No. 1,028.—“On Breakwaters.” Part. II.¹ By MICHAEL SCOTT, M. Inst. C.E.

IN December, 1858, a Paper by the Author was read before the Institution, “On the Breakwater at the Port of Blyth, and Improvements in Breakwaters, applicable to Harbours of Refuge,”² which gave rise to a long and animated discussion. Having been requested to contribute another Paper, in continuation of this subject, and believing that a notice of the portion of the Blyth Breakwater, which has been completed since the date of the previous communication, will be interesting to the Institution, the Author gladly acceded to the request.

It was originally intended, that the present Paper should contain a discussion of some important questions, relating to harbours, including entrances, jetties, and quays; but it has been considered best to postpone this part of the subject to another opportunity.

THE COMPLETION OF THE BLYTH WORK.—To quote the words of the former Paper:—“In the case of the portions of the Blyth Pier just referred to, the site was either dry, or nearly so, at low-water spring-tides; but the line upon which it was to be continued, led into a depth of 5 feet, or 6 feet, at lowest spring-tides, and about 22 feet at high-water spring-tides.”³ During last year, this extension was carried out, and the breakwater has been completed, with entire success. After the particulars given in the former Paper, it will be unnecessary to enter into any lengthened description of the part of the work now referred to; it will be sufficient to direct attention to one, or two points of importance. In the course of the discussion on the former Paper, the two main objections to this system of constructing a breakwater of timber and stone, were the assumed difficulty of erecting large frames in deep water, and an alleged deficiency in strength, when completed. It does not often happen, that the experience of a single season affords so complete an answer to both of these objections.

First; as to the difficulty of erecting frames in deep water. The frames at Blyth are 10 feet apart from centre to centre; but

¹ The discussion upon this Paper was resumed on the first evening of the following Session, 1860-61, but an abstract of the whole is given consecutively.

² *Vide* Minutes of Proceedings Inst. C.E., vol. xviii., p. 72.

³ *Ibid.*, p. 74.

notwithstanding this projection of each successive frame beyond the end of the work, and of the existence, at times, of a cross current of about $3\frac{1}{2}$ miles per hour, they were erected with the greatest ease, and generally, between half-tide and high water. So far from a still greater depth of water being any objection, it is believed, that it would facilitate the work. The Author, therefore, considers, that there is no longer room for doubt, that the work described last year, and designed for erection in 10 fathoms of water, could be constructed with expedition and success. It should be remembered, that in the larger work, the frames are only 6 feet apart, instead of 10 feet, as at Blyth.

The method by which the panels of planking, which were fixed with great facility, were hauled down under water, was somewhat novel. At each end of the panel, a hook was fixed, from which a hauling line was carried through a single block below, up to the water level. This block was held in position by another line attached to it, and passed through a staple, driven into the frame before being sunk, and temporarily made fast to the work above. There was a similar arrangement at each end of the panel. The panel being placed between two uprights, and the ropes made fast to it, by means of the hooks, it was hauled down to the bottom and secured; the upright bars serving, laterally, as guides. When the panel was fixed, the line was cast off, and the block and ropes were hauled to the surface. This system of planking was the most suitable in such cases as Blyth, but the Author would not recommend it for adoption in deep water; for not only would the large panels be difficult to handle, but this form of construction is not so strong as the arrangements formerly described.

With respect to the time occupied in the erection of a work of this description, the experience at Blyth shows, that two frames, or 20 lineal feet of breakwater, could be completed per day during the season. With regard to cost, it has been proved beyond doubt, that the system of depositing frames is much cheaper than piling.

Secondly; as regards strength. The power of the sea on the coast of Northumberland during a storm, is so well known, that it is unnecessary to adduce proofs of the fact. As formerly mentioned, the long fetch of the North Sea must, occasionally, produce a very heavy sea, and yet the weakest part of the work described, has now been exposed for four winters, without injury. The storm which occurred on the 25th of October, 1859, was stated to be the most severe that had been felt on the eastern coast, for many years; and the damage done to many sea works attests the truth of the statement. But although a tremendous sea broke against the Blyth breakwater, it was not injured in the slightest degree. An important consideration, which should not be lost

sight of, for it affects both the questions of facility of construction and of strength, is, that the frames at Blyth are 10 feet apart; whereas in the designs exhibited last year, which were objected to as deficient in strength, the frames were only 6 feet apart, which would, of course, render the work proportionately stronger than that at Blyth. The Author is still of opinion, that such breakwaters are stronger, and that they can be erected for less money and in less time, than any arrangement previously in use. The round end constitutes an elegant termination to the breakwater, and has proved, as was anticipated, to be a work of great strength. The planking is interlaced in such a manner, that the planks become a series of hoops, tending to bind the whole work together, and imparting great strength, in proportion to the material employed. Scarcely any difficulty was experienced in the erection of this part of the work. The cost per lineal foot of the breakwater, including the round end and the lighthouse, was about £11.

The Author would again refer to the importance of saving time in construction; for surely, the time which is required to inclose a harbour, is a matter of the greatest consequence. Every year saved represents not only commercial advantages, but, in refuge harbours, life itself. Now the system of construction described, possesses these qualifications in an eminent degree. The harbour is speedily inclosed, and a large saving of money is effected, by deferring an important part of the expenditure.

It might have been thought impossible to question the rigid correctness of this principle. But it has been questioned; and therefore, the Author would refer to the Tables printed with the former Paper,¹ to the evidence given by him, last year, before the Royal Commission on Harbours of Refuge, to their Report thereon, and to the Author's reply, by which it was clearly proved, that by erecting a breakwater, like those described, in the first instance, and subsequently, removing the timber, and facing the work with stone, the result would be a considerable saving both in time and money. With regard to the durability of creosoted timber, it may be stated, that whilst at Blyth, the timber in its natural condition is rapidly destroyed by the worm, the creosoted timber has undergone no change during the past four years.

PROPOSED FORM OF BREAKWATER.—Whilst such arrangements, as have been described, present many advantages, there are situations to which neither they, nor any ordinary kind of breakwater, would be applicable, and conditions which none of them

¹ *Vide* Minutes of Proceedings Inst. C.E., vol. xviii., pp. 154-158.

fulfil. It was the consideration of this point, which led to the designing of the breakwater now to be described.

In order to explain the advantages which are claimed for this work, it is necessary to advert to certain questions of principle involved in the formation of harbours, and in the construction of breakwaters. As it will be unnecessary to repeat all that was advanced upon the subject in the previous Paper, and as it is intended to avoid nautical and commercial questions, so far as possible, attention will only be directed to the following points, which should be kept in view by the Engineer :—

First ; A desirable site, offering sufficient area and depth of water, having been pointed out, the facility for obtaining suitable materials for constructing the breakwater, becomes the principal question.

Secondly ; Although the direction of the entrance, or entrances, is chiefly a nautical question, and may be considered as partly included in that of suitability of site, yet the Engineer must have regard to it, as it affects his work, and it might, for example, involve silting.

Thirdly ; The object of a harbour being to afford shelter from the sea, the inclosing work will be efficient, in proportion as it produces freedom from undulation in the harbour.

Fourthly ; The depth of water in the harbour must be maintained, and silting prevented, as far as possible. Then with regard to the inclosing work, or breakwater, the following considerations will weigh with the Engineer, in addition to those previously mentioned.

What is the magnitude of the waves to be encountered, and will they be so large, or the depth so limited, that the waves will break on the work ?

How can the work be most rapidly executed ?

Is it possible to apply mortar work, in place of dry work, the former being so much stronger ?

Having premised thus much, the Author will refer, for illustration, to a well-known instance, in which great difficulty has been experienced in designing a suitable breakwater, and to which none of the forms hitherto employed would appear to be applicable, —Table Bay, Cape of Good Hope. In this case, the principal difficulties arise from the immense magnitude of the rollers, which are waves of the first order, or waves of translation, and from the risk of silting, which there is reason to apprehend, would be produced by the current round the bay.

A brief notice of the leading peculiarities of the ordinary forms of breakwater, will suffice to show, whether any one of them would meet the requirements in the above instance. The first form of breakwater, taken in the order of time of its introduction, is the

slope, of which the work at Plymouth is a type. (Plate 8). The advantage which may be claimed for this form, where stone is very abundant in the immediate vicinity, is the supposed cheapness; but this advantage is neutralised, to a great extent, by the necessity for employing large blocks of dressed stone, to form the face of the slope. From the great quantity of stone used, it really becomes costly to construct, and is expensive to keep in repair; and, except in special cases, it is not so efficient as some other forms, as the sea partly rolls over it, producing disturbed water inside, which would be seriously felt in a harbour of limited area. It is clear, that for the situation in view, even although rough stone be abundant and cheap, this form would not be suitable.

The second form, is the vertical wall on a rubble bank, the bank sloping from low-water mark downwards to the bottom, like the breakwater at Alderney. (Plate 8.) This form would be objectionable, because the waves would break on the work; and how far it would be likely to stand the blows of the tremendous seas at the Cape, is problematical. It would be objectionable in a minor degree, because it requires squared and well-set stones in the face of the wall, which, together with the necessity of building from one end, renders it expensive and tedious in construction; and this form would not prevent silting.

The same observations apply to the third form, which is that adopted at Holyhead, and also at Portland, (Plate 8,) where there is a vertical wall on a rubble bank, which slopes from a few feet above high water downwards. If such a work failed to resist the seas at Table Bay, not only would the breakwater be destroyed, but the harbour would be ruined, by the large stones being strewed over the anchorage. Of course, this form is only applicable where stone is abundant, and even then, it becomes a tedious and comparatively expensive work.

The fourth form is the vertical wall, built either from the bottom, or from the depth below low water, at which the action of the waves ceases to be felt; the pier at Dover, (Plate 8,) is an example of the former. These two modifications are both correct in principle, when the sea is unbroken. But in the locality referred to, Table Bay, the waves are said to be breaking waves; and even if they were not, the height of the wall above high water, necessary to receive the rise of such enormous waves, would render this form inapplicable. Moreover, the hydrostatic pressure of the water against so high a wall, would require great width of structure to afford the necessary stability. For, it must be remembered, that a wave rises against a vertical wall to twice its height; and if the wall is not high enough, unbroken water is sent over into the harbour, doing damage on its way, and reproducing a wave inside. Neither of these forms would prevent silting.

It would, consequently, appear, that none of the ordinary kinds of breakwater would be applicable to Table Bay; and none of them would provide in any way against the silting up of the harbour and entrance, a point of importance, not only in Table Bay, but in other situations.

The Author has now to submit to the notice of the Institution, the proposed new kind of breakwater, (Plate 8,) which, it is believed, will be found to possess several advantages, and which, he thinks, would be applicable in such localities as the Cape. It will be observed, that it is a modification of the wave screen, described in the Paper contributed by the Author in 1858. But whilst the same principle is involved, the new arrangement differs from the screen of 1858, in some important particulars, such as being applicable in deep water, &c. In the case of deep water, and where stone is to be readily obtained, a bank of rubble might be deposited, rising to within, say 15 feet, or more, of low-water mark, the height of the bank varying with the circumstances of the locality. Upon this bank it is proposed to build a face wall, up to low-water mark, and behind this wall, long counterforts, the upper surface of which would rise from low water, at an inclination of about 2 to 1, and extend back for a distance dependent upon the amount of slope, rendered necessary by the magnitude of the waves. These counterforts would be placed at sufficient intervals, say of 20 feet, as to be conveniently spanned by iron girders, and the whole of the sloping surface would be converted into a sort of gridiron, by girders laid from pier to pier, the upper flanges being about 1 foot wide, and the girders laid at intervals of about 18 inches.

Supposing such a breakwater to be erected and exposed to a heavy sea, if the waves are not breaking, the water would be projected up the slope, and would drop through the spaces between the girders; and if the waves are breaking, they will rush up the slope as a confused mass of water, dropping through on their passage. But, although it is anticipated, that the great bulk of the water would pass through the grating, and not return to the foot of the slope, the operation would be gradual and be diffused over a considerable surface, so that a wave would not be reproduced inside. The only effect would be a stream of water into the harbour, and in this particular, the proposed form differs in principle from all vertical screens, or gratings, which, by permitting the waves to pass through, at the same instant of time, have not the effect of destroying the undulation. The breakwater should, if possible, be placed at an angle with the direction of the greatest sea, so that a wave should not only run up the slope, but along it, diffusing itself in this manner, over a much larger area; and this would be especially desirable in a case like Table Bay, where the waves are of such

magnitude. It is supposed, that this form of breakwater possesses further advantages; it would not only be efficient as a breakwater, but it would also, in the opinion of the Author, be sufficiently strong to resist waves which would probably wreck any other form, arranged to afford equal protection. Moreover, it will be observed, that the surface exposed to the blows of the waves, is covered with mail, so to speak, and could not be disintegrated. It would be durable, for the iron is not of the nature of thin plates readily destroyed by oxidation; but it is in solid masses, the whole of which is above water, and could, therefore, be preserved by painting. From its simplicity, it would be easily and quickly constructed. The face wall and counterforts might be formed of large rubble blocks prepared on shore. The risk of interruption to the progress of the work, would then be confined to the period during which the blocks were being deposited; and with the facilities described in the former Paper, a great length of breakwater might be erected in a single season. It should also be noticed, that as each counterfort constitutes a complete and separate work, the risk of damage, by storms during erection, is reduced to a minimum. It would be cheap, and it would cost considerably less than the breakwaters at Dover, Alderney, Holyhead, or Portland. A breakwater for Table Bay would stand in water, on the average, about 7 fathoms deep. Calculated at prices current in this country, the cost of such a work, in 7 fathoms of water, would not amount to £80 per foot run. Moreover, whilst ordinary rubble work will withstand the action of the sea for an indefinite time, it requires the best work to resist the blows of the waves. In this respect, it will be obvious, that the new work possesses great advantages, so that comparatively inferior material might be employed with success in its construction. Again; in the case of the work being erected abroad, where skilled labour was scarce and expensive, the whole of the iron work, in a finished state, could be advantageously supplied from this country. Finally; and this is a novel feature of the new form, whilst it would operate successfully as a breakwater, it is thought, that it would tend to prevent the silting which arises from sand brought in by the tide.

This question, however is too important to be dealt with incidentally, and belongs to the next Paper, in which it will be discussed.

The Paper is illustrated by diagrams and models, from which Plate 8 has been compiled.

[Mr. J. SCOTT RUSSELL.]

ALDERNEY

CROSS SECTION OF WEST BREAKWATER

PLYMOUTH

SECTION OF BREAKWATER.

DOVER

CROSS SECTION OF WEST BREAKWATER

PORTLAND

SECTION OF INNER BREAKWATER.

Sea Face

PROPOSED CRIDIRON BREAKWATER.

Scale