NOTES ON HARBOUR ENGINEERING.

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The immense increase in the size and tonnage of ships during the past twelve years is causing very great activity in harbour engineering throughout the world, and it may interest those present, many of whom will no doubt take up this branch of our profession, were I to place before them this evening some particulars of the modern steamships as compared with those of earlier times, and the steps being taken to provide for their accommodation at some of the principal ports of call.

The following table gives an average of the leading dimensions of the twenty largest vessels afloat for each decade from 1881:—

	1881	1891	1901
Length	460 feet	507 feet	599 feet
Beam	45 feet	54¼ feet	65 feet
Depth	30 feet	31 feet	32 feet
Draft Loaded ..	24 feet	27 feet	32 feet
Tonnage	4,900 tons	6,980 tons	14,150 tons

In the present year (1911) we have several vessels ranging from 680 feet in length and 30,000 tonnage to that of the latest leviathan the "Olympic," with a length of 882½ feet, 92½ feet beam, tonnage 45,000 tons, and load draft 34 feet 6 inches. The other White Star ship now nearing completion, the "Titanic," of similar dimensions as the "Olympic," the Hamburg American liner "Europa" of 50,000 tons, the latest announcement that the Cunard Line are making a great stride forward with a vessel of 60,000 gross tons, and the huge vessels about to be laid down by the North German Lloyd are further proofs that the limit has not yet been reached. There can be little doubt that, within the next few years, vessels of 1000 feet in length will be constructed, and harbour authorities will have to provide accommodation for them, no matter at what cost.

Up to the present these vessels have only been used in the Trans-Atlantic service, where, owing to the immense cargo and passenger trade, and the absence of any difficulty of providing coal for the short passage, they are especially suitable; but it is inevitable that, in the near future, vessels of this class will supersede those at present trading to Australian ports.

To provide deep water and berthing accommodation for these Trans-Atlantic leviathans has been an anxious and costly task for the harbour authorities at the terminal ports. I cannot better describe the situation than by quoting the first paragraph of a very interesting article which lately appeared on this subject in one of the American scientific journals:—

"A race between engineers: such might describe the condition of affairs in the maritime world of to-day in regard to two of the most important branches of civil engineering. On the one hand, we have the ship designers turning out larger and larger vessels; on the other is the harbour engineer, striving vainly to provide a sufficient depth of water in which to float these large steamships. It is a tremendous struggle. The former has set the pace, and the latter finds it hot, so much so that he is hard put to it to keep on his rival's heels."

It must be borne in mind that even one of the large Trans-Atlantic liners takes a relatively short time to construct, whereas dredging deep-water channels and constructing docks and wharves to accommodate them is a long and tedious work. At New York the work of cutting an approach channel 2000 feet wide, to provide 40 feet of water, necessitating the removal of some 42,500,000 cubic yards of sand and mud, at an estimated cost of £800,000, was started in 1901. When the "Lusitania" sailed on her maiden trip some years later, only half the work had been completed. The channel was then seven miles long, and carried 40 feet of water for a width of 1000 feet, 40,000,000 tons of sand having been removed. At the present only seven-eighths of the channel is completed, thus showing over 10 years' work to provide an adequate channel at New York for the use of this class of vessel.

At Liverpool, the home of the Cunard Company, the Mersey Docks and Harbour Board have started a comprehensive dock system, which is estimated to cost over £3,500,000 by the time the work is completed. In addition to the provision of these docking facilities, a large amount of dredging has to be done to make the approach channels adequate. The sand pump "Leviathan," which is at present employed on this work has a capacity of 10,000 tons, and is capable of filling herself in 50 minutes. This plant started work in April, 1909, and in the first year removed 12,121,700 tons of silt.

London is making provision for the accommodation of the modern ship: the river channel from Tilbury to London is to be widened and deepened to 30 feet, and three large docks are to be constructed at Tilbury. This is a huge undertaking, and will probably cost £14,000,000.

Large expenditure is also being incurred at all the other leading ports of Europe and America to meet the ever increasing requirements of over-sea traffic.

It is interesting to note from the table of dimensions of ships given above, that, while there has been a very large increase in the tonnage of steamships during the last ten years, the loaded draft has not increased in the same proportion as the length or breadth. Let us hope that the conclusion to be drawn from this, viz., that the limit of draft has nearly been reached, is correct, and that the draft of the vessels of the future will not exceed 38 feet. To accommodate vessels of this draft will be a serious problem for engineers in charge of the large majority of the harbours of the world. The following table gives the depth of water in the approaches to a number of the principal harbours, and from this it will be seen that, at the present time, those with a depth of 35 feet at low water spring tides are comparatively few in number:—

PARTICULARS OF WATERWAY AT VARIOUS PORTS ABSTRACTED LARGELY FROM LLOYD'S REGISTER OF 1911.

Name of Port	Depth at Berth.	Existing Width.	Channel Depth at L.W.O.S.T.	Range of Tide from L.W.O.S.T.
	ft. in.	ft.	ft. in.	ft. in.
Amsterdam	30 0	—	32 0	—
Auckland	29 0	—	31 0	11 0
Baltimore, U.S.A. ..	30 0	—	30 0	1 6
Boston, U.S.A.	30 0	1,200	30 0	9 6
Belfast	—	—	25 5	4 8
Bulogne	32 0	—	33 0	36 0
Halifax, Nova Scotia ..	24ft. to 50ft.	—	very deep	6 0
Hamburg (Elbe).. ..	26 5	—	26 0	7 0
Hobart	—	—	60 0	4 6
Hong Kong	42 0	—	40 0	7 0
Lisbon	27 9	—	41 0	12 0
Liverpool	36 0	—	31 6	29 6
London	34 0	—	28 0	20 8
Manchester Canal ..	26 0	120	26 0	—
Marseilles	29 6	—	52 5	—
Montreal	32 0	450	30 0	—
Melbourne	29 0	—	33 0	2 8
New York	35 0	1,000	40 0	5 6
Panama Canal	—	—	35 0	—
Philadelphia	39 6	2,000	30 0	—
Rio de Janeiro	—	—	30ft. to 70ft.	—
St. John's, Canada ..	30 0	—	30 0	26 6
San Francisco	22ft. to 40ft.	—	33 0	5 6
Singapore	30 0	—	30 0	10 0
Southampton	32 0	—	32 0	13 0
Suez Canal	—	213	29 6	—
Sydney	32 0	700	35 0	5 0½
Vancouver, Canada ..	30 0	—	27 0	13 0
Wellington	33 0	—	42 0	4 0

Of course, the difference in the rise and fall of tide must be taken into consideration when comparing the depth available at various ports; for example, there is but 23 feet on the sill at Tilbury docks; but, owing to the high rise of tide at the port, namely, 20 feet 8 inches ordinary spring tides, deep draft vessels can be taken in and accommodated there. Barry, with a 36 feet rise ordinary spring tide; Liverpool, 31½ feet rise equinoctial springs, and 29 feet 6 inches at ordinary spring tides are other examples of this. On the other hand, the constructing of berthing accommodation is, as a rule, less difficult and less costly in ports such as those in Australia, where, owing to the small range of tide, tidal docks are not required. The depth of water in the Suez Canal at present is 29 feet 6 inches; but it is proposed to deepen it throughout to 34 feet 6 inches. The proposed depth of the Panama Canal, now in course of construction, is 35 feet.

In 1828 the British Empire owned 293 steamers, aggregating 32,000 tons, and, during that year, 31 steamers of less than 2500 tons were added to the list. In 1909 there were 22,522 steamers entered in Lloyd's Register, and, during the year, 465 steamers of 972,799 tons were launched in the United Kingdom. Last year (1910) 1163 vessels of 1,339,488 tons were launched in the United Kingdom; the world's grand total of vessels launched in 1910 being 2541 vessels, of 2,375,735 tons.

Coming nearer home, let us now consider the state of affairs in the port of Sydney. The following is a table showing the number of vessels entering the port of Sydney at various dates:

Year.	No. of Vessels.	Aggregate Tonnage.
1830	157	31,225
1840	709	178,958
1860	852	292,213
1870	1,006	385,161
1880	1,277	837,738
1890	1,525	1,644,537
1900	1,819	2,716,651
1905	9,626	5,681,071
1910	8,844	7,137,308

The figures for 1905 and 1910 are worthy of note. They show that, although the number of vessels was 782 less in the later year, the tonnage had increased by nearly 1½ million tons. The number of vessels visiting the port in 1903 exceeded that of the previous year by 2371, the figures being 6093 and 3722 respectively, and the great difficulty of providing accommodation for this large, sudden increase in volume and tonnage of shipping will readily be realised. It must be remembered that, prior to the formation of the Harbour Trust, a large proportion of the wharves and jetties were owned, and had been

Tyser's Wharf, Miller's Point, Sydney.

constructed by private companies to suit their individual requirements, without system and without regard to future expansion. Most of these jetties had been in existence for many years, and had been constructed to suit the small class of vessels then trading to Sydney. These narrow jetties, few of which exceeded 300 feet in length, and with about 80 feet to 90 feet waterway between them were found quite unsuitable for the larger ships to berth or discharge at. In order to afford some immediate relief from this state of things it became necessary to practically reconstruct the whole of the wharfage between Miller's Point and the head of Darling Harbour. The demolition of a number of these old wharves, many of which had been in existence for 30 to 40 years, gave me an exceptionally good opportunity of closely observing the behaviour of the various classes of timber and other material used in their construction, and, as the information thus gained has been of considerable value in connection with subsequent wharf construction, it may be of interest to my hearers.

PILES.—Nearly all the private wharves from the head of Darling Harbour to Circular Quay were constructed with unsheathed turpentine piles of from 9 to 12 inch diameter. Though the exact dates of erection in some instances were unobtainable, it is known that the majority of them were from 30 to 40 years old. Some of the piles drawn were found to be entirely crippled; but an examination showed that such were usually not turpentine timber. Many of the piles removed from Smith's Wharf, at Miller's Point, which had been in service for some 30 years, were found to be quite sound, and were used again for various purposes, such as sleepers for cargo sheds, repairs, etc. Some 400 piles drawn from other jetties were driven again in the reclamation behind Nos. 2, 3 and 4 Jetties, Darling Harbour, in connection with the foundations for the sheds. A number of piles, which looked quite crippled above the water line, were cut into for examination, and it was found that only the sap wood had been destroyed by sphæroma and limnoria terebans—two marine borers which work near the surface of the water—the timber itself being as sound as the day it was first driven. Quite 80 per cent. of the old turpentine piles drawn were used again for various purposes. It may be noted that the water in the vicinity of Miller's Point is in the line of tidal current, and has always been comparatively free from sewage matter, so that pollution of the water can have exercised very little influence in preserving the piles in Smith's Wharf from marine borers. It is, of course, well known that borers, more especially the teredo, will not, as a rule, attack piles in the vicinity of sewage or water polluted by greasy matter; but in clean, brackish water they are more destructive than in pure, salt water.

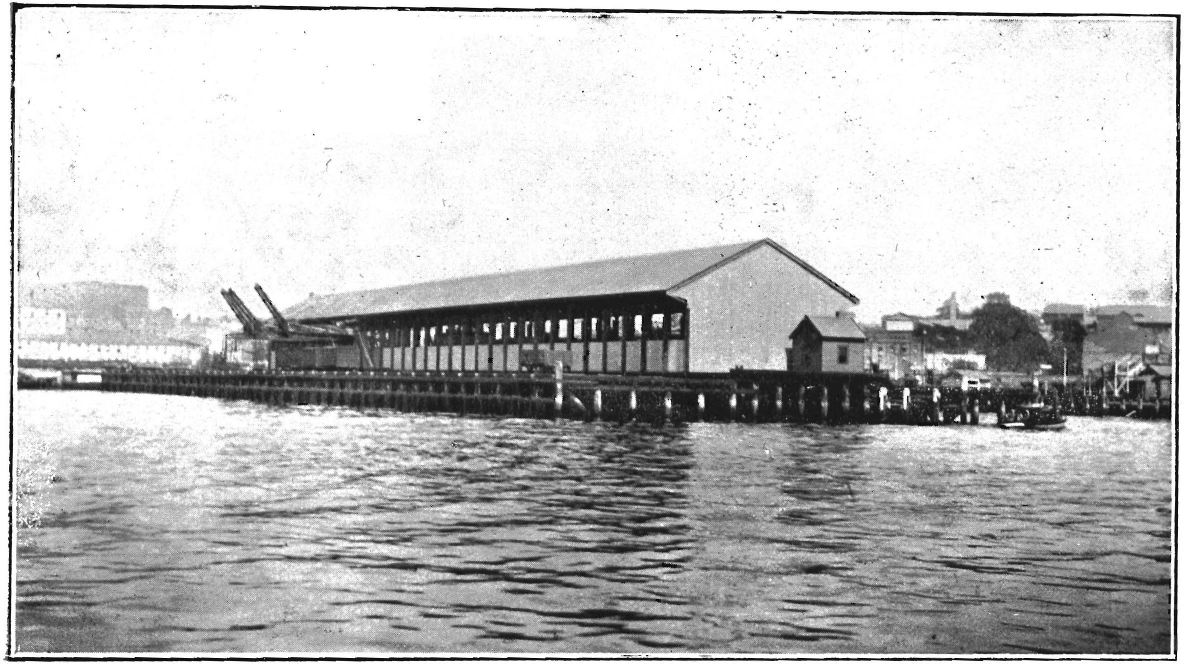
Unsheathed turpentine piles drawn from a jetty at Woolloomooloo, after a service of 20 years, were found to be quite sound, with the exception of a few small teredo holes in the sap wood, and slight erosion at and below low water mark due to sphæroma. Turpentine spring piles drawn in Circular Quay, after 12 years' service, were found in the same good condition, and were again driven in the same positions.

In my opinion, which is based on many years' experience of wharf construction in this State, turpentine piles are incomparably superior, not only to any other Australian timber, but also to any other obtainable of the same size for use, unsheathed, in the latitude of Sydney. The value of turpentine (syncarpia laurefolia) as a teredo resisting timber has been so amply proved by long use in this harbour that I have felt satisfied in using it in the construction of nearly the whole of the large wharves and jetties recently constructed, and, during the past year, I have driven some 4640 turpentine piles, varying in length from 40 to 80 feet. I look forward with every confidence to a life of 30 to 35 years for these piles.

Ironbark piles, if properly sheathed, are undoubtedly the most durable and strongest of all our timbers. A few years ago the piles from the old Pyrmont Bridge were drawn, and were, with very few exceptions, found to be perfectly sound after standing in the salt water for 48 years. These were re-sheathed and used in the construction of a new wharf in the same locality.

Theoretically, piles can be driven at the same rate with a light monkey and a long drop as with a heavy monkey and a short fall; but, in practice, the latter method is found the more preferable. A long fall means greater oscillation of the monkey and consequent jar, and is therefore more wearing to the plant and injurious to the pile. Better work can be done with a 2½ ton monkey and 4 to 5 feet fall, than with a 1 ton monkey and 8 to 10 feet fall, although the blow delivered on the head of the pile is practically the same.

If the work of driving a pile be suspended for a time it is found that the resistance to driving is materially increased. This is more noticeable in the case of clay or stiff mud bottom and is, no doubt, due to the consolidation and clinging of the material round the pile, which, when being driven, carries down with it an amount of extra moisture, which, for the time, reduces the friction. Many years ago, when, as junior in charge of some pile driving in soft clay bottom, the author noticed that, for no apparent reason, the pile-driver frequently broke down, and the work had to be suspended till the next day. On further investigation, it was found that these break-downs invariably



Grain Shed, Darling Harbour, Sydney.

occured when a pile was down to within a few feet of the cut-off level, and was still going freely at each blow. On resuming work the next day, the pile, as a rule, drove to test. The contractor evidently knew what he was doing.

In many parts of Sydney Harbour the bottom is composed of a fairly stiff red clay, and the practice is to allow for 25 feet of driving in material of this class, and though some piles do not finish to the recognised test, this has been found ample to carry any load that may be placed on the superstructure. In designing wharves, 20 tons is the load allowed to each pile. It is also our usual practice to allow five cwt. per square foot as a maximum loading on wharf decks. A load of three cwt. is provided for in the case of the upper decks of wool sheds; this allows of dumped wool being stacked five bales high, or a total height of 16 feet.

METAL SHEATHING.—In cases where yellow metal sheathing has been thought necessary for the protection of ironbark and other piles, the question of providing a suitable material has caused much anxiety of late years to engineers, and samples of yellow metal taken from the piles of the old Prymont Bridge, which had been in use for 43 years, although worn in places, were found to be sound, fairly flexible, and capable of being polished.

Other samples removed from various places and which had been standing in salt water for upwards of twenty-five years, were found in a similar state of preservation. The yellow metal obtainable for the past ten years, however, is far from satisfactory, and its use as sheathing for piles has in most cases been attended with conspicuous failure. Manufacturers state that they are unable to afford satisfactory explanation for this sudden and rapid deterioration. It has been suggested that the modern electrolytic process in the production of copper, whereby chemically pure copper is produced, may have something to do with the rapid corosion.

WHARF BEAMS.—Ironbark (Eucalyptus Paniculata, and Eucalyptus Creba) are the most durable of Australian timbers for caps and girders, grey gum (Eucalyptus punctota), and brush box (tristania conferta) are also good, reliable timbers for this purpose. Turpentine is a good timber and only a little less durable than ironbark, and also possesses the advantage of being less open to attack by white ant. Turpentine girders and headstocks used in the construction of one large wharf in Sydney Harbour thirty years ago, are still in fair condition. The chief cause of rottenness in wharf girders arises from the opening up of the top of the logs by the deck spikes. A row of ½ inch or ⅝ inch spikes driven into a girder creates long cranks which allow the rain and dirt to enter, and rot is set up. To overcome this difficulty, I have, for some years past, laid a damp-course of malthoid on top of each girder before spiking down the decking. The extra cost (0.6d. per foot run of girder) is very small, and the result has been most satisfactory.

Decking.—Experience shows that it is highly desirable that where possible, only one class of timber should be used in a wharf deck. To lay planks of various timbers with different durability indiscriminately, usually causes a very uneven surface after short service, which makes trucking over it very difficult and even dangerous. In Sydney Harbour, brush box only is used for deck planks. It is found most durable and wears more uniformly than any other available timber. Sheathing over deck planks on wharves is not desirable, as it tends to rot the planking. A coating of chinam, consisting of lime and boiling tar, and worked up to the consistency of mortar, has been successfully used to prevent the retention of moisture between the planking and sheathing. The life of wharf decking, of course, depends largely on the amount and nature of the traffic; but, generally, the life of a box deck four inches thick on our cargo wharves may be put down at ten to twelve years.

Sea Walling.—The very variable nature of the foreshore in the vicinity of our wharfage accommodation has made the work of sea-walling one of considerable difficulty. In some cases, rock is met with at a shallow depth, in others over 30 feet of water, with soft mud bottom 40 feet deep had to be dealt with, while in Darling Harbour, north of the Gas Works, it was found that the bottom consisted of a very slippery clay, which had to be dredged in benches in order to prevent the ballast from slipping down when the filling at back was put in.

The circumstances of each case had to be taken into consideration when designing these sea-walls. No generalisation was possible, and on this account, eight different kinds of sea walls have been constructed to suit the various localities.

Work carried out under water is always more or less open to doubt on account of difficulty in inspection, and, besides, mass-work concrete laid in water is uncertain in quality.

The earliest practice was to tip stone ballast up to low water mark, and build thereon, as a foundation, a cut stone wall. The walls round the Botanical Gardens, Circular Quay and at Dawes' Point were built in this way, and it is both interesting and instructive to note the amount of settlement and movement out of alignment that has taken place.

This practice was adhered to for many years, and the shipping used to lie off the walls boomed out by ironbark spars