large increase in plant and the work caused by the development of the inner harbour necessitated important additions to the workshops and machinery. A general plan to be worked to as requirements increased was laid down, and the following shops were erected:—

Blacksmiths' and coppersmiths' shop (190 feet by 40 feet), containing twenty-two forges and two steam-hammers.

Fitting-shop furnished with a 7-ton overhead gantry-crane.

Foundry (100 feet by 40 feet) capable of producing castings up to

5 tons in weight and provided with a 10-ton overhead crane, boiler-makers' shop, machinery-store, stores, etc. With the exception of the engine- and boiler-house, which was of brick, the whole of the shops and stores were built of timber and galvanized iron.

The machinery installed included the usual varied equipment of a first-rate repair-works, all of a very substantial character. The workshops find employment for about 300 Europeans and a large number of natives.

The slipway, built in 1886 for vessels of 500 tons, was lengthened in 1895-6, and the fact that after 10 years' hard work the ways were sometimes called upon to carry 1,100 tons (vessels of this weight being raised without mishap) speaks well for the original construction. In 1897 the cradle was divided into sections, so that any portion could be removed.

A large number of borings were taken in 1902-3 with the idea of constructing a dry dock near Cato's Creek, but in view of the fact that a large floating dock was on order and that an alternative site had been suggested, the matter was allowed to lapse.

WORKS AT CONGELLA.

In 1904 it was decided to reclaim a large area near the Albert Park, which might be leased to private firms. The dredging of the Congella and Esplanade channels is described under "Floating Plant."

Numerous borings were taken over the site of the proposed wharf, as in the Esplanade Channel. Stiff clay being found over the whole area, a dredger with a cutter working on the end of the suction pipe was ordered. Fig. 1, Plate 2, shows the area reclaimed, and a section of the wharf is given in Fig. 8. A gantry 1,600 feet in length, behind which the sand for reclamation was to be pumped, was first constructed, and some small suction dredgers were put to work; little progress was made, however, owing to the presence of the stiff clay. The cross banks for retaining the dredgings were begun in March, 1905, and 3 months later an area of about 65 acres was enclosed; by October this was increased to 80 acres, 15,000 cubic yards of sand and clay having been used in these retaining banks.

The estimated quantity of spoil required to reclaim the first section, namely, 65 acres, was 629,200 cubic yards, and during the year 1906 no less than ten dredgers were engaged from time to time upon this work, among them being the "Pelican," the vessel with the cutting-appliance.

Pile-driving for the approach to the permanent wharf was begun

in October, and 410 lineal feet were finished early in December, the whole being completed on the 15th February, 1906. Round piles of turpentine-wood were used, and this timber proved to be better than jarrah for underwater work.

The first permanent pile was driven on the 22nd March, 1906, and by the end of the year 805 feet of wharfage, having a depth of 25 feet alongside at L.W.O.S.T. was completed, while an additional length of 200 feet was well in hand.

It is worthy of note that the inner pile of bay No. 6 had to be scarfed twice and driven to a depth of 42 feet before a firm bottom was reached, while the remaining piles encountered what was evidently hard clay at a reasonable depth. The timber gantry for retaining the spoil was extended to 2,000 feet, and the suction dredger "Octopus" continued the reclamation, being fed by the dredgers engaged in cutting the channel: she pumped 299,861 cubic yards in 8 months, and was then relieved by the "Pelican." The length of pipe-line through which sand and clay were pumped for this work ranged from 100 to 2,200 feet.

Reinforced-concrete sheet-piling, anchored to concrete tie-blocks buried in the sand backing, served over a portion of the length to retain the filling at the back of the wharf. The levelling and ballasting of the area reclaimed was begun in March, 1906, and by the end of the year 50 acres had been completed.

The S.S. "Ilderton," which arrived at Durban on the 5th October, was the first vessel to discharge commercial cargo at this wharf: she landed 6,600 tons of timber.

The authorized length of wharfage—1,500 feet—was practically completed in December 1907, and, with the exception of the railway reserve, nearly the whole area reclaimed (94 acres) was leased to private individuals, who erected their own buildings.

Reclamation of low-lying land for the Durban Corporation was taken in hand by the Government, as a set-off against certain lands handed over by the Corporation. The area lies on the north side of the main railway-line between Durban and Congella, and as it was too remote for the work to be done by dredgers, ballast-wagons were employed. The spoil was at first obtained from the Point, but latterly a very suitable spoil-bank consisting of red sand close to the Bluff railway was utilized. This work was begun in February 1907, and by the end of the year about 388,000 cubic yards of sand had been got, loaded, run to site, and levelled. Approximately 60 acres were thus raised by an average of 4 feet, and the cost worked out at 8*d.* per cubic yard, a figure which included railway carriage, tools, plant, service-lines, etc.

WORKS AT SALISBURY ISLAND.

In 1902 it was decided to construct a relief slipway for tugs and other craft not exceeding 200 tons dead weight. The gut-way was dredged by the "Sandpiper," the material being pumped ashore on to some low-lying ground in the neighbourhood. Pile-driving for the ways was commenced in March and was completed in May, thirty-four piles being driven and 240 lineal feet of staging completed. The crossheads and longitudinals were fixed by divers, and hauling-machinery was built in the shops.

Owing to an outbreak of bubonic plague the island was placed in quarantine, and it was not until September, 1906, that the slip was put into use. The bulk of the timber used was jarrah, which, when wholly submerged, resists the attacks of the sea-worm exceedingly well. Karri, which is very similar in appearance, is practically useless for underwater work. If any doubt exists in identifying the two woods it can be settled by burning a chip: karri leaves a white ash and jarrah a black ash.

A small landing-jetty was built near the slipway, the piles and struts being of double-headed rails and the upper work of pine. Another jetty was built at the east end of the island, which proved of great service during the time the island was used as a plague-camp.

GENERAL STATISTICS RELATING TO DURBAN HARBOUR.

	Ft. Ins.	
Mean range of spring-tides (average for 6 years)	6	6
" neap- "	1	8½
Highest tide record	7	4 above zero.
Lowest "	1	3 below zero.

Number of days on which wind blew (average for 6 years):—

Miles per Hour.	East. Days.	West. Days.
20 to 30	74·0	64·33
31 to 40	33·16	37·0
41 to 50	5·33	9·5
51 to 60	nil	1·16

The highest wind-velocity recorded, 63 miles per hour.

Average rainfall for 7 years, 38·89 inches.

Average number of rainy days per year, 117·50.

Barometer- and thermometer-readings (average over 7 years):—

	Barometer.	Thermometer.
High	30·03	79° F.
Low	29·93	64° F.

Available depths of water at entrance at L.W.O.S.T. :—

	Ft.	Ins.
Average in 1895	12	1
Average in 1907	32	8

Tonnage entering :—

	Tons.
1895	319,878
1907	2,542,130

Draught of deepest vessel :—

	Ft.	Ins.
1895	19	0
1907	30	7

The works described in the foregoing pages are connected with the harbour of Durban alone, and the Author proposes now to touch upon the various lighthouse improvements which have been carried out along the coast under his supervision, and upon the works at Port Shepstone, also under his control.

LIGHTHOUSES.

The Aliwal shoal lies about 26 miles south of the Bluff, and about $2\frac{1}{2}$ miles from the mainland. It has a length of about a mile, and the least depth of water over it is 12 feet. This shoal was formerly marked by two fixed white lights, exhibited from points about 5 miles apart on the mainland. These lights were replaced, under the Author's supervision, by a single second-order double-flash light placed on a suitable tower on the headland known as Green Point, lying about opposite the middle of the shoal. A subsidiary light shows red over the shoal itself. At the official inspection in October, 1906, the red light was seen distinctly at 8 miles, and the flash at 18 miles, although the night was not particularly clear. The old towers were taken down for use elsewhere, their positions being marked by conspicuous beacons.

The south tower, with the light modified to an occulting character, was erected at Port Shepstone, 60 miles south of the Bluff, and was commissioned on the 1st March, 1906. Only one European is employed at this light, the watches being kept by Indians. An electric alarm, indicating when the driving-weights need winding, is fitted in the quarters of the European light-keeper.

The north tower, with light complete, was re-erected at Cape St. Lucia, about 120 miles north of the Bluff. This light has been installed 392 feet above sea-level, as no suitable site at a lower level could be found. The difficulties of transport over a roadless country, through swamps, sand dunes, and dense bush, were very great, but

eventually all the materials were delivered within a short distance of the site.

The light was exhibited for the first time on the 15th December, 1906, or about 8 months after the tower was removed from its old position.

PORT SHEPSTONE HARBOUR.

Port Shepstone lies at the mouth of the Umzimkulu, a river which is navigable for small craft for a distance of 7 or 8 miles up. The entrance is encumbered with an enormous sandbank. The works as designed, when the Author was asked to take them over in October, 1903, consisted of a rubble and concrete training-wall on the south side of the entrance; but only 136 lineal feet had been built by 1903, owing to the difficulty of coping with the rapid accumulation of sand. Early in 1904 a narrow channel existed between the training-wall and the sandbank: this, after an unsuccessful attempt, enabled the suction-dredger "Snipe," which had been ordered for these works by the Government, to get into the river at the top of the high water of a spring-tide. She was useless, however, in attacking the bar in the ordinary manner, because, if working from the inside she could not pass out with her load, and if from the outside there would have been danger from her not being able to enter the harbour during bad weather, except at rare intervals; she was, however, employed in pumping the sand over the training-wall.

The wall was extended by means of timber wharfing, the piles, which were of jarrah, being driven without difficulty 5 to 7 feet into the hard bottom, which was previously considered to be rock.

In 1905 the Author reported that a fair depth at the entrance could not be expected without a north wall, but no money was voted for this. A very severe storm was experienced on the 31st May, 1905, but comparatively little damage was done to the staging. The making-up of the foundation for the training-wall under the staging was continued until the end of July, and the concrete superstructure was begun at once. By the end of the year, 504 lineal feet of bottom course and 434 feet of top course had been built. Forty-eight 2-ton concrete blocks were put in between the end of the old training-wall and the new wall to prevent the rush of water through the opening.

The "Snipe" was again employed in reclamation, and completed the filling-in of the low-lying land at the back of the training-wall (known locally as the "Dead Lake"). She also carried out a considerable amount of reclamation on the north side of the river to the north-east of the goods-shed, a bank 300 feet in length having previously been formed to retain the sand.

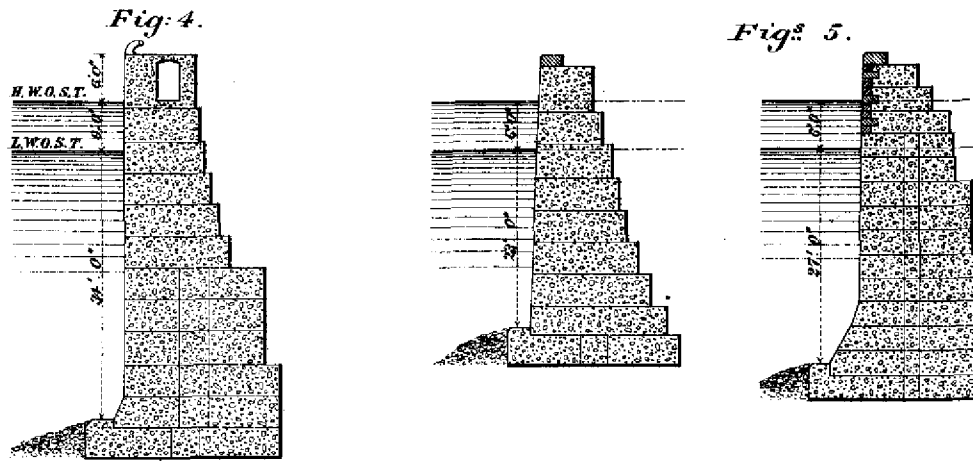
The training-wall was completed in June, 1906, and the making-up of the aprons continued to the end of the year. No further works were authorized, it being generally conceded that the railway to Durban could deal with the produce from all existing industries in the neighbourhood for the time being.

The total cost of the works described in this Paper and of the general maintenance in the 12 years under review was nearly £3,000,000.

The Paper is accompanied by eleven drawings, from some of which Plate 2 has been prepared.



NATAL HARBOUR - WORKS.



QUAY-WALLS AT THE POINT.

