if their make depended upon the very scant knowledge applied to the manufacture of cement. The result is that the contractor or engineer receives a cement, a substance of undetermined composition, varying in quality with every circumstance of its manufacture, and every condition of its storage and preservation, and from this, by the addition of sand, water, etc., he must combine a material the strength of which he is to determine, although every variation in the materials of and in the method of combining the ingredients will affect the result. I would further recommend that every barrel of cement should be tested up to a Government standard before being placed on the market for sale, and its strength, with date of inspection, stamped upon the barrel.

Wooden structures must of necessity soon become obsolete, and the cost of timber is every year greater, and the renewals and repairs are too frequent. Concrete for all structures is very desirable, and for repairs would be cheaper in every way, as well as stronger and more lasting. Now is the time to start and gain experience in this mode of construction. We have at nearly every harbor the stone, gravel and sand for the taking, and only the cost of cement, labor and plant required to do the work need be considered.

For THE CANADIAN ENGINEER.

BREAKWATER CONSTRUCTION.

COMPILED BY W. G. WARNER, TORONTO, FROM THE U. S. ENGINEERS' REPORTS.

(*Concluded from September number.*)

METHODS OF CONSTRUCTION.

The superstructure of breakwaters at Colombo, Madras, Mormugao, Manora and Kustendjie consisted of super-imposed blocks of concrete arranged in a series of sections, each free to settle in planes transverse to the axis of the breakwater, independently of the other sections, and without disrupting any bond between these sections, each section being massive enough to sustain the shock of seas.

Superstructure of Odessa and Ymuiden consists of concrete blocks in horizontal courses as ordinary bonded masonry. That of Fume breakwater, in part of concrete in mass, deposited in frames in the water, so as to make a monolith of entire superstructure.

DIMENSIONS OF BLOCKS IN FIRST FIVE BREAKWATERS.

LOCALITY.	Height. feet.	Depth. feet.	Length. feet.	Weight. tons.
Colombo.....	6	5½	8, 9 and 14	17 to 30
Madras	8	4½	12	27
Mormugao	8	4½	13 and 17	28 to 37
Manora	8	4½	12	27
Kustendjie	6	5	12 to 18	20 to 30

At Colombo each sloping section of blocks, constrained from transverse movement by five joggles, consisting of oblong grooves in the blocks, filled subsequently with concrete in bags. These grooves were eighteen inches at right angles to axis of breakwater, and gave for each set of sloping blocks a united cross-section of 225 square feet. The general arrangement of joggle-bond not only connects several sections, but also individual blocks of each section, and seems to be an evolution from preceding methods. Mr. Kyle, the resident engineer, stated that while the system worked well, it was still open to improvement.

At Madras blocks of each sloping section are connected by a mortise and tenon, 4½ inches wide and 2½ inches deep, formed on top and bottom respectively of each block, but no attempt was made to connect sea and harbor rows of each section or several sections together. In revised plans for extending breakwater, provision is made for clamping together the upper pair of blocks. This lack of transverse bond was the cause of part of the injury to the breakwater in 1881.

Mormugao—Similar mortises and tenons used as described for Madras, and in addition a rectangular vertical joggle 15 inches square connected each pair of blocks of the upper two courses. Upper pair of blocks were further secured together by 2-inch square iron clamps and a dowel of iron 7 feet long penetrating 3½ feet into the upper pair of blocks. (See first article).

Manora—No attempt was made in any way at first o connect sections of blocks. Subsequently, when it was found that the action of the sea displaced upper blocks, an attempt was made to add to their stability by inserting stone dowels between top blocks and block immediately below. The breakwater still remained as two independent walls placed side by side without even a connection at top between them.

Kustendjie—Blocks extended entirely through wall in single pieces, and no attempt was made to connect blocks of each section or the sections together.

In Colombo, Madras (revised), Mormugao and Kustendjie breakwaters, top of blocks, after settlement had ceased, were tied together by a monolithic mass of concrete for entire width of superstructure and from 4 feet to 6 feet in depth. This secured upper blocks, protected top of work from pounding action of waves, and largely removed danger of injury to the upper joints of blocks from compression of air and water.

Kustendjie—Where sections of blocks were laid at angle of 48 degrees with horizontal, toe of lower block had a tendency to slip ahead, finally producing a concave slope to transverse sections of superstructure. From plate 2 it will be seen that plane of foot of lower row of blocks was at right angles to face, and in setting ower blocks, supporting rubble stone had to be placed under base of block. This naturally gave block a tendency to settle outward, and finally produce concave slope described.

Mormugao—There was a slight tendency for the angle of the slope to flatten and become concave at 2nd or 3rd courses above base. By reference to plate 2, that the lower face of lower blocks was a compromise between forms used at Kustendjie and later works.

At Colombo, Madras and Manora no such tendency towards slipping of lower blocks, and, consequently, flattening of the slope, is alluded to.

At Colombo ultimate settlement of tops of blocks was from 8 to 18 inches. This was allowed for by keeping outer end of work slightly higher when first laid.

Madras—Settlement 6 inches to 4 feet, latter over bottom of yielding sand and mud.

Manora—Settlement excessive, 3 feet to 4 feet. Here the deposition of rubble mound only slightly preceded construction of superstructure, and its settlement was not complete before superstructure was added. Sand bottom also yielded in an unexpected degree.

Mormugao—Settlement of superstructure was from 1½ to 2 feet, and quite even in extent. The principle of using sloping blocks arranged in more or less vertical sections independent of each other, was devised to overcome the difficulty appertaining to settlement and result-