Discussion.

The PRESIDENT moved a vote of thanks to the Author for his The President. Paper.

The AUTHOR exhibited a number of lantern-slides illustrating the The Author. progress of the work, and also three photo-micrographs of wood-boring crustacea. With regard to mortar and cement, he remarked that it had been a common idea that Roman cement was an inferior and archaic material, but he had a specimen taken from the old work which he thought would convince members that if Roman cement was used in a proper manner it was not altogether worthless. The specimen had been in the work for many years. He also exhibited two samples of decomposed mortar, and various specimens illustrating the condition of the old work.

SIR WILLIAM MATTHEWS, K.C.M.G., Past-President, thought the works were of a unique character, inasmuch as they were commenced sir William Matthews. in 1856 and finished in 1909, so that they had been under way for upwards of half a century. During the whole of that time the engineers, who were the most experienced men obtainable, were continually battling with the sea. The length of time taken to complete the work showed the very serious difficulties that had had to be contended with. Before 1853 designs were prepared by John Rennie and by other engineers, but it was only in 1853 that the works began to assume a tangible shape. The late Mr. James Walker, an esteemed Past-President of The Institution, was commissioned by the Tyne Board, supported by the Admiralty, to prepare a design for the works, and he accordingly submitted a design which contemplated the carrying out of two piers, the north pier, beginning at point A (*Fig. 7*) and terminating at G, and the south pier, beginning at the shore and terminating at H. A contract for the first section of the north pier, AB, was let in 1856, for a length of 1,400 feet, and in 1861, when the work had been in progress for some time, it became evident that in consequence of the increased draught of ships visiting the Tyne, a greater depth would have to be provided at the entrance than was contemplated in the first design. In Mr. Walker's design of 1853 the depth of water at the entrance was assumed to be 15 feet at low water. Mr. Walker therefore prepared a further design which contemplated the carrying out of the curved piers as shown. The terminal point of the north pier was just beyond F. The entrance was to be 1,300 feet in width and the depth at low

Sir William
Matthews.

water 30 feet. At the time the works in connection with the two piers were authorized, Mr. Ure, who was the engineer called in by the Tyne Commissioners to advise them with regard to the deepening of the River Tyne, proposed deepening and widening it, cutting off bends, and otherwise improving the river so as to make it

accord with a depth of 30 feet in the new entrance. The dredging work was carried out by Mr. Ure and the late Mr. Messent, and continued by the late Mr. James Walker, M. Inst. C.E. (a relation of the original designer of the pier-works), whose recent death was so much lamented. As an indication of the success of the works, he might

say that at the present time, from the mouth of the Tyne upwards, there were no less than 30 feet at low water and 45 feet at high water; and at the lower end, where there was a variation of about 5 feet due to the effect of gales, an additional depth of 5 feet was also available as compensation for accretions. So that almost exactly what was prognosticated and aimed at by the engineers had been achieved. In attaining that result there was no doubt that the two piers had exercised a very important influence, inasmuch as they ensured that the scour in and out of the entrance should always take place at the same spot. It was a matter of great satisfaction to the profession that the width of the entrance should have been so nicely adjusted to provide almost exactly the depth contemplated. With regard to the north pier, it would be interesting to consider how it was that the accident mentioned occurred. First of all, in 1856, when the works were commenced, few data and little experience existed with regard to the action of heavy seas on works of that character, so that the old engineers had really nothing to go upon. It was all very well for engineers at the present day, with the work and experience of the past at their command, to speak with some confidence on such matters, but in those days the experience was very small. Consequently Mr. Walker, when he designed the piers, contemplated starting at A with the foundations 2 feet below low water, and the structure was to be placed on a rubble mound. The late Mr. Messent, an esteemed member of The Institution, was the resident engineer, and as the work advanced seaward he very soon found that the foundations were placed at too high a level; consequently the engineers kept lowering the foundations as they went along, as far as it was possible to do so, having regard to the depth at which the rubble mound had been deposited. When the outer end of the pier was reached, the foundations were at a level of 27 feet below low water. The pier was practically complete when, in the succeeding winter, 1894, the first difficulty arose, through the drawing out of the blocks in the foundation-courses under water and the displacement of the apron of large concrete blocks protecting the footings of the work, which were laid on a rubble base throughout. Mr. Messent, as explained in the Paper, fought against those difficulties for about 3 years, but finally a breach 300 feet in length was made clean through the work by the sea, as indicated in *Fig. 7* by E F. Other difficulties were also met with. On the land side of the point E, and on the sea side of the point F, the work was undermined to an extent that rendered it necessary to rebuild and reconstruct a length of 750 feet of the pier in order to

Sir William
Matthews.

Sir William
Matthews.

make it good, on the old line. That was a very serious task. Sir John Wolfe Barry and he were called in, and they considered very carefully whether it would be possible to make good the work on the old line: they decided that it would be preferable to obtain alternative tenders for doing the work on the line which was ultimately adopted, the straight line in the diagram, and for making it good on the old curved line. Sir John Jackson, whose tender was accepted, was a man who never shirked responsibility and who was accustomed to take big risks, and he put in a tender for both works, the difference between the two amounting to £80,000. But in one case there was included the reconstruction of 750 feet of pier on a rubble mound, with the risk attached to it, and in the other case, for the additional £80,000, there was 1,500 feet of work mostly founded on the shale bed and thus carried down to the solid bottom. On the advice which was given to them the Commissioners did not hesitate to adopt the latter work, and in consequence the pier had been reconstructed in that way. It was needless to say that no engineer would have been a party to tearing up, as it were, the work of a fellow-engineer unless it was absolutely imperative to do so. On the old line 750 feet of work would have had to be rebuilt, and that was considered to be practically impossible; the divers could not stand there, there was an incessant surge of the sea, and the work was of almost insuperable difficulty. He was quite clear, now that the work was completed, that the right course had been adopted. In justice to the engineers who designed the original structure it should be remembered that since that work was designed engineers had considerably modified their views with regard to the action of the sea on works, and the depth to which sea-action extended. When he first started marine work, more than 45 years ago, it was assumed that sea-action on a rubble mound in an exposed position did not extend to more than 15 feet below low water, on rubble of any size. At the Tyne foreshore blocks weighing 41 tons had been moved in 27 feet of water. At Peterhead blocks of 41 tons had been displaced in 37 feet at low water. There was also the interesting example he had mentioned before in the Institution, and which had been referred to by the late Sir James Douglass, as showing the effect of the sea during gales on lobster-creels at the Land's End. He had verified the fact among fishermen there that lobster-creels lying on the seabottom off the Land's End had been filled during strong south-westerly gales with coarse gravel, when lying in 20 to 30 fathoms of water which showed the great depth to which sea-action extended. That knowledge was not available to the old engineers. Engineers beginning the work *de novo* at the present day would not

think of starting in such an exposed position with foundations 2 feet below low water, but in the old days engineers acted according to the experience they had, and they must be judged generously. He felt sure that if he himself had had to design such works at that time he would have done exactly the same as they did, and no better. It might be thought to be a dangerous thing to put a row of cylinders in the way described in the Paper, but in order that the work should not sit down on the cylinders by settlement, 2 inches was allowed between the tops of the cylinders and the under side of the solid block-work above, so that by no possibility could a fracture be caused in the work where the cylinders existed. At the present time it was impossible to say where the cylinders were in the work; there had been no appreciable settlement, and no dislocation due to their presence. With regard to the checking of the courses, there were only two works with which he was acquainted that had ever been constructed in that way; one, the first in which checking was adopted on the advice of his firm, was at Peterhead, and the other was the work before the meeting. The reason for the introduction of the checking of the courses—the stepping of course into course—was that when the sea struck the work the shock of the wave was distributed, and any possibility of sliding was prevented. That had to be done at Peterhead in consequence of the abnormal weight and force of the waves. There was some slight tendency to slide, and it was necessary to check it by putting steps in the courses. The cost of the work had not been increased thereby in any material degree, and certainly he would recommend, where very heavy seas had to be encountered, that the courses should be checked. Where the seas were not abnormal no such device need be adopted. With reference to the granite facing that had been used, not only in the Tyne work but in several other works carried out by his firm, when Mr. Ker's Paper on the Folkestone Pier was read, a friend of his sitting at the Council table ventured to characterize the granite facing as a "splendid veneer." Being in the Chair at the time he did not feel at liberty to comment upon the expression then, but he might explain now what the "splendid veneer" was like. The accompanying diagram (*Figs. 8*) represented part of the face of a 20-ton block. About 18 years ago, in the Prince of Wales's pier at Dover, where also his friend Sir John Jackson was the contractor, he tried as an experiment to wedge off with steel wedges the granite facing from the concrete backing, and he found it rather difficult; after a good deal of trouble the face of one block was removed, but it broke off through the granite and left the tail-stones in the concrete. That showed, he thought, that a

Sir William
Matthews.

Sir William
Matthews.

thoroughly good job was made in uniting the facework with the concrete backing, and that it was anything but a veneer. Even the prefix of "splendid" scarcely rendered the term applicable. With reference to the failure of the lias-lime mortar, when the work was being carried out along the portion C D—the exposed sea portion—it was observed that a movement was going on in the length B C. The movement was in the parapet and the promenade part of the work. It was thought that might be checked by putting in tie-bolts, and these did check it to some extent; but during the 10 years or so which followed, material changes took place in the work and a swelling was evidently taking place in the lias mortar. The result was that at length the Commissioners gave instructions for the removal of all the work that was affected, over the length B C, and for its reconstruction in cement, to harmonize with the new portion of the pier, which was done. The curious action

Figs. 8.

going on there was alluded to by Mr. Messent in the Institution many years ago. When the work was renewed it was possible to scrape the mortar out of the joints with a piece of wood, or even a finger, and to roll it up like putty; there was absolutely no strength in it, and it was quite evident that the lias mortar had failed. His own view was that this was probably due to the saturation of the lias mortar in the top of the work by the sea breaking over the parapet and getting down into the mortar. He would like to say, especially to his younger brethren, that after prolonged experience in work of that class and in the use of lias-lime mortar and Portland cement, he very strongly recommended the adoption of Portland cement in preference to any natural lime. In these days, when Portland cement was made so perfectly, when the proportions of the raw materials were gauged with absolute precision, and when the mixture was chemically analysed, a much more reliable material must be

produced artificially than could be produced naturally. No one knew the conditions under which the ingredients had come together to form a natural lias-lime, nor in what proportions they had been intermingled. Therefore his advice was to use Portland cement and not lias lime for work of that class. In carrying out work where the seas were not sufficiently heavy to render staging impracticable he was in favour of a stage mode of construction in preference to what he called a titan mode of construction. At the Tyne the engineers had been privileged to carry out their work under the shelter of the work of the older engineers. Mr. Messent when carrying out his original work had the full stroke of the sea upon him, but the modern engineers had avoided that except for a comparatively short length. Sir John Jackson, good contractor as he was, met with serious accidents to his staging at that point, but he made his work good again at once, and the mishaps made no difference in the long run. In less competent hands, however, it might have been otherwise, because the making good of bays of staging of that character meant the expenditure of very large sums of money. His own view was that sounder work was obtained by the use of staging, and that the work was more expeditiously carried out thus than by the titan mode of construction.

Sir William
Matthews.

Sir JOHN JACKSON observed that he had been greatly interested in the Author's accurate description of the work, and considered that the Paper, supplemented by Sir William Matthews's remarks, covered practically all there was to be said. If any questions were asked, however, he would be glad to answer them.

Sir John
Jackson.

Mr. W. DYCE CAY asked if Sir John would state the cost of the work.

Mr. Cay.

Sir JOHN JACKSON did not care to go into the costs; from a contractor's point of view he did not think it proper to do so. With reference to the difference between construction with a titan and construction from a staging, he remembered that in the early days—in the time of Mr. Ure—a staging was used, which was often carried away, and the conclusion was come to that the only proper plan was to carry on the work from a titan. There was no doubt that the titan plan was cheaper, but it was quite obvious that it was not possible to get, with one machine at the end of the breakwater, the speed of working that could be obtained when working with three or four machines, one preparing the foundation, another setting the lower blocks, and a third setting the upper blocks. When he commenced the work, the breakwater had been under way for 55 years, but he thought it was only fair to state that, although it had taken 55 years, the

Sir John
Jackson.

Sir John
Jackson.

engineers, in his opinion, had never been pushed very much, because the Commissioners had not been anxious to spend more than a certain sum of money annually. That should be borne in mind, because there was a great difference between the 55 years occupied in carrying out the work as a whole and that required for the portion of it done later, which he supposed roughly represented about two-thirds as much value, and the contract time for which was only 7 years. He had never felt so ill complimented in his life as when the River Tyne Commissioners sought to obtain a penalty from him for being a year behind time, that was, for taking 8 years for his part, when the other part of the work had taken 55 years to do—work which at his rate of progress would have only taken 12 years. Everyone must agree with what Sir William Matthews had said about the early designs. Engineers then had not the experience they possessed now, and 50 years ago any engineer would, in all probability, have designed a breakwater on very much the same lines as Mr. Walker's design, carried out by Mr. Messent. He had been much amused by Sir William's sketch of the granite facework, because it was a splendid compliment to the contractors, showing as it did that at any rate they did not scamp the mortar. With regard to the lime question, from his experience he entirely agreed with Sir William, and he never ventured to use lime for any work of that class. He always used cement. Of course in connection with such a work there had been a few mishaps but nothing which had not been contemplated. It was impossible to undertake a big sea-work occupying 7 or 8 years without expecting to lose some temporary staging and so forth. What he did not like to see was the failure of temporary works on account of lightness of design, and he was pleased to say that he had never had that experience. Whenever staging had been lost on the Tyne pier and other breakwaters his firm had had to do with—Dover, for instance—his own opinion was that it had always been due to some wreckage hitting the piles. He was delighted to take the opportunity of saying that—as in the case also of the Dover work—from beginning to end Sir William Matthews and he had never had an unpleasant word.

Mr. Cay.

Mr. W. DYCE CAY observed that as far back as 1867 or 1868 he was acquainted with the works under discussion, as he was then carrying out breakwater works at Aberdeen, and the late Mr. Messent afforded him every facility for inspecting the Tyne works. He considered that what happened there was due to the rubble base, and that if Mr. Messent had not had a rubble base to contend with, he would have found out the muddy substratum that was

subsequently discovered, and would have applied the remedy. The Mr. Cay.
great objection to rubble mounds was their want of weight and stability under water. The late Mr. Dobson, of Holyhead, had told him that a ton of stone occupied 20 cubic feet of the rubble mound there; so that, owing to voids and displacement, it had less than half the weight of solid work above water. Hence it was dangerous to put a heavy structure, rising out of the water, upon such mounds, especially when it was liable to be battered by heavy seas. Splendid works, however, had been constructed on that system, such as Holyhead and Cherbourg breakwaters, and the system was still in vogue on the Continent, in the new works at Cherbourg, Zeebrugge, Barcelona, Bilbao, and Biserta, where large floated blocks were used, standing on rubble mounds. Except Cherbourg and Barcelona, all those works had suffered serious damage on account of the rubble base. The Zeebrugge works were described before the International Engineering Congress at Glasgow in 1901. It was explained at Milan by Mr. Nyssens Hart, the engineer, that the cause of the subsequent displacement of five of the large caisson blocks of 4,500 tons each was due to the backing not being filled in at the time. He also said that owing to scour round the point of the breakwater as it was advanced, the height of the rubble had been greater than originally intended. Biserta had suffered very considerable damage in that way. He himself considered it possible to build very good breakwaters on rubble mounds, by sorting the stones out, as the French did, into different sizes, and putting each size in its proper place, and depositing them in successive layers as the Italians did, giving each layer time for settlement, and carrying the work up high enough—20 to 30 feet above water, so that where the sea struck it had practically a beach as on dry land—and covering the whole of the exposed parts of the rubble with large 50-ton blocks or bags of concrete. There were some places where it was impossible to build the solid structure from the bottom. For instance, Genoa and Naples had 30 metres (98 feet) of water, a depth to which it was difficult to dive. The diagrams he exhibited showed designs he had made with a view to retain the economy of the rubble base and at the same time, by means of cylinders or piles, pass through it to the solid substratum, thus getting a solid foundation for the superstructure. *Figs. 9* was a design for 30 metres depth of water, with cylinders 15 feet in diameter, which would be made up, floated out, and up-ended by a floating crane. In *Figs. 10 (a)* was a design for 8 fathoms of water, having 18-inch reinforced concrete piles supporting the mass-work placed above the mound; *(b)* for comparison, showed mass-work from the bottom, and *(c)* bag-work without a

Mr. Cay. mound. He thought the reason why foreign engineers did not generally adopt the system of building with blocks from the bottom was the cost; for example, it had been stated by

Figs. 9.

Mr. de Joly that the Carnot breakwater at Boulogne cost 6,000 francs per lineal metre, or £219 per lineal yard, and the late Mr. Vernon-Harcourt had stated that the Admiralty Pier at Dover

Figs. 10.

cost £1,113 per lineal yard, or more than five times as much as the former. The North Pier work at Aberdeen cost only 30s. per cubic yard and the breakwater only 26s. 6d., including all the

expenses, and he had no doubt the Sunderland breakwater had Mr. Cay. cost a similar moderate amount; whereas, as far as he could make out, this new Tyne north pier had cost 56s. per cubic yard of new work including all expenses, and the cost per lineal yard of its deep-water section, Fig. 3, Plate 4, at this rate would be £1,067. He had asked Sir John Jackson a question with regard to cost merely with a view to ascertain the relative cost of the Tyne pier as compared with other works. Everybody must admire the style of work at the Tyne, which was very like cabinet work; but of course such work was out of the question in connection with many harbours. In the north of Scotland, for instance, harbours could not go to the expense, and had to adopt something cheap. There were cases where the exposure was very severe. At the Aberdeen breakwater there was a broadside sea of enormous force and the waves threw spray 80 feet into the air. There the kind of work under consideration would be certain to fail—the joggles would give way and the blocks would come out—and in such cases it was necessary to devise some way of putting in enormous blocks. That had been done at Aberdeen by means of caissons lined with canvas, in which blocks weighing up to 1,300 tons were deposited. Abroad they used floating shells filled in situ with concrete to form masses of as much as 4,500 tons. By using concrete in bags very large blocks could be obtained—50 to 100 tons—without much cost or trouble, and no staging or anything of that kind was required. He did not wish to go into that question, because he had discussed it recently¹ in connection with the Folkestone Pier, and had also read a Paper before the Royal Scottish Society of Arts,² giving details of the plant and of the various places where it had been used, and that Paper was available in the Library of The Institution. He wished, however, to read a short letter which he had received recently from the Royal Harbour Director of Norway. When carrying out the works of Aberdeen he had the honour of showing them to many distinguished engineers, both British and foreign, including the late Sir John Coode, Past-President Inst. C.E., the late Mr. J. F. W. Conrad, Inspector-General of the Waterstaat, Holland, and the late Mr. Oluf Roll, Chief Engineer of the Norwegian Harbours, some of whose staff he allowed to work in the office at Aberdeen for some months in order to study the system for use in connection with Norwegian harbours. Mr. Roll published his Preliminary Reports on three hundred projected Norwegian harbours in 1880 in

¹ Minutes of Proceedings Inst. C.E., vol. clxxi, p. 80.

² Transactions of the Royal Scottish Society of Arts, vol. xii (1891), p. 121.

Mr. Cay. two large volumes, and his estimate of the cost was $1\frac{1}{2}$ million sterling. Two hundred and twenty of the schemes, mostly fishery-harbours, were sanctioned, at a cost of £780,000. In 1908 Mr. Cay wrote to inquire how matters were progressing, and he received from the present director, Mr. Gabriel Smith, a letter from which the following was an extract:—

“Those projects for fishing harbours here, which you are referring to, have partly not been executed, and partly the plans, especially the sections—or the type—of the breakwaters have been considerably altered. In the northern parts of our country we have had much trouble with the concrete; a few years after the execution of some breakwaters, the concrete in the superstructure showed traces of a speedy decay in the parts between low and high water, which have continued and caused heavy expenses in repairs and reconstruction. If in any way possible, we use stone either as masonry or as large rubble, the seaward surface covered by natural blocks from 5–18 tons. Concrete in bags has only been used as submarine foundation for masonry walls on rock, where this has been uneven—and occasionally concrete bags have been deposited on the top of a rubble foundation to protect the foot of the masonry wall. But these cases have been rare.”

He had always found that that kind of concrete construction in exposed places required experienced direction. It could not be put into the hands of a department to carry out without disastrous failures; also, the cold at many seasons in the north of Norway might be against the prompt setting of the concrete. They could procure immense blocks of natural rock in Norway, and if they could get them into the piers nothing better could be done. They had used bag-work in certain parts of the foundations and it had been of use to them. With regard to the new Tyne north pier, he had an opportunity of seeing the work when near completion. At that time the staging had been partly carried away by the sea, and they were working with a titan, which the people employed said was not so good for setting the blocks. He thought that in time the protection the new work received from the remaining old work would disappear, and something would have to be done to protect the base from the strong scour of the waves along the seaward side, unless the shale foundation was very strong. Such a thing had happened at Musel in Spain in 14 metres (46 feet) of water, and blocks had been placed along the base for protection. The breakwater there was founded on concrete bags, in the manner he introduced at Aberdeen about 40 years ago, and above that there were 70-ton to 80-ton blocks laid by an 80-ton titan, so that it was a very solid work. The work on the Tyne was not exposed to heavy broadside seas, otherwise no doubt blocks would have been used such as those at Musel. With regard to the bag-joggles, he had used joggles at Aberdeen for the

round-head of the breakwater, but of a different kind. They were cast solid on one block with a corresponding recess in the other, and the joggle went from top to bottom of the block, forming a semi-cylindrical projection or pillar cast on one block and a semi-cylindrical groove in the other.

Sir WHATELY ELIOT thought the history of the Tyne pier was one of great interest to all who had been or were engaged in the construction of works of a similar nature, and was also an example of the importance of practical experience. It was a work commenced on a rubble bank with the foundations a little below low-water mark, and completed without any rubble bank at all, and with the foundations taken down into the solid shale to a depth of 44 feet below low water. That was the outcome of experience on one work extending over 50 years. He happened to have been engaged as an assistant to Mr. Messent on the construction of the works in the years 1865-67, and he could remember quite well that the sea was already then beginning to show what it intended to do at a later date. At that time they were engaged in underpinning some of the lower courses of the sea-wall, where the rubble was being torn away and the wall getting undermined. For more than 2 years that work went on gradually; as the rubble was torn out the holes were filled with concrete in bags, bundles of old chain, and anything that could be obtained to stop the gaps. In December, 1867, there was a very disastrous storm, which caused remarkable damage. In that storm the rubble was taken from underneath the lower courses on the sea side, a breach being made at the point C in *Fig. 7*, where the pier was beginning to curve outwards, 1,500 feet from the commencement. As a result of the storm 240 feet of the sea-wall came down altogether, parting from the rest of the structure in a straight line, and the bonding blocks in the cross walls being broke in half. The concrete hearting was left to withstand the sea, and it spoke well for the construction that that hearting withstood the sea for months without any further damage until the wall could be rebuilt. Six or eight large travelling cranes were on the staging for setting the work; several of them were washed into the sea, and two or three of them were left in a damaged state on the top of the staging, only one being intact. In that same storm the harbour-wall at the end of the north pier, at the back of the part that was damaged, also separated from the concrete hearting and was moved inwards several feet, and had to be rebuilt. On the south pier 250 feet of the harbour-wall was undermined in a similar manner to the north pier, and the wall had to be taken down and rebuilt. The repairs were carried out and the rubble on the base was protected by 40-ton

Sir Whately Eliot.

Sir Whately
Eliot.

blocks of concrete, and he believed the foundation was lowered about 4 or 5 feet. At the time the piers were designed there must have been a sort of fashion in rubble mounds for breakwaters, because there were several then in progress at the time round the British coast and a great many on the coasts of France and Italy, and some still existed. With regard to blue lias lime, it should be remembered that in those early days Portland cement was only just coming into general use. He remembered that it was quite a common occurrence then to use blue lias lime mixed with pozzolana, which made a very good hydraulic mortar. It was used at Sunderland to a considerable extent in the dock-works. Portland cement would have been used from the very first if it had been in such general use as it was at the present day. Blue lias lime had stood very well before, but directly it was found that it gave way, Portland cement was at once used. He did not suppose that any engineer would ever dream of using anything but Portland cement on sea-works to-day.

Mr. Thorow-
good.

Mr. F. N. THOROWGOOD thought the Paper was one of the most interesting he had had the pleasure of hearing in The Institution, and was very practical, giving an account of the difficulties and how they had been overcome. At the time of the storm to which Sir Whately Eliot had referred he was Assistant Engineer, having succeeded Sir Whately Eliot, and he had one correction to make with regard to the storm. Sir Whately Eliot had stated that the concrete hearting stood for some months, but as a matter of fact it stood for $2\frac{1}{2}$ years, until the wall was built up again. There was no doubt that the cause of the accident was the undermining. In examining along the sea-wall with a diver 2 days before the disaster occurred, he found that the foundation, which was then as in Fig. 2, Plate 4, was one course below the course that went into low water, and that that course had dropped from the low-water course 1 foot 2 inches. The gap tilted forward and it was possible to put a rod in and touch the hearting. Three days afterwards, in the severest storm he ever saw during the 9 years he was there, the whole of the sea-wall, to the extent of about 300 feet, fell down completely, and the south pier was damaged at the same time. As an illustration of the height of the waves he might mention that a tug-boat was trying to make the Tyne from the north-east in the neighbourhood of the rubble base in advance of the pier, when a wave struck it and carried away a wheel, and the next wave swept the vessel clean out of existence, and neither men nor boat were ever seen again. He reckoned the waves were about 14 feet from trough to crest. He had been struck by the sinking of the eight cylinders across the pier in order

to make a fresh start and get down to a hard foundation. He had had 25 years' experience in harbour-works, and to his knowledge the use of cylinders for sea-work had never been thought of before, and the engineers and the contractors were to be heartily congratulated. The Author might give a diagrammatic explanation of the 13-foot cylinder and the 8-foot cylinder, with the 2-foot 6-inch annular space filled with concrete, as Mr. Thorowgood did not quite see how the inner cylinder was taken out. There was no doubt in his mind that the only thing to do at the Tyne was to go through the rubble on to the hard foundation. The form of a deep-sea breakwater coming from the office of Messrs. Walker, Burges and Cooper was almost stereotyped: a mound of rubble with the structure on the top. In a case like the Tyne, the dynamic force of the waves against a vertical wall during north-easterly gales was tremendous. When an enormous wave struck such a high wall, a great deal of it went 60 or 70 feet into the air, and then came swooping down with a force that would drag out anything. But he did not think that such piers as those at Dover or at the Tyne had anything now that could be dragged out. He believed that in time all piers built with a movable base and subjected to a very heavy sea would be destroyed. It was best to deal with the matter as had been done at Alexandria and Madras, by putting random work of concrete blocks into the sea to find their own slope. However big the wave, it no sooner got into the entanglement of concrete blocks than it was broken up, and did not go over the top of the breakwater. The first row of blocks referred to by the Author was the outcome of the first disaster of 1867. The blocks weighed 36 tons each and were made of iron-puddlers' slag, which had a little higher specific gravity, but apparently from the Paper they had been knocked about almost like the others. Sir William Matthews had mentioned the wonderful force of the sea in moving a very heavy block at a depth of 40 feet. He himself had found stones easily moved at 40 feet below mean sea-level in a cyclone in Madras—moved as though they had been dug out of the ground. It was very difficult to say what was a safe depth. Having had considerable experience of both staging and overhanging titans, he preferred for small work—a breakwater upon which there was no superstructure or promenade or high wall—the overhanging titan; but for such work as that under discussion, or a breakwater with a parapet or promenade, staging was required, in order to be able to work in two places at once, in advance on the foundations, and at the back on the superstructure. He would be glad if the Author in his reply would give a few more details about the construction of his staging, which was of Oregon piles driven

Mr. Thorowgood.

Mr. Thorow-
good.

several feet into the shale or hard bottom, and apparently right through the rubble base. When he was an assistant engineer on the Tyne north pier he saw that rubble base deposited; it was of magnesian limestone from the quarries on the side of the south pier, was very hard and irregular, and some of the pieces he thought were 3 feet 6 inches across. It was very difficult to drive a pile by percussion into any hard material, but it seemed to him a wonderful thing to have driven the piles right through that mass of magnesian limestone, and therefore he wished for a little more detailed description of the shoe used. Were there side straps on the pile with pins through? The bearing he took to mean the area of the timber as it rested on the extreme point. In one of the lantern-slides the end of the tenon of a pile had been seen, and it was noticeable that the sides of the tenon were not parallel to the sides of the timber, but were almost diagonal, owing to the twisting of the pile in driving. All engineers would be agreed that it was no good trying to correct a pile when it began to twist; it must be allowed to go its own way. With regard to the *Limnoria terebrans*, when he was on the Tyne pier-works he certainly found the *Teredo navalis* eat into the pine piles, which were from Vancouver, to an enormous extent, but he thought the *Limnoria* made the small holes. Certainly the teredo was there, because he had taken several of them out of their holes in an old bit of pile; but no doubt the greatest destruction was done by the limnoria. He visited the works 2½ years ago, and noticed the magnificent masonry that had been built, and it was dreadful to him to see how the old work, which as a young man he had been taught to regard as a very good example of masonry construction, was all to pieces, as it were, apparently owing to the use of blue lias lime. No one now used blue lias lime, but there still remained Smeaton's Eddystone lighthouse, and, he thought, Ramsgate harbour-works, which were built with blue lias lime and were standing perfectly well. He could not help thinking there had been some defect in the particular blue lias lime used at Tynemouth.

Mr. Wheeler.

Mr. W. H. WHEELER considered that the Paper was a very valuable contribution to the Proceedings, as it gave a lucid account of the work which would be of great aid to any engineer charged with similar work. The members owed a further debt to the Author for the beautiful lantern-slides he had shown—slides which practically took one over the work and enabled one to realize the difficulties that had been encountered in carrying it out. He himself had had a good deal to do with the North Sea, and could realize the difficulties and dangers of carrying out such a work in North Sea gales in an

exposed position. For many years he had taken a great interest in Mr. Wheeler. the Tyne pier, having been over it several times with the late Mr. Messent, and he had seen it a few days after the great storm in 1895. Afterwards he had the pleasure of being personally conducted over it by the Author, and he thought it was a magnificent engineering work, reflecting the highest credit both on the designers of the works and on the resident engineer. These works presented to all engineers engaged in harbour-work an object-lesson of the danger of putting a vertical wall on the top of a rubble mound. About 60 or 70 years ago a Royal Commission was appointed to inquire into that question, at the time the Admiralty pier at Dover was under consideration, and evidence was taken from all the great engineers of the day and other experts as to the relative advantages of sloping mounds and vertical walls. The evidence was so strongly in favour of vertical walls and of their power to resist waves, that Dover pier was built in a different manner from that at Tynemouth. He thought there could be no question, reading that evidence and seeing what had occurred since, that Sir William Matthews was quite right in building a vertical wall instead of restoring the old wall on the rubble mound. The chief example of walls built on rubble mounds was Alderney breakwater, the design of which was very similar to the Tyne pier. In that case there was a rubble mound the top of which was 15 feet below low water, and this was allowed to stand 3 years without any further structure, in order to see the effect of the waves upon it. During that period it suffered comparatively little damage, but as soon as a vertical wall was erected on the mound the waves assumed an utterly different character; they became broken and struck the vertical wall, and, according to the account given by the late Mr. Vernon-Harcourt,¹ the water striking the wall was projected upwards to a height of 200 feet. If it really did reach that height, certainly the effect of its fall would be tremendous. The rubble mound was gradually cut away, the foundations were undermined, and finally a breach was made through the wall very similar to that at the Tyne. On the Tyne, of course, the pier was exposed to the waves, but the waves, although large, did not reach a height of 200 feet. He had a photograph of the storm referred to, showing the waves going nearly as high as the top of the lantern of the lighthouse, which he believed was 50 to 60 feet above high water. It could easily be understood that a wave breaking against a wall and dashing down upon it would do the damage that the sea was said to have done. When Sir William

¹ "Harbours and Docks." London, 1885.

Mr. Wheeler. Matthews and Sir John Wolfe Barry were called in, the wall had become so shattered that there was no alternative left but to rebuild it: no patching or anything of that sort could be done. But it was a question whether, if the work had been taken in time, it might have been saved at much less cost. The damage done over half the length of the pier from the shore was not very great, up to a depth of 12 feet at low water; but as the pier extended outwards and reached a depth of 30 feet at low water the damage gradually increased, until at the end the waves striking the wall were so powerful as finally to shatter it to pieces. It was suggested at the time—and there was some little controversy on the point—whether, if the end of the pier in deep water had been placed in a similar condition to that half-way down, where there was only 12 feet of water, the waves would have had less force and the walls would have been saved. It was proposed to do that by increasing the rubble mound, raising it against the wall, and extending it outwards so as to assimilate the condition at the outer end to that of the middle. It would have required a very large amount of rubble to do that, but there was plenty of stone to be got in the neighbourhood, and it was said the cost would not have been one-tenth of that now incurred. About £17,000 was expended by the Commissioners in fighting the sea, by putting down large blocks of concrete and other material, but that did not meet the real cause of the evil, namely, the great depth of the water, and the whole of that £17,000 was practically wasted. All the damage did not take place at once; it was not one sudden storm but the gradual wearing away of both the shore and the rubble mound, extending over 5 years. If it had been taken in time it was possible the old pier might have been saved by the means described. Of course all that was long before the Author came upon the scene. He thought, however, it would be instructive to other engineers who had to do with works of the kind if the Author in his reply would say whether, if that course had been adopted, the walls could have been saved.

Mr. Bamber. Mr. H. K. G. BAMBER remarked that the Author described in a very interesting manner the condition in which he found the mass concrete in the centre of the old work. The description the Author gave of the condition of the Roman cement was instructive, but, in view of the vexed question of the action of sea-water upon Portland cement, it would be very interesting if the Author would give some further information as to the condition of the Portland-cement concrete which was midway between high and low water. It did not fall to the lot of many engineers to have the opportunity of dismantling such a large structure as the Tyne pier, which had been subjected

to sea-water for a considerable number of years, and there must Mr. Bamber. have been unique opportunities of settling in a decisive manner the question to which Mr. Bamber had referred. He would like the Author to say in what condition he found the Portland-cement concrete, and whether there was any difference between the material immediately behind the facing and the centre. He was glad, as a Member of the Engineering Standards Committee on Cement, to see that the latest test that had been introduced into its specification, namely, the Le Chatelier test, was found to be extremely useful. He was prepared to say that it was the most valuable test that had been introduced in late years in connection with Portland cement, and with that test now embodied, many of the other clauses in the British Standard specification became somewhat unnecessary. In taking the specific gravity of the cement used, the Author's chief difficulty seemed to have been in connection with the air locked in with the petroleum. That difficulty was well known to all experts and was not easily overcome, but there was a further difficulty which the Author did not mention, namely, the high coefficient of expansion of petroleum as compared with that of cement; and possibly some of the variations found by the Author in his tests might have been due more to the expansion and contraction of the petroleum he was using than to the interlocked air, the effect of which, in Mr. Bamber's experience, was generally uniform. During the progress of the works, which had been under construction for some years, a great improvement had been place in the manufacture and in the quality of cement, and he would like to know whether the Author had found latterly that the very heavy expense entailed in storing and turning over and in various ways aerating the cement was at all compensated for, now that the quality of the material had so much improved. It was well known that in former years, when cement was manufactured practically by rule of thumb, there were no other means of ensuring stability and ultimate safety in any work constructed with such material; but Mr. Bamber ventured to think that of late years the quality had been so much improved that any money which the engineer spent in attempting to aerate the cement after it was delivered to him was entirely wasted. He would like the Author's opinion as to whether, especially of late years, he had found any improvement at all in the cement after 5 or 6 weeks' turning.

Mr. C. R. S. KIRKPATRICK had listened with great interest to the discussion, particularly in the hope of obtaining some information as to the actual cost of the new work per lineal foot. Sir John Jackson had remarked, quite naturally, that he did not want to say

Mr. Kirkpatrick

Mr. Kirkpatrick. anything as to costs, but without wishing to inquire too closely into Sir John Jackson's costs, it would be of great value if the Author could give a rough approximate sum per lineal foot of wall built, and this could probably be given without disclosing private figures.

Mr. Butler. Mr. D. B. BUTLER observed that in referring to the tensile strength of cement at various ages the Author did not mention whether he made both neat and sand tests, but presumably the cement was tested as usual in both ways. Until recent years the sand test had been somewhat in disfavour, people believing that it was first necessary to test the sand; but Mr. Butler thought it was now well understood that standard sand could be obtained which enabled comparative results to be obtained from various Portland cements. The second test referred to by the Author was that for soundness, which was the most important quality of cement. It was well known that cases had occurred in which cement had been used and had subsequently expanded. Those cases were not very frequent now, owing to the great improvement in the manufacture of cement in the last few years, but at the same time cases of expansion were occasionally met with, which rendered it all the more necessary that cement should be carefully examined in that respect before being used. One of the tests mentioned by the Author was 7 days in cold water. That was scarcely severe enough. Unless the expansion was extremely marked, 7 days in cold water would not detect it. The next test mentioned was one introduced by Mr. Butler's late chief, Mr. Henry Faija, about 25 years ago. It consisted in subjecting a pat of neat cement first of all to moist air of about 110°F. , for 6 or 7 hours or until it was considered set, and then immersing it in water at about 120°F. for about 17 hours, which accelerated the hardening. If at the end of that period the cement showed no signs of expansion, his experience was it was quite safe to use it. He was well aware that within the last few years much more severe tests had been introduced. Instead of a temperature of 120°F. , a temperature of boiling water had been used, and in some cases in Germany they had tried steam at a pressure of many atmospheres; but those tests he thought were fantastic and altogether too severe. With regard to the Le Chatelier test, Mr. Bamber and he were rather at variance over it. It did, as the Author said, give a quantitative expansion, but his own contention was that boiling water, to which the pat was subjected under the test, was unnecessarily severe. It had not yet been proved that because cement would not stand boiling water after setting 24 hours, it would therefore cause expansion in the work.

With all due deference to the British Standard specification, Mr. Butler. he contended that a temperature of 120° F. for the final test was quite severe enough to detect any disruptive agency which would cause expansion in the work. The Author mentioned weight per bushel as a working test, but that was now quite obsolete. Weight per bushel was introduced some years ago with the idea of determining the degree of calcination, but the weight per bushel depended entirely, first, on the fineness of the grinding, and secondly upon the age of the cement. Some experiments made by Mr. Faija 20 years ago showed that the weight per bushel of fresh cement might be 120 lbs.; by keeping it a week it dropped to 114 lbs.; and it gradually decreased with age until in a year the cement only weighed .95 lbs. per bushel. He thought specific gravity was a fallacy. It was supposed to indicate the amount of calcination to which cement had been subjected. He had the honour about 4 or 5 years ago of presenting a Paper to The Institution dealing with the subject of the specific gravity of cement, and he showed that the specific gravity of absolutely yellow, unclinkered material was the same as that of black, well-burnt clinker when it first came from the kiln, and that the difference in the specific gravity was simply due to the absorption of water and carbonic acid from the atmosphere. The specific gravity of all cement was alike when freed from water and carbonic acid. At the end of that Paper he gave the conclusions to which his experiments had led him, namely, that the specific gravity of Portland cement was no indication whatever of proper calcination; that the specific gravity of Portland cement depended upon its age and the opportunities which had been afforded it of absorbing water and carbonic acid from the atmosphere; and that by calculation, after expelling water and carbonic acid and determining the amount of water and carbonic acid in that cement, it was possible to determine the specific gravity of the unignited material with a fair degree of accuracy. Therefore he contended that for an engineer at the works to attempt to determine the specific gravity was simply waste of time.

Sir JOHN WOLFE BARRY, K.C.B., Past-President, observed that the reconstruction of the Tynemouth breakwater was a very interesting and instructive work for many reasons, and one great reason was the opportunity which it afforded for the study of a failure, a source whence a great deal of knowledge with regard to engineering problems was derived. He did not wish to say a word in criticism of those who designed the original structure, and designed it, he thought, as being well within the limits of what was believed in their day to be safe; but the fact remained that the depth of

Sir John
Wolfe Barry.

Sir John
Wolfe Barry.

water at the end of the pier and at the part which gave way was so great that the wave-stroke on that portion of the pier was far more severe than the engineers at that time thought possible. It used to be considered almost as a canon that if a rubble mound was 15 feet below low water wave-action might be almost neglected. Mr. Messent, who carried out the work, evidently found that such a canon was susceptible of considerable qualification, and that much greater caution had to be used. As he went seaward he put his foundations deeper, removing the rubble mound where it had been tipped too high till at the pier-end he built the masonry superstructure at a depth of 27 feet below low water. Even that depth was however quite insufficient, and the result was that the scouring action of the reflux of the sea removed the rubble mound, displaced the foreshore blocks, and gradually pulled the masonry out of the seaward side of the wall, so that the work became a disastrous wreck. He did not blame Mr. Messent in the least for the error; but engineers to-day recognized that such a depth as 27 feet below low water was altogether inadequate in certain localities, although it might be quite sufficient elsewhere, and that no generalization could therefore be made upon the subject. Each locality must be studied by itself. The question of the "fetch" of the sea was not the only question that had to be considered. The fetch on the line of exposure might be many miles, and yet the force of the waves might be less than a priori would be anticipated. It was in fact a question not only of the fetch but also of the nature of the soundings as the sea-bottom approached the shore. In the case of the Tyne breakwater the soundings were particularly steep, so that towards the end of the breakwater the sea was of the most turbulent and heavy description. That was due not only to the length of exposure, great as it was, but also to the fact that the soundings were steep, so that the great waves came in with their size and force to a large extent undiminished by the friction of the bottom. Though rubble mounds were seen standing at some places where there was very considerable fetch, he did not think anyone nowadays would dream of placing the top of a rubble mound only 15 feet or thereabouts below low water in exposed situations. They certainly would not stand in such a place as the outer end of Tynemouth Harbour. He did not think for one moment that Mr. Wheeler's suggestion of tipping rubble outside the wall after it began to show signs of weakness would have had any beneficial effect; the rubble would have been removed by the sea towards the shore, and the thing would have had to be done over and over again without success. As the physical conditions of the bed of the sea could not

be altered, it would be hopeless to attempt to make another rubble mound which would be really stable at the extremity of the Tynemouth north breakwater. All those considerations had been before Sir William Matthews and himself when they came to the conclusion that the only proper thing to do was to found with solid masonry on the shale at a far greater depth than had been previously contemplated. As proof of what he had said as to the nature of the soundings and their effect, he might point out that at the Tynemouth north breakwater, and about half-way along the pier, the rubble mound was 15 to 20 feet below low water, and that the pier remained stable on the top of it, merely because the bottom of the sea was such as to prevent the heavy stroke of the waves against that portion of the pier which was experienced farther out, a stroke that was at its full force at the extremity by the lighthouse. For those reasons Sir William Matthews and he came to the definite conclusion to recommend to the Tyne Commissioners the reconstruction of the breakwater of the type and for the length that had been adopted. No one who had been on the Tynemouth breakwater on a really rough day could doubt that it was a very difficult position for the construction of such a work, or that the fight with the sea there would always be one of the severest in Great Britain. With regard to driving piles through the rubble mound, one of the reasons which had led Sir William Matthews and himself to recommend that the line of the new portion of the pier should deviate from the original line and be made straight, not following the old line of the rubble mound, was that by straightening it they soon got away from the great depth of rubble mound, and there was less thickness of rubble in which to drive the staging piles. Another reason was that there seemed to be no particular cause for the curve that had been previously adopted; while further, it was obvious that the old work, though more or less wrecked, would be a great protection in the construction of the new work; and so it had turned out. Some remarks had been made about blue lias lime. He did not suppose many nowadays used blue lias lime for sea-work, but it had been used by the earlier engineers with great success, and he had used it himself also without drawbacks at the Barry docks, where in the early days scarcely anything else was used, owing to the fact that the docks were constructed in the heart of a blue lias district. But before starting to use blue lias lime he knew well that it was a good servant but a bad master, and he therefore instituted an elaborate series of experiments by building piers of masonry with different mixtures of lime and sand. Probably twenty such experimental piers were tried, and the results differed to an

Sir John
Wolfe Barry.

Sir John
Wolfe Barry.

extraordinary degree. Even with the same mixture of sand and blue lias lime one pier would be completely shattered merely by exposure to the weather, while another pier would be perfectly sound. These results appeared to depend very much upon the amount of water used, the time given to slaking the lime, and the treatment of the lime before it was made into mortar. Eventually, by trial and error, which after all was a very good way of finding out things, the best method of treating the lime—the number of days it had to remain slaked, and the mixture and character of sand to produce a good result—was arrived at. Throughout the whole of the first two or three contracts at Barry docks, involving a very large quantity of masonry, he had not heard of any failure whatever from the blue lias lime, and where accidents had occurred, such as a ship running into the wall and disturbing the masonry, the blue lias lime had been found to be perfectly good. At the same time, at the present prices of Portland cement and with the knowledge now possessed of that material, he did not think it was worth while for engineers to trouble themselves much with blue lias lime for sea-work, except in special cases. It had been asked whether any indication could be given of the cost of the work per lineal foot. It was impossible to give even a distant idea of the cost of the work in that way. The price per lineal foot of course varied greatly with the depth and with the section, while a large part of the contract consisted of the lighthouse head, involving a great deal of the expenditure in the deepest part of the water. The best plan would be merely to tell the gentlemen who desired to know the cost that the total expenditure on the work was approximately £450,000. The work apparently was standing extremely well, and he thought the Tyne Commissioners were well satisfied with it. It had been carried out for very little more than the estimate first submitted to the Commissioners. He congratulated both the contractors, Sir John Jackson and Company, and the Author upon the completion of their task. The contractors attacked the work—which was a very difficult and formidable one—with great resource, excellent administration, and first-class plant, and the result was that the work went on well. Although there had been some very heavy attacks by storm, yet, the staging being strong, very little difficulty had been experienced in connection with the contractor's temporary works. He specially congratulated the Author on the successful completion of the undertaking, which he had had very much at heart. Nobody could have given greater care to the execution of the work and nobody could have exercised better judgment than Mr. Barling. He was certain that he spoke the thoughts of Sir William Matthews

as he did his own when he said that they recognized thoroughly the assistance they had received from the Author and the devotion which he always showed to the work under his charge. Sir John Wolfe Barry.

Mr. W. B. TRIPP, speaking of the question of the use of blue lias lime in the old Eddystone lighthouse, said it would be found by reference to a Paper read some years ago on the new Eddystone lighthouse¹ that the blue lias lime in the old building had been in an extremely dilapidated condition and had almost disappeared from many of the joints. He thought the late Dr. Deacon had been an advocate for the use of blue lias lime under certain circumstances, but only after it had received very careful treatment. Portland cement in the present state of manufacture could be used with much more confidence than blue lias lime. Mr. Tripp.

The AUTHOR, in reply, tendered his thanks to the members for the kind way in which his Paper had been received and discussed, and especially to Sir William Matthews and Sir John Wolfe Barry for their remarks. He felt much indebted to Sir William for his very clear description of the reasons which led to the adoption of design B, and endorsed his remark that it would have been practically impossible to reinstate the pier on the old lines. He had watched the coast for the past 10½ years, and thought even Sir John Jackson's fortitude would have been put to a test if he had had to maintain his staging in that breach. It had been remarked that the pier was rather like cabinet work, and he took that to refer to the granite facing. He did not think the granite facing could be regarded as an embellishment; it was a necessity. If anyone had seen the pier as he had seen it, with boulders being thrown against it by the waves and had seen the courses thus cut into and undermined, he thought they would realize that some substance a little harder than the limestone previously used was necessary. Had concrete facing been used he was afraid there would have been a disaster sooner or later. Granite was not so expensive as was sometimes imagined; the difference in cost per superficial yard between limestone and granite was very small. He could hardly follow Mr. Dyce Cay's suggestion as to giving the price of the pier per lineal foot, and Sir John Wolfe Barry had really expressed the sense of what he had been about to say, namely, that to price a pier at so much per foot was like saying that if a tug-boat 100 feet long could be bought for £7,000, a vessel like the "Mauretania," 790 feet long, would cost £55,300. It would not even be fair—although, perhaps, a little less unjustifiable— The Author.

¹ Minutes of Proceedings Inst. C.E., vol. lxxv, p. 20.

The Author. to compare the price per cubic yard. Breakwaters were sometimes made of tipped rubble, when the price per cubic yard would be very small, although the cost of the whole structure might be large. Even if similar classes of work were compared it would still be necessary to consider that in some cases a large portion of the work was below water and in other cases practically none at all. Mr. Dyce Cay had also mentioned that at Aberdeen the waves striking the breakwater were thrown up in the air to a height of about 80 feet. That was much the same as occurred at the Tyne, and the Author had been pleased to hear Mr. Thorowgood confirms this. He did not think there would be any fear of the blocks being drawn out if the pier were at Aberdeen. With regard to the scour, it was hardly realized, perhaps, that the pier-head was founded 44 feet 6 inches below low water and that the nearest point of the sea-bed at which the sounding was 44 feet was more than 1,000 feet away, so that a large wedge-shaped piece of sea-bed would have to be scoured out before there could be any scouring round the pier-head. He thought it was almost impossible for such a thing to take place, but if it did he felt sure the Tyne Commissioners would congratulate themselves on having got 44 feet 6 inches of water at the entrance to the Tyne without having had to go in for dredging. He had been greatly interested by Sir Whately Eliot's and Mr. Thorowgood's descriptions of the storm of 1867. That storm had always been held up as one of the worst that had happened on the Tyne, and he was inclined to believe it. He had seen large waves, but nothing in comparison with what had been described. With regard to removing the temporary tube in connection with the cylinders, the tube was made in sections and had a key-piece; on the latter being taken out, the sides folded inwards. It had been a moot point at first whether the piles of the staging could be driven through the rubble mound. It was said that there were pieces in it weighing about 10 tons, but he did not remember seeing blocks of that weight or anything like it. With a sufficiently large shoe, such as was described in the Paper, and with a heavy hammer, there had been really no difficulty. Frequently after a pile had been driven the pile-point had to be undercut, and the shoe was more often found intact than disturbed. The twisting undoubtedly took place through the pile fouling the large lumps of rubble. It was really no detriment, as it involved nothing beyond bending the bracing to bed against the pile, and putting the mortices as shown in the lantern-slide. Sir John Wolfe Barry had answered Mr. Wheeler's question in regard to the possibility of remedying the work by depositing rubble round the old head. In

order to reduce the height of the waves striking the head to that of The Author. those encountered by the shoreward portion of the work, it would have been necessary to raise the whole sea-bed for very considerable distance out, and the quantity of rubble required would have been enormous. The question of cement was more for a chemist than for an engineer, but perhaps Mr. Butler would remember that the specification was laid down $10\frac{1}{2}$ years ago, when the tests were not quite the same as they were to-day. In the official specification it was optional for the resident engineer to have sand briquettes tested, and the option was exercised freely. With regard to soundness, he thought they had found the Faija test quite satisfactory as a rule, but he could hardly agreed with Mr. Butler that the cold-water test was useless, because he had on more than one occasion found the cement to show expansion with the cold-water test and no such expansion with the Faija test. With regard to specific gravity he had hoped, when writing that paragraph, to get a little information as to how the specific gravity might really be accurately taken. From the fact that no one had ventured to put such information forward, it might be assumed that the difficulty of getting concurrent results had been experienced by others. According to Mr. Butler, it was waste of time to take specific gravity. He did not know whether he dared confess it, but he so much agreed with Mr. Butler that after about the first ten cargoes he never took one himself, but wrote down the one which was sent by the chemist. There was no doubt in the Author's mind that the cement manufactured according to modern methods did not require aeration to the same extent as the product of 5 or 6 years ago. He felt deeply the very kind remarks that Sir John Wolfe Barry had made in regard to his work.

Correspondence.

Mr. E. T. BEARD observed that in the description of the block- Mr. Beard. moulds the term "lambs' tails" used by the workmen was mentioned. He had always understood that this applied to the tails of the tailed nuts and not to the bolt-ends; but of course the expression might have different meanings in different localities. It would be useful if the Author would state the nature of the emulsion used to prevent the blocks from sticking to the moulds and how it was prepared; Mr. Beard assumed that it had proved satisfactory.