ing dislocation of blocks bonded and arranged in horizontal planes. Again, in system of ordinary horizontal bond the outer end of the work required to be left in an unfinished condition, from necessity of stepping back the successive courses of masonry on each other. With system of sloping blocks the outer end of work is at all times in a closer and more secure condition. Sloping block system first adopted at Manora in 1870, and directly afterwards at Kustendjie; then at Madras and Colombo, and lastly at Mormugao in 1880.

Vernon Harcourt says: "Mixed system, *i.e.*, an upright wall founded upon a rubble mound, will probably have most extended application, and of all varieties best appears to be a superstructure founded some 20 feet below low water upon a simple rubble base formed of large concrete blocks laid with overhanging cranes upon sloping block principle, securely connected vertically and horizontally, and capped with concrete in mass after settlement had ceased."

Advantages of using concrete in mass or in bags mainly confined to small works, which would not justify expenditure for plant, or to localities where stone is scarce and foundations firm.

Disadvantages are: Not suitable for irregular settlement; that locality should be sufficiently protected to use piling and sea-staging; requires larger proportions of cement; introduces an uncertainty as to character of concrete below surface of water; only permits labor during times of comparatively calm weather.

Great advantage of cranes over staging upon exposed sites is, while latter must be left exposed to storms, former can always run to shelter, and though the first cost of suitable cranes for handling heavy blocks is quite large, their use dispenses with great labor, ultimate cost and delay incident to use of staging. Advantages are entirely in favor of cranes; they have practically taken place of staging in modern works.

At Kustendjie alone staging was used, but total length of breakwater was only 253 lineal feet, and work would not have economically carried any large expenditure for plant.

COMPOSITION OF CONCRETE BLOCKS.

| LOCALITY.  | Cement. | Sand.                                       | Gravel.  | 'stone.                         | Propor-<br>tions.  |
|--|---------|---|--|---------------------------------|--|
| Aberdeen<br>Kustendjie<br>Ymuiden<br>Colombo<br>Mormugao<br>Alderney<br>Wick<br>Dublin<br>Madras |         | 4<br>2 ½<br>4<br>3<br>2<br>1<br>1<br>2<br>2 | 5<br>5 <sup>3</sup> 4<br>5<br>1<br>4<br>2<br>5 | 5½<br>3¼<br>6<br>40%<br>4<br>7¼ | 1 9<br>1 8<br>1 13<br>1 8<br>1 9<br>1 7<br>1 7<br>1 9<br>4 |

Parts above used are by volume.

Authority of best practice in work of this kind seems to be the use of Portland cement for manufac. ture of concrete blocks in proportion of 1:8, of which sand equals 2 parts, gravel and broken stone  $(2\frac{1}{2} \text{ inches})$ for remaining 6. If gravel or clean shingle cannot be economically obtained, the 6 parts of broken stone are divided into 4 parts broken to  $2\frac{1}{2}$  to  $3\frac{1}{2}$  inches ring, and 2 parts clean screened stone broken to  $\frac{3}{4}$  inch to  $1\frac{1}{3}$ inch cubes.

Under Mr. Kyle at Colombo, concrete blocks of the

latter composition gave after 3 months average tensile strength of 41 pounds per square inch of section, and crushing strength of 4,231 pounds per square inch of section. To such a mixture of concrete hard rubble stone was afterwards added to extent of about 40 per cent. of entire volume while material was being placed in molds. Care was taken that none of this rubble came within 4 inches from surface of blocks.

At Colombo molds were removed after three days, and three weeks after blocks could be set. Manora blocks were three to four weeks old; at Mormugao when about three weeks old; at Kustendjie when two weeks old.

|   |  |   |  |                                | •                                     | ••• •  |   |  |
|---|--|---|--|--------------------------------|---------------------------------------|--|---|--|
|   |  |   | RUBBLE                                 | : IN II                        | A5K.                                  | CONC   | RFTK N  | 1.0CK5.  |
| LOCALITY.   | Length Breakwater                                | Total Cost.   | Gross Tons.                            | Average Cost per<br>Gross Ton. | Cost of Levelling<br>per Square Yard. | Quantity of<br>C. Yards.                         | Cost of Making.                               | Cost of Setting.<br>Total Cost in<br>Position. |
| Colombo<br>Madras .<br>Manora<br>Marmugao<br>Aberdeen | Ft.<br>4,212<br>7,836<br>1,503<br>1,176<br>1,050 | \$<br>2,430,000<br>2,402,000<br>529,000<br>420,000<br>373,500 | 320 400<br>438,100<br>96,703<br>79,500 | 2 C<br>1 63<br>86<br>86<br>59  | 8 c.<br>1 80<br>3 00<br>75            | 124,984<br>202,343<br>29,180<br>56,900<br>22,851 | 8 c.<br>9 57°<br>3 77<br>4 23<br>4 10<br>3 15 | 2 c. 2 c.<br>                                  |

\* This price includes cost of setting.

In connection with cost of concrete in blocks, the cost of concrete in bags and frames follows. Prices given as in case of blocks, exclusive of cost of plant and superintendence :—

| LOCALITY.   | Proportion of   | Cost in                                | Cost in  |  |
|---|---|--|--|--|
|   | Concrete.   | Bags.                                  | Frames.  |  |
| Fraserburgh<br>New Haven<br>Sand Haven<br>Aberdeen, N. Pier<br>S. Pier<br>Wicklow | 1:5 to 1:7<br>1.8<br>1 6<br>1 7<br>1:8<br>1 7<br>1:8<br>1 7 | \$6 34<br>5 82<br><br>5 05<br>6 12<br> | \$5 06<br>5 00<br>4 32<br>4 97<br>3 90<br>4 56 |  |

No comparison can fairly be made between cost of bags, frame, and block system. In former cases work was done in India, largely with native labor and employment of women, and heavy freight charges had to  $b^{\mu}$  added for cement, tools and machinery. In latter cases, though prices of labor may have been higher, it was more efficient, and cost of concrete was in several cases materially reduced by use of shingle dredged from site of work.

Entire cost of works at Colombo was \$3,274,000, including dredging of harbor, foreshore reclamation, shore works, and all expenses of administration. Amount in table, \$2,430,000, was cost of breakwater proper increased by its proportion of general and administrative expenses. Ordinary labor was furnished by prisoners paid at rate of  $37\frac{1}{2}$  cents per day of 8 hours. Cement, tools, machinery, etc., and skilled labor, were brought from England. Stone was brought 12 miles by rail.

Madras-\$2,402,000 includes \$395,000 for preliminary expenses of surveys, railways, buildings and plant, and \$150,000 for superintendence.

Manora-\$529,000, contains about \$75,000 for plant.

Mormugao-\$420,000, contains about \$20,000 for superintendence, and \$133,000 for plant and maintenance.

Progress in placing concrete superstructure, Colombo —166 prisoners, 8 hours per day, made 6 blocks per day, and 309 prisoners, 12 hours per day, made 12 blocks. Season possible to work lasted six months, during which