REINFORCED CONCRETE DOCK FAILURES.

THE subject of reinforced concrete dock construction has been given considerable study in these columns. In our issues of August 27th and October 1st, the extent of this form of dock construction was outlined as regards practice in England and America respectively. In reviewing what has been done thus with reinforced concrete, it is necessary to state that it has not withstood in every instance subjection to the action of sea water. For the results of an extensive investigation into the effect of alkali and sea water upon concrete structures, the reader is referred to an article on the subject in *The Canadian Engineer*, July 31, 1913, page 233. The following, which is a continuation of the subject of reinforced concrete dock construction, outlines the failures that have occurred, and it is to be noted that they are due chiefly to the above cause.

In discussing reinforced concrete docks, the fact that there have been failures among them must not be overlooked. In Massachusetts waters, north of Cape Cod, a number of serious cases of deterioration of concrete have been caused by the disintegrating effects of sea water, wave action, and frost, especially in Boston Harbor, where nearly all the concrete structures standing in sea water have been affected badly between high and low tide, the most notable instance of which is the concrete pier at the Charleston Navy Yard. Although that part of the pier which is constantly submerged has given but little trouble, the part exposed alternately to the sea and air has been seriously affected, many large pieces having broken completely away, making it self-evident that some other agent than the chemical action between cement and sea water was at work.

As is well known, winter temperatures on the whole eastern front of the New England Coast run far below zero. In Boston Harbor 12° below zero is not uncommon. In the same way that hard earth and porous rocks are broken up by frost action, permeable concrete in freezing water will gradually be destroyed between wind and sea, as the water which gets into the concrete simply exercises its natural expanding function in freezing, which *a priori* is detrimental to the concrete structure. It is generally admitted that the exterior concrete in these Boston structures, especially in the Navy Yard pier, has failed almost entirely from the effect of the alternate freezing and thawing with each tide during the winter, due to permeable concrete.

A number of failures similar to that already cited have occurred in Boston, the disintegration taking place in all cases between low and high tides. In the case of the Dover Street draw-bridge pier, built in 1894, the disintegration had extended 1.4 ft. into the pier at the end of 17 years, the greatest damage being just below high-tide level. The pier was built of 1:2:5 concrete, with a 1-in. plastered mortar facing. English Portland cement was used throughout. Whether the 1-in. facing mortar was expected to act as a waterproof shield to the interior concrete is not apparent. Evidently, it did not act thus, as might have been expected.

As all the concrete in these disastrous cases seems to have been placed in the wet, that is, the sea water was allowed to come in contact with the concrete before it had become thoroughly cured and hardened, such results are not to be wondered at, for one of the axioms of a successful use of concrete in sea water is that it must be kept from contact with sea water for such a period of time as to enable it to become thoroughly hardened, especially that part between tides in freezing climates.

In several cases in Boston Harbor where the concrete was placed inside of a coffer-dam, or used in the form of pre-moulded, driven, concrete piles, the concrete does not seem to have been affected as in the other cases cited. These successful cases go a long way toward substantiating the truism that concrete, to be used successfully in sea water, especially in freezing water, must be made impermeable in the process of making, with full consideration given to the brand of cement used, the mixture, the sand, and stone (or gravel), the skilled labor of placing, as well as keeping it from contact with sea water until it has set and hardened sufficiently. It is very apparent, from a study of the method used in placing the concrete in the disintegrated structures in Boston Harbor, that that method was far from possessing the essential features necessary for a successful solution of the problem, viewed in the light of present-day knowledge.

In comparison with these Boston failures, it is fitting to state that at Dundee, Scotland, where the climatic conditions are said to be worse than at Boston, and where there is a rise and fall of the tide of about 12 ft., the combined action of the sea, waves, and frost has had no ill effect on the concrete docks in that harbor, the concrete piles of which were allowed to harden for 30 days before being put in place.

Another noted case of the destruction of concrete by frost and sea action is the large concrete sea wall along the water front of Lynn, Mass.—a massive concrete sea wall exposed to the pounding of the winter storms and seas. The steps to the beach in the front of this wall were destroyed to such an extent as to be hardly recognizable as steps. It might be of interest to state that this wall and some of the damaged structures in Boston harbor have apparently been repaired effectively by the cemen gun process.

In reviewing these failures in Boston and vicinity, it is well to consider the results obtained in using concrete in another port subject to freezing and ice conditions, viz., New York Harbor. In addition to freezing conditions, New York Harbor has to contend with a strong tidal effect, which results in large solid ice floes and fields of broken ice moving back and forth with a tide of considerable velocity, ice floes of such size coming down the Hudson as at times practically to compel abandonment of all transfer traffic in that river. This is an effect from which Boston docks are perhaps free, as no large rivers flow into that harbor, the Charles being kept under control by the so-called Charles River Dam.

In discussing this additional handicap and destructive force at work on New York City's 8¼ miles of concrete sea walls, some of which have been in existence for 41 years, Charles W. Staniford, M. Am. Soc. C.E., Chief Engineer of the New York Department of Docks and Ferries, states:

"Up to the present time (August, 1911), no disintegration has been discovered that can be attributed to the existence of the structure in salt water. The concrete itself is in an admirable state of preservation, absolutely hard, and is undergoing no regular process of disintegration." * * * "this sea-wall which has been under construction * * * for 41 years, is at the present time an excellent piece of work and is subject to the same climatic conditions as all cities on the Northern Atlantic Coast with the attending ice, cold and rain characteristic of this latitude."