The Author. order to reduce the height of the waves striking the head to that of 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 10½ 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. Beard. Mr. E. T. Beard observed that in the description of the block-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.

Mr. Beard. Under the heading "Blocks," the Author referred to a novelty in the design, namely, the provision of a check. This seemed to be a valuable improvement and had probably saved much time and money. From Mr. Beard's own experience of work on the north-east coast, he would say that heavy seas there were rather normal than abnormal, and similar checks had been used on his own work to prevent courses of blocks from being forced back. In the account of getting the cylinders down it was stated that a pipe was left through the concrete seal until set, so that the water and compressed air might be in contact and no blow-through occur. A similar plan had been adopted in the case of a sea-wall for which Mr. Beard was engineer; pipes were left at intervals through the wall, so that during construction the pressure might be equalized by the water flowing to the back.

Mr. Bell. Mr. W. REID BELL observed that, as the Author pointed out, little had hitherto been published about the Tyne harbour, and he wished to offer some remarks upon the history of the Tyne Improvements—the great life-work of the late Mr. Philip J. Messent and of his predecessor, Mr. J. F. Ure. Mr. Barling quoted Mr. Rennie's survey of 1816 as showing a depth of 6 feet on the bar at Tynemouth at low water, and Mr. Messent in 1888 had given the same low-water depth of 6 feet "previous to the year 1860"—after the piers had been 4 years in progress; but Mr. Bell had a recollection of statements by an eye-witness of people wading across the bar between South Shields and Tynemouth; this would probably refer to some time between the years 1830 and 1850. The Paper stated that in Mr. Walker's Report of 1853 it was intended to place the pier-heads in 15 feet depth of water at low tide, and this was the statement in the memoir of Mr. Messent.[1] The latter's report to the Tyne Commissioners of 6th December, 1887, "as to the present state of the Piers Works and the position proposed for the ends of the piers," stated, however, that the depth at the entrance proposed in 1853 was 13 feet at low water, and the plan accompanying the report showed that depth. In the same report Mr. Messent stated that the tidal water passing up through the narrows had been increased by 16 million cubic yards since the initiation of the works, and that this would be increased by another 3 million cubic yards on completion of the whole scheme of river-improvement. There was no more interesting river from the engineer's point of view than the River Tyne. The great progress achieved on the Clyde in 1859 led the Tyne Commissioners to secure the services of the late

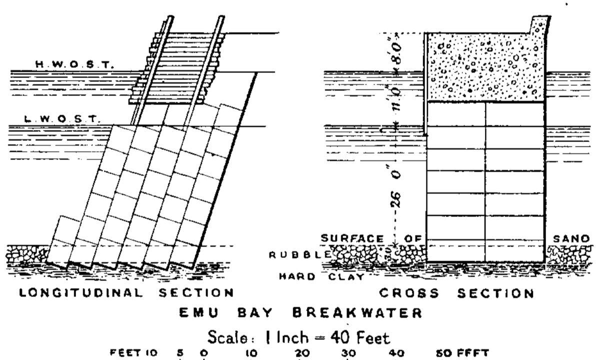
[1] Minutes of Proceedings Inst. C.E., vol. cxxix, p. 378.

Mr. J. F. Ure as their River Engineer. The comprehensive scheme Mr. Bell. prepared by him and carried out by him and by Mr. Messent, and the Tyne piers—Mr. Messent's special work—were together one of the most instructive as well as successful works of river engineering. Even the disaster to the north pier, in the closing days of Mr. Messent's life, could not injure his deserved reputation as a sound and able engineer, and his successors on the piers were to be congratulated on having successfully restored the work practically on the lines laid down by Mr. Walker and so faithfully carried out by Mr. Messent and his assistants. Among these might be mentioned the late Mr. A. D. Cairns, M. Inst. C.E., who was in charge of the pier-works for 12 years or more. The experience gained in all parts of the world, during the 40 years that the Tyne piers were under construction, had proved over and over again that such sea-works would not stand if built with "hearting" in any form, and the Tyne piers might be cited to show the necessity for regular maintenance, and the fact that damage might occur after many years of successful resistance to storms. Mr. Bell's experience led him to the conclusion that in heavy sea-works, with the materials and appliances now available, rubble foundations in breakwaters were in many cases neither economical nor safe Sooner or later they were liable to extensive damage from the attacks of the sea, and independent of any undermining of the superstructure, the rubble as soon as it began to move became a very efficient grinding agent. It followed that the safest protection to the foundations of a masonry breakwater was a blockwork apron, and, from the nature of such apron, exposed to the vertical return stroke of the sea and of necessity presenting many joints and a large extent of surface, repairs would always be necessary from time to time. It was not possible in the nature of things to design or build an exposed work in the sea that would not require occasional maintenance and repair. This had always been recognized in the case of rubble breakwaters, but one was rather apt to look upon a masonry pier when completed as a work that should stand indefinitely without maintenance. There had also to be taken into consideration changes in the meteorology of a locality which seemed to alter the climate or exposure in the course of years. He had in mind one particular coast where the exposure to easterly gales was, 20 years ago, very severe; but he was told lately that in recent years these heavy gales had been unknown. Such variations might easily mislead an engineer in designing sea-works. He had a preference for the over-end mode of construction, combined with the employment of unbonded and unjointed blocks

Mr. Bell. below low water, but in the complicated problem of the Tyne pier restoration there was no question as to the superiority of staging for expedition in a stormy sea, as the several operations could in favourable weather proceed simultaneously. It might be permissible to point out again the excellence of the Messent concrete-mixer for reliable work. The great difficulty with concrete at all times, was to secure efficient mixing, but the Messent mixer never failed to effect satisfactory incorporation, provided the limited speed of revolution mentioned in the Paper—12 revolutions per minute—were strictly adhered to. With higher speed the sand, if at all damp, was thrown into the corners of the mixer and remained unmixed. The output of 206 cubic yards per 10 hours from a 1-yard mixer left nothing to be desired in the way of speed. He noted that the old plan of cored holes with detachable lewises was used for lifting the blocks. Such holes were a double source of weakness, as the block was not only weakened by the hole, but with such obstructions in the block-boxes it was impossible to obtain such dense concrete in filling the moulds. After experience with T-headed lewises, Mr. Bell had discarded them altogether and in their place used heavy round-iron rods, bent like hairpins, with the ends turned up and with rough billets of hardwood threaded on these ends. They were built solid into the block with the loop flush with the top surface. While the concrete was still green it was scooped from under the loop to allow of the insertion of the lifting-hooks. This method of lifting had been perfectly successful, and its economy of time in building and in handling the block and releasing it under water paid for the cost of the iron or steel bars. The Author gave the minimum size of the blocks used in the work as $5\frac{1}{3}$ cubic yards. Presumably, these were not used exposed to the direct stroke of the sea, but the section in Fig. 3, Plate 4, showed blocks of 9 cubic yards between wind and water, on the outer side. With the experience of the old pier in view this certainly seemed bold practice, because such blocks depended for their stability wholly upon the soundness of the mortar joints and the joggles. The locality was not unknown to Mr. Bell, who had had experience of a heavy sea on the pier; and, however sound the work was at present, he considered that such small blocks, after being subjected to the vibration of the sea-stroke for 50 years, would probably have their joints very severely strained. The strength of the Tyne piers lay in the great width—50 feet—and with this great mass acting like a horizontal anvil it was more necessary that the face-stones should be of sufficient mass to prevent their being thrown out against the sea by the recoil transmitted from the inner mass. Further, in working with 12-yard blocks at a less exposed site, he had tested the difference between having the concrete spread and poached in the moulds by one man and by two. When two were employed the 12-yard box took two more $\frac{1}{2}$-yard charges to fill it than when one man was employed, and the point to be remembered in this connection was that in a box of that capacity 5 feet high, encumbered with lifting-rods or cores, and with battens or tramways over it, it was not possible for two men to work effectively. The difficulty might possibly be overcome in part by filling the mould at a slower rate, but there would be no certainty of getting the required density, and the importance of this matter impressed itself so strongly upon Mr. Bell, that in blockwork in which density and impermeability of the concrete was a necessity—as was the case in all concrete exposed to sea-water—he would hesitate to use blocks of less than 15 or 20 cubic yards. Judging from the sections of the work, the granite appeared to be rock-faced. It appeared that too little attention was given to ensuring a smooth face on masonry exposed to heavy seas. Many years ago at North Sunderland Mr. Bell observed the effect of a heavy swell coming obliquely on a work where there were two classes of face. While the rollers passed along a smooth face of Portland cement they were unbroken, but the instant they touched stone masonry with its rough face they broke in a very destructive manner. This was a well-known phenomenon, and the destructive effect of breaking seas was so thoroughly recognized that it seemed extraordinary engineers had not availed themselves more generally of the protection afforded to their works by a smooth surface. A glass-hard and homogeneous surface could be produced on cement concrete at little cost, and, without counting the wear and tear which it would save the face, its effect upon the seas would lengthen very materially the life of the apron protecting the foundations. Mr. Bell.

With regard to the cement-testing, the Author's experience with the specific-gravity test was interesting, and Mr. Bell would endorse his opinion, looking on the specific gravity only as an indication in interpreting the results of the other forms of test. It was well to direct attention to the anomaly of gauging cement by measure instead of by weight, the latter being the practice in most foreign countries. Gauging by weight would not ensure a good quality being employed, but it would eliminate the personal element of the workman in filling the measure. He would take exception to the Author's statement attributing hair-cracks to expansion. The hair-cracks were due to contraction, not to expansion. The concrete being moulded, each piece end to end, was in tension longitudinally. It was held down in contact with the layers below, Mr. Bell. and when the vibration of the sea-stroke occurred the tension was relieved by the development of hair-cracks. These cracks never altered if the work was solid. A concrete arch might or might not rise and fall with change of temperature, but in a solid work such as a pier the heated surfaces became stressed without change of form. It was quite against reason to suppose that solid masonry in the sea was subject to any "concertina" action under change of temperature. Regarding the use of incandescent mantles in lighthouse illumination, the intrinsic brilliancy of the light gave a great advance in intensity of beam, but it must not be lost sight of that the opaque mantle prevented the utilization of the light projected in the dark arc by means of reflection through the focus, and until some means of obviating this was devised half the benefit of incandescence lighting was lost. Exception might be taken to the manner of disposal of debris, and to the means taken to prevent the breaking up of the old work at low-water level seaward of the breach. Having regard to the heavy cost of any operations of removal, it was a difficult matter to determine how far it had been necessary to raze the old work, but the operations carried out would seem to have resulted in an accumulation of incoherent masses of masonry and loose debris, in exactly the position, where, if any apron at all was to be allowed, it should be of the most substantial and durable character. The hoop of double-headed rails binding only the top course of the old head was not likely to preserve the masonry many years, as the sea would probably in time lift the whole course off its bed. Looking at the sections of the old and new work, and considering the history of the piers, Mr. Bell felt his objections to rubble mounds strengthened. Whenever there was any possibility of founding on the natural bottom or of going through the sand or mud to the rock it would pay to do so. Provided there was no transition from one kind of rock to another there was little chance of unequal settlement; and further, with structures in the sea, the pressures on the foundations were so modified by the buoyancy due to the water that a comparatively weak shale or clay would, if the bedding were favourable, afford a very sound foundation. His experience was that such a foundation, carefully prepared, practically eliminated the risk of settlement. This permitted the employment of the strongest of all superstructures—the mass-work built in situ from low-water level. Every consideration of economy and strength condemned the use of blocks of varying size. Jointed work in or about the sea was not homogeneous, and the expense of trying to make it so might be better employed in adding to the weight. Below low water strength and economy demanded the largest and simplest blocks possible without attempts at uncertain bonding, and this work must be kept down with the heaviest mass possible above water. In the section shown in Fig. 3, Plate 4, there was an objectionable ledge at low water and the mass was tapered off upwards, leaving the face-blocks at low water relieved of much of the weight that was there an absolute necessity. The vertical check shown in the section—if a good bearing could be ensured—seemed to be a very satisfactory arrangement. The Author was to be congratulated on the success of the precautions taken in setting the foundation-courses. Too much insistence on this point could not be made, and Mr. Bell would point to *Figs. 11*, showing the section of a sloping-block breakwater built in Tasmania over 20 years ago from the designs Mr. Bell.

Figs. 11.



of the late Mr. C. Napier Bell. It was, he believed, the first sloping-block breakwater founded on the natural bottom. After careful consideration of different modes of laying the foundations, it was decided that speed of construction demanded that the sand should be completely removed and a bed for each block dressed by divers. This enabled the mass-work capping to follow up the block-setting without waiting for settlement, and as a result the work was standing to the present day without the slightest sign of settlement. On p. 163 the Author insisted upon the danger of depositing unprotected mass-concrete near the level of low water. Mr. Bell agreed so far as unprotected concrete was concerned; but if the joints of the casing and of the adjacent blocks were properly plugged, the whole area lined with hessian, and the concrete made with a safe proportion of cement—even up to 1 of cement to $2\frac{1}{2}$ of sand, his

Mr. Bell. experience was that mass-concrete could be put in at low-water level perfectly safely. With good concrete he had had the workmen driven from the work by heavy seas and yet no damage done that could not be repaired with a few barrow-loads of concrete on the top of the work. The fathom-lines shown on the plan (Fig. 1, Plate 4) were not marked with the date of the survey; it would be interesting to have a comparison of the depths previous to the breach with any changes that occurred within the north pier-head before or after the execution of the repairs.

Mr. Box. Mr. E. Box thought the Author was to be congratulated on the method he had adopted, of not merely giving a description of the work as an accomplished fact, but of following in detail the methods by which the work had been carried out. The Tyne north pier was particularly interesting from the fact that it afforded an example of failure of a pier built upon a rubble mound. The reason given by the Author for its failure seemed perfectly feasible to anyone who was familiar with the locality, and who had had an opportunity of observing the never-ceasing wave-action at the back of this particular pier, which intercepted at right angles the furious northern seas. The position it occupied was an exceptionally bold one. The undercurrents set up by such a combination must be considerable, and it would be interesting to know whether the Author had made any observations respecting the behaviour of these currents. Many swimmers had of recent years lost their lives there, due, it was stated, to the development of a considerable undercurrent attributed to the influence of the north pier. The system adopted for carrying out the work was no doubt the most expeditious for producing satisfactory work when all the conditions were taken into consideration. The contractors were fortunate, however, in having the old pier to protect the works and secure the gantry to, otherwise the system might have been impracticable in such an exposed situation and thus the time taken in the completion of the work might have been prolonged. There was a quantity of rubble on the foreshore opposite the Castle point, and it would be interesting to know whether there was reason to believe that this was part of the original bed upon which the pier was founded, thrown up by the action of the sea. Referring to the concrete blocks, the gauging of the ballast was not stated, and it would be interesting to know whether this had been done by observation or whether it was mixed in definite proportions and what the proportions were. Mr. Box's practice in dock-works was to use 1 of cement to 5 of aggregate as a general rule, but in such massive work as that under review a proportion of 1 to 6 might be sufficient

Mr. Box.

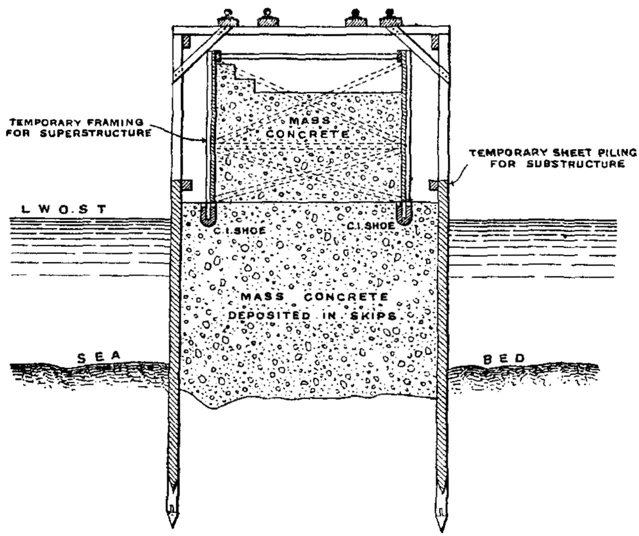
when it was remembered that the facing was protected by granite. With regard to the block-moulds, boxes for concrete work were seldom made strong enough to resist bulging, and no doubt the cheapest way to overcome this weakness when possible was to use tie-rods. In dock-walls or single-face work where tie-rods were not applicable, he framed his boxes so as to give sufficient stiffness when fixed at the ends only. This system might be applied with advantage in a modified form to block-work so as to enable the tie-rods to be kept outside the blocks. To compensate in material the facing-boards could be reduced in thickness. He had recently demolished a very substantial graving-dock head by means of gelignite. Generally his experience conformed to the Author's remarks, but the procedure might be worth describing, as the demolition had been carried out in a densely populated district where greater care would be necessary than in the case of the Tyne north pier. The dock-head had a mean thickness of about 5 feet, and was opened out on both sides when blasting was commenced. The bore-holes were drilled vertically, not less than 5 feet deep (6 feet being preferred), and about 8 feet apart. The charge was 5 oz., and each hole was charged and fired separately by time-fuse. The results were very satisfactory, the wall generally splitting from the top longitudinally, and the debris, with ordinary care, being kept well under control. This work had been carried out while a vessel was in dock whose bow was within a few yards of the wall. If the work were under water $7\frac{1}{2}$-oz. charges could be used with perfect safety. He used gelignite in preference to powder under such conditions.

Mr. Carey.

Mr. A. E. Carey mentioned that the original design of the Tyne north pier was a subject which he had frequently discussed with the late Mr. Messent, and he had then expressed great misgiving as to the stability of the resultant structure. Everyone who had had the privilege of knowing Mr. Messent deeply deplored the disaster which overtook the work to which he devoted his life. The alteration in the alignment of the work, as now built, appeared to be a step fully justified by the circumstances. All harbour-engineers were agreed that the works, now so successfully carried out, involved, during construction, very formidable difficulties. Mr. Carey did not agree with the opinion expressed by the Author that in breakwater construction the deposition of mass-concrete up to low-water level, through and under water, if properly carried out, was a system liable to result in unsound work. He had found that, by enclosing foundations with piling, by subsequently grabbing out

Mr. Carey. the sand and other material down to the desired ultimate level of the work, and then depositing mass-concrete through the water, in the proportion of 1 to $5\frac{1}{4}$, using skips for so doing, entirely satisfactory results were obtained. *Fig. 12* showed a typical cross section of work constructed on this system. This was obviously a system the cost of which was much less than that involved in the levelling of a sea-bed by means of a diving-bell and the setting of large concrete blocks. He believed that, in many instances, the staging for transporting the block-setting plant would be found to cost more per lineal foot than the entire expenditure involved in

Fig. 12.



building a breakwater of similar section in mass-concrete in the manner he had described. The elimination of the risk of unequal settlement of the concrete blocks and the absence of joints were advantages of first-rate importance. Of course there was no difficulty in facing with granite blocks a mass-concrete structure built as described. The repeated irruption of sand and the subsequent necessity of excavating this over and over again, as described by the Author, were also avoided by such a method. With regard to the remarks on the specific-gravity test for Portland cement, he would ask what the Author proposed to substitute for this. It was obviously a far more certain and reliable test than that of weight per bushel. Mr. Carey thought that two statements as to the specific-gravity test might be accepted: (1) That it was highly valuable in the detection of adulteration. Adulteration was, however, much less in vogue than formerly; in fact, in cement manufactured in the United Kingdom, he thought it was now almost unknown. (2) That it furnished little index as to whether the clinker had or had not been properly burnt. The variation in the specific gravity of cement, in relation to the fineness or coarseness of its grinding, would not, he thought, be found to be a matter of much practical moment. With regard to the Author's experiments, the difference he had found in using petroleum and turpentine was probably due to the impurity of the latter. Turpentine, unless distilled so that its resin was extracted, was apt to cause difficulty in taking a specific-gravity test. It was, of course, common knowledge that, with the extremely fine grinding at present in vogue, the old standard of weight per bushel, now obsolete, would be a physical impossibility. With regard to the method of mixing concrete detailed by the Author, Mr. Carey could never understand the merit of intermittent mechanical mixing. It seemed to him that the first condition of uniformity in the resultant concrete was a continuous mixing. The remarks as to the deterioration of concrete in the sea recalled the long discussion which took place at the Institution in 1891.[1] Mr. Carey thought that it might be fairly claimed that that discussion had established the accuracy of the opinion, then so widely expressed, that, granting sound Portland cement, proper mixing, and skilled manipulation in the deposition of concrete so as to ensure watertightness, the alleged deterioration of concrete in the sea was unproved. With regard to the method described in the Paper for preventing concrete from sticking to the mould in which it is cast, he had found ordinary whitewash quite effective. As to the destruction of the Oregon-pine piles supporting the staging, Mr. Carey was responsible for a number of piers in the North Sea, which were built of creosoted pitch pine, and he regarded 30 years as a fair estimate of their life in that sea. He believed that in the English Channel, owing to its higher summer temperature, the life was about 25 years. The west pier at Newhaven had to be rebuilt 26 years after its construction. In tropical waters much greater rapidity of destruction was to be looked for. In the construction of the La Guaira harbour-works, for instance, pine timber was utterly destroyed in about 18 months. Mr. Carey.

[1] Minutes of Proceedings Inst. C.E., vol. cvii, p. 98.

Mr. Carey. *Vera*, a native timber, had resisted the worm, which, in the Caribbean Sea, attacked even greenheart. *Gunyacan* and *araguano* proved nearly as worm-proof as *vera*. Mr. Carey had noted at the Dover harbour-works, that the blue-gum (*Eucalyptus globulus*) piles used for the staging, when drawn after several years' immersion, were perfectly sound and not infested with the limnoria. Not even sea-anemones were found adhering to them. This was probably due to some acid or poisonous quality in the timber, and the chemical reason of the fact would be worth investigation. Its chemical cause might perhaps be the clue to methods of rendering other timbers immune from the attacks of the teredo and limnoria. He thought much worm-proof timber must exist in many of the tropical forests within the British Dominions, and that the introduction of such timber, not now on the market, would be well worth the consideration of exporters.

Mr. Carron. Mr. F. G. CARRON suggested that the canting of a portion of the old work at the "inner length" might be due to the crushing of the mortar in the joints near the face by excessive stress caused by the thrusts from backing, superstructure, and superload, if any. The maximum compression per unit area might be greater on the joints down to low-water level than at any lower level, seeing that the mean width of the wall was less above that level and that the weights of the materials to be considered from that level upwards were their weights in air.

Mr. Larminie. Mr. J. C. LARMINIE considered the Paper to be a record of a very difficult piece of work, carried out with great skill and with unexampled perseverance and patience, during a period of over 8 years. The decision to abandon the rubble-base foundation in favour of blocks founded on the shale would appear to be a sound one, in view of the exceptional character of the seas at Tynemouth. At the same time, such rubble foundations had been successful elsewhere, for example at Colombo; and again, in the early days of the Madras harbour, though an extensive break had occurred from failure of the rubble mound, the work was made good by merely flattening out the slope of the rubble and by the addition of heavy wave-breaking blocks along the outer toe of the breakwater wall. No particulars were given in the Paper as to cost, but contingent expenditure on excavating foundations with a grab and from a diving-bell, in sand which kept running in at such a rate that it took 6 hours to get out 1 cubic yard, and on the construction of the necessary eight-cylinder steel dam (which took nearly a year to complete), must have been abnormally heavy. No doubt the work had been well done on a secure basis, so that the only criticism which now suggested itself was, could it not have been executed in a more economical manner and in a shorter period? He believed that this might have been effected on the following general lines: First, the construction of an entirely new pier starting from the rocky foreshore about 700 feet south of point A and running straight to the present pier-head. Such an alignment sufficiently removed from the old structure, would have eliminated much trouble and expense in dealing with the old work, and there would have been no necessity for the cylinder dam. Of course such a work would involve the construction of fully 750 feet of additional new pier, but of this length about 300 feet, it would appear, might have been founded directly on exposed rock. The alteration of the alignment would be more beneficial than otherwise in regard to scouring tidal action on the adjacent sand-shoals. The adoption of an entirely new alignment would have vastly facilitated the pile-driving for the goliath staging (it was difficult to realise how timber piles could ever have been driven through the old rubble mound). But a still greater saving might have been effected, by the adoption of the end-tip block method, with an overhanging titan, and thus omitting staging altogether. The same or other arrangement of bond could have been carried out; and the alignment being sufficiently removed from the old work, the excavation of the sand from the foundation-trench could have been expeditiously carried out by a small suction dredger. Mr. Larminie.

Dr. J. S. OWENS noticed that on p. 138 it was stated that for each charge the mixer was turned fifteen times, and the speed was limited to 12 revolutions per minute, the resulting concrete leaving nothing to be desired. He would be interested to know on what lines the number of revolutions of the mixer had been fixed. Having devoted some attention to that very point himself, he had been driven to the conclusion that the fixing of the number, while exceedingly important, was by no means a simple matter. There was not only the difficulty of fixing it for any particular ballast or mixture, but also the further difficulty that it differed for different mixtures, or rates of revolution of the drum. He would also like to know what degree of uniformity of the strength of the concrete had been attained. In determining whether concrete had been mixed to a uniform strength, too much reliance was, in his opinion, placed on the value of inspection. In order to enable one to say whether concrete had been mixed sufficiently or not it was essential that the method employed should be capable of distinguishing between two samples of the mixed concrete which were made with slightly different proportions of cement. Now he had found by experiment that unless the variation in the proportion of cement Dr. Owens.

Dr. Owens. present in two such samples was considerable, no difference could be observed in their appearance. In fact, he had found that to cause an obvious difference in the appearance of the two samples, it was necessary that one should contain about 50 per cent. more cement than the other. Again, in a heap of *apparently* well-mixed concrete he had observed a variation of more than 20 per cent. between the proportion of cement at two points of the heap. The chief point he wished to bring out was that to rely on inspection of the concrete as a test of proper mixing was unsafe and misleading. Every particle of aggregate might be nicely covered by a coat of cement and water, but the danger was that the coat might not be of the same thickness or strength at all points of the concrete, while presenting the same appearance to the eye. Suppose, then, a concrete in which the cement content at some points fell below that specified by 10 per cent.; it might be that the strength of the whole structure was reduced by that amount, especially where concrete was used in small quantities surrounding embedded steel. In larger masses, as in the work described, such a reduction of strength could hardly occur, but with a material of non-uniform strength, engineers calculated on the minimum strength; here, to say the least, if perfectly uniform concrete could be assumed a great saving in cement might be made. Even 5 per cent. on the cost of the cement for large works was not a negligible amount. With all this in view Dr. Owens had worked out recently a simple method of detecting non-uniformity in the mixture before it was placed in the work. The method had been thoroughly tested experimentally and had the advantage that it could be applied by any engineer on the works. Briefly it consisted in placing two measured samples of concrete, from different parts of the heap, in two tall, graduated glass vessels full of water. The water and concrete were then shaken up and placed to settle, when the sand dropped to the bottom and formed a distinct layer in about 10 seconds, whereas the cement came down slowly and formed a second layer on top of the sand. With certain precautions in the application of the test, the thickness of layer was proportional to the amount of cement or sand present in the sample. It would thus be seen that when the two samples showed layers of the same thickness, or the same ratio of thickness of cement to sand, uniformity was indicated. The coarse stones were removed from the samples by washing them into the glass vessels through a screen of about 10 meshes per lineal inch. This was found to involve no fallacy, so long as conclusions were drawn from equality or otherwise in ratio of the thickness of the cement layer to the sand layer in each sample. The whole test occupied approximately 15 minutes.

He found it especially useful when hand-mixing was employed, and had also used it to determine the end of the mixing process in a mixer, and thus the number of revolutions necessary. In one case, having fixed for the makers, by this method, the number of revolutions necessary for a certain mixer, a prospective customer of theirs had independent tests made by mixing concrete for the number of revolutions indicated and preparing test-blocks. These were subsequently broken and analysed, with the result that practically perfect uniformity in strength and composition was shown. Dr. Owens.

Mr. J. A. SANER congratulated the Author on the successful completion of a difficult work. The important point to be adduced from the Paper, which appeared to be a very complete record, was, to his mind, the danger to be anticipated from not carrying foundations deep enough; and although no doubt when the original pier was constructed 50 years ago, the appliances for carrying out work were not what they were to-day, yet it did appear to have been a very bold scheme to build on 10 feet of sand and mud in such an exposed position. It was quite evident, however, from the difficulties met with during the reconstruction, when the old pier afforded a certain amount of protection, that the best possible was done with the appliances then available; and as the pier had contributed very largely to the safety of shipping using the Tyne, and therefore, indirectly, to the prosperity of the Tyne ports, the risk which was taken had been fully justified by the results. The Author's experiments on cement deserved to be followed up. They rather pointed to great care being needed to pun newly-placed concrete very thoroughly and while still plastic, so as to force out as much air as possible, and to the avoidance of too wet a condition, so as to allow of such punning, insufficiently punned concrete being frequently found honeycombed with air-bubbles which could not always be accounted for. It was not quite clear from the Paper how the junction between the old pier and the new cylinders was secured against future scour. The Author stated that the cylinders were 80 feet seaward of the old portion, and that the soft material was 28 feet thick at that point. It would be interesting to know to what depth the mass-concrete had been taken, and what precautions, if any, had been adopted to prevent the washing away of the soft material from underneath. Mr. Saner.

Mr. WILLIAM SHIELD found in the Appendix a quotation in regard to the teredo, which had been taken from a book of which he was the writer.[1] "This (the Author of the Paper stated in the most unreserved manner) is entirely incorrect, the writer having doubtless mistaken Mr. Shield.

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[1] "Principles and Practice of Harbour Construction," pp. 132-3. London, 1895.

Mr. Shield. for the Teredo the harmless Nereis." Mr. Shield wished to make some comment on this. From the beginning of the year 1876 onward, for about 9 years, he was executive engineer of the harbour-improvements carried out at Port Elizabeth, Cape Colony. These included the removal of a long breakwater composed of black ironwood piles and rubble, and a landing pier or jetty composed entirely of timber of various kinds. The structures contained many hundreds—indeed thousands—of piles, all of which were destroyed by the *Teredo navalis*, many of them being eaten completely through. So energetic was the teredo at that port, that after the removal of these structures and the erection of iron landing-piers fitted with greenheart fenders, the fenders were so vigorously attacked that they had to be renewed after the lapse of about 7 years. He carried out all these works departmentally, without the aid of a contractor, and therefore had everything under his immediate notice. During the time that the demolition of the old breakwater and jetty was in progress, anyone who cared to take the trouble could have easily filled a bucket with teredos, so there was no lack of specimens. Being curious to find out how such soft "worms" could, with apparent ease, eat into such hard and tough wood as black ironwood, he, on several occasions, had taken live teredos out of their holes, and had treated them as described, with his own hands and penknife; and he endorsed every word of the paragraph to which the Author took exception. The teeth were surrounded and hidden by an exceedingly strong sphincter muscle, hence the "considerable pressure" necessary to make them appear. The head of the teredo, or more correctly, the part where the head ought to be, for they were acephalous, was a perfectly designed grab, with sharp chisel teeth actuated by this powerful muscle and admirably adapted to their work. Now, after having made these investigations, and in view of the large number of specimens continually under observation, not to mention his lengthened acquaintance with teredos elsewhere, he held that he had been fully warranted, without further inquiry or investigation, in "taking for granted" that these worms or molluscs, which, beyond all doubt, were responsible for the mischief done to the piles, were *Teredo navalis*. Mr. Shield had been an amateur naturalist all his life, and was not unacquainted with the "harmless Nereis" to which the Author referred. It was, however, quite a different animal to the *Teredo navalis*. Although a Tyne-sider he had never been acquainted with a real, live Tyne teredo; but as the Author professed to be an authority upon them, and in view of his statement that too much had been taken for granted in the past, it seemed to be incumbent on him now to state how many live teredos he ever handled with his own hands, up to the date of writing his Paper, and, in the event of his having handled any, whether he examined them as closely as Mr. Shield did his specimens. An accurate description of the anatomy and mode of working of the Tyne teredo, illustrated by a sketch if possible, would also be useful. Unless this were done, the Author could not fairly complain if Mr. Shield for one, refused to accept his unsupported statement. Mr. Shield.

Mr. W. A. P. Tait considered the historical portion of the Paper to be very interesting, relating as it did, how, in the case of the Tyne as in the case of other British rivers, Nemesis had overtaken a dilatory municipality, which had then been replaced, with the authority of Parliament, by a representative Commission. Near the end of the Paper a paragraph appeared relieving the original designer from any blame on account of the comparatively shallow depth at which the original work was founded. Neither the Paper nor the illustrations attached to it, however, gave any information as to whether the Tyne Improvement Commission's engineers or the Admiralty advisers had ever suggested that the new pier-works should not be founded in the shale. Perhaps the Author in replying would clear up this point. He might also state the amount subscribed by the Admiralty and the amount of national money granted on the recommendation of the Royal Commission on Harbours of Refuge, and whether any conditions other than those stated on p. 134 were attached. Notwithstanding the great change in design recommended about the year 1859, there was no reference to an amending Act of Parliament. It would be interesting to have some figures of the cost, both of the original and of the reconstructed works. The latter, however, to a large extent had proceeded under the shelter of the original work. The Author in replying might perhaps state his idea of what extra cost might have been incurred if the foundations of the original work had been carried down into the shale at the outset. Several references were made to sand running in on the new foundations. Part of this was no doubt mud in suspension, but the Author did not state to what slope the contractors endeavoured to work. With reference to the statement in the Paper that the contractor bought by weight, and sold by measure, it might be pointed out that troubles with contractors in regard to payment for cement were not infrequently lessened by the practice which prevailed both in the Loch Katrine and new Edinburgh water-supply works, in which cases cement was paid for by the ton. The engineers were thus enabled to change at will the composition of concretes, mortars, etc. Mr. Tait.

Mr. Voisin. Mr. VOISIN, of Boulogne-sur-Mer, remarked that if about 1850 the technical knowledge on the subject of foundation was not sufficiently advanced to render it possible to foresee what actually took place, it was evident from the experience since gained that, owing to the fact that the pier was founded on a bed of sand of varying thickness, overlying materials of differing degrees of solidity, it was inevitable that subsidence must occur sooner or later. The sand was bound to be scoured away in course of time by the surf arising from the presence of a work the exterior facing of which was not designed in such a way as to break the force of the waves. Further, the rubble mound at the base of the pier was not more than 10 feet below low water. It seemed probable that this scour would not have taken place if the pier had been founded on a large mound of rubble work, levelled to the height of dead water at low tide, and protected towards the offing by blocks with a relatively flat slope, rising nearly to the height of half tide; for in that case the action of the surf would have been considerably reduced, if not entirely prevented. By the construction of the new pier on firm ground, as had now been done without hesitation, there would seem to be nothing to fear, even with an almost vertical face in section, unless the surf, the action of which would no doubt be intensified by the removal of the rubble work, should be powerful enough to attack the soil beneath the foundations. This would appear to be in certain places of a clayey nature. It was true that the depth in this case amounted to 44 feet 6 inches below low-water level, and that at this depth the action would be slight; but it was advisable to point out that it had been found necessary in certain places at Dover to protect the foot of the piers founded on the chalk at similar depths. Turning to the plans, it was no doubt in every way advantageous to do away with the considerable curvature adopted in the case of the former pier. Experience pointed to the fact that in very exposed works the curved portions entailed the greatest difficulties in the maintenance (it was partly, perhaps, on this account that the breach had been first formed in the curved portion). Besides this, owing to its outline, the old pier tended to direct the swell towards the entrance under more unfavourable conditions than was the case with the new one; this latter, however, would appear calculated to cause a greater amount of surf. There could apparently be no question of any important modification of the situation of the entrance, and while the sea might be rather more rough at the outside, there would be a greater degree of calm within, since the entrance had been narrowed from 1,500 feet to about 1,300 feet. It might be observed that the section of the new pier presented many analogies in its

Mr. Voisin.

general features to the piers enclosing the Admiralty harbour at Dover. It would be interesting to learn what precautions had been taken to guard against the effects of expansion and contraction in the work. Experience tended to prove that piers became slightly fissured on this account alone, and not in consequence of any defects in the foundation. Such cracks might be found at distances of not less than 100 metres (328 feet) apart. The new lighthouse was very similar in character to those in use in France, notably at the Cape of Alpreck, Boulogne, and the fog-signal differed only in a few details, and in the character of the sounds emitted, from that in operation at the end of the south-east jetty at Boulogne. With respect to the organization of the yards, on a former occasion he had observed that English practice in these matters was on a more liberal scale than that in France, and on this account there was greater safety and rapidity in operation. It was a question for consideration on which side the advantage rested from the financial point of view. It was impossible here to judge of this, since the Author gave no figures as to the prices and the cost of the work; probably he could supply these in his reply. The general arrangement of the yards coincided in many particulars with the necessarily much larger operations at Dover, and was of great interest. The results observed with respect to the lime mortars employed at the outset were by no means surprising, and it was even remarkable that decomposition had taken place at so slow a rate. Moreover, if in accordance with continental practice, mortars of this kind had been used only in the erection of masonry carefully faced, and not for the formation of an internal core in concrete, the evils resulting from their decomposition would have been reduced to a minimum. The new pier was constructed with blocks of concrete cast on land, which was no doubt better than the employment of large masses of concrete in situ. It was difficult in this latter case to avoid the partial washing out of the cement. As the composition of the blocks was stated to be 1 part of cement to 6 parts of Tyne ballast, it was not possible to ascertain precisely what their relative worth might be. This proportion might represent either too rich or too poor an admixture of cement, according to the relative proportions of the sand and gravel constituting the ballast; could the Author give these proportions? The steps taken to ascertain the quality of the cement were very wise, notably in the matter of aeration. Not much importance could be attached to the tests of specific gravity, as the latter varied greatly in accordance with the duration of exposure to the atmosphere and the degree of hydration of the cement. In conclusion, while congratulating the Author on his interesting communication, Mr.

Mr. Voisin. Voisin considered that information on the following points would be useful:—The nature of the steps taken to guard against fissures due to expansion and contraction; the amplitude of the swell at the entrance to the port; the cost per lineal foot or metre of the various sections of work employed; and the exact composition of the Tyne ballast used in mixing the concrete for the blocks.

Mr. Walmisley. Mr. A. T. WALMISLEY considered that whatever influence the existence of the piers might have upon the situation of Tynemouth, it was clear that they had an influence upon the river higher up and assisted the scour of the estuary, thereby forming a better channel for the discharge of flood-waters. He favoured the construction here adopted, by means of overhead gantries and goliath cranes, as it facilitated the connection of the underwater measurements with open-air measurements upon the upper platform and rendered the setting out of the work both reliable and accessible. With regard to the Appendix to the Paper, the Author emphasized the necessity of creosoting or otherwise preserving the softer classes of wood used in sea-works. As a rule the destructive action of the worm appeared to be most active, in his experience, just above the level of low water. At Dover some creosoted Oregon-pine piles, 7 years after fixing, had been reported by the diver to be in good condition from low-water level down to the mud surface (that was to say, the surface of the timber appeared hard when tried with a sharp-pointed pricker), while walings and struts at a low level but exposed at low tides had their surfaces invaded to an average depth of $\frac{1}{2}$ inch, and the ends of the struts against the masonry of the pier were entirely attacked. He had also had some pitch-pine struts and filling-pieces, in a landing-stage, exposed to rough weather, which were coated with raw tar only when fixed, and not creosoted, and had found after 7 years that the filling-pieces at the foot were eaten away $\frac{3}{4}$ inch to 1 inch deep and the main struts only $\frac{1}{2}$ inch deep. The worm did not appear to attack this timber more than 5 to 6 feet above low-water level, and at Dover there was a rise and fall of water at ordinary spring-tides of 18 feet 9 inches. As was well known, the worm followed the grain, and after entering soft timber it generally increased the diameter of the cavity to $\frac{1}{4}$ inch or $\frac{3}{8}$ inch, leaving the interior honeycombed or lined with a coating of white shell. The small irregular grooves on the surface also showed that the worm followed the grain. As regarded hard woods—so essential for exposed positions where the shocks of rough water in severe weather tended to loosen the fastenings in soft wood—he found the worm had very little influence on blue-gum piles. In the case of blue gum it tried to enter at the angle or sharp edge of

Mr. Walmisley. the piles, and after a short journey very little below the surface it left again at this edge without penetrating the interior section. In the case of a greenheart pile 14 inches square, removed because accidentally broken after 20 years, he had found that the worm had attacked the surface all round the lower end, but above the mud, as this pile was not driven, and had reduced the surface by between $\frac{1}{4}$ inch and $\frac{3}{8}$ inch. This seemed just below low-water level, but the heart of the timber was not touched. Generally speaking, greenheart piles 14 inches square were dry and sound. The larger the section the sounder they usually were, and traces of the worm penetrating into the heart of this timber were seldom found. For fender-piles he had found Flemish elm successful. Rock elm tended to splinter when struck by a vessel, while the former broke across. The worm limited its action to the lower ends, not only on the surface but also through the centre of the timber. At Dover faggot fenders had been suspended to protect the elm fenders. They sustained the crushing which would otherwise graze the surface of the elm fenders.

The Author. The AUTHOR, in reply, wished first to express his thanks to those who had been so good as to offer their criticisms. Mr. Bell referred to people wading across the bar between South Shields and Tynemouth. So far as the Author's information went, this feat had been performed on a single occasion, when the tide was exceptionally low, and even then by one individual only, who, besides being very tall, was an experienced swimmer, and had thus no fear of the consequences of being carried off his feet. The proposal to mould a lifting-shackle in each block would appear open to several objections, notably, that there would be no means of varying the position of the point of suspension; a slight adjustment in this sense had frequently had to be made when setting heavy blocks on the Tyne, particularly when these were of the irregular shapes necessary in the head. The contours marked on the plan referred to the year 1908, and the Author had no reason to think that the works described had had any appreciable effect upon the depth in the fairway. In reply to Mr. Box, no observations of currents had been made which would lead to the conclusion that any material alteration in these had resulted from the new works. The large bank of limestone now lying beneath the Castle Cliff had doubtless been washed from the toeing of the original structure. Owing to the extreme exposure of the site and the presence of such large quantities of sand the Author would be inclined to doubt the practicability of Mr. Carey's proposal to adopt sheet-piling as shown on the sketch, and he could under no circumstances admit that such

The Author. system was "obviously" less costly than that adopted. As regarded tests for Portland cement the Author could not suggest a substitute for taking the specific gravity, but his opinion being that the test was incapable of being carried out with such accuracy as to make it of the slightest value—an opinion which had not been contested throughout the whole discussion—he would prefer to abandon the test altogether. Mr. Larminie's suggested alteration of the line of the work might, from the point of view of cheapness in execution, have good points, but such an alteration could only result in affecting prejudicially the reduction coefficient of the harbour and thus increasing the range up the river. Again, any such modification would entail a risk of producing undue scour in some places and silting in others, all of which had been avoided, possibly in some measure fortuitously, in the old alignment. The Author could not agree with Mr. Larminie's view that a saving would have resulted from the adoption of an over-end machine in lieu of staging; indeed, he was strongly of opinion that any such substitution could only have added to the cost of the work, and more especially to the time required for its completion. Dr. Owens was undoubtedly right in saying that the task of fixing the number of revolutions of the mixer necessary to produce a satisfactory concrete was by no means an easy one, but the Author would point out that a few additional revolutions involved the expenditure of but little time or power, and thus the cost of being on the safe side was small indeed. The test for uniformity of mixing proposed by Dr. Owens was extremely interesting, and the Author hoped in the future to experiment in the same direction. As regarded Mr. Saner's question, the re-entrant angle between the old and the new work had been filled up as described on p. 155, and protection to the footings on the harbour side of the work landward of the cylinders had been provided by depositing there some of the larger material derived from the demolition. In the Appendix the Author had avoided mentioning the name of the writer from whose work he quoted an inaccurate passage, and he regretted that Mr. Shield should have replied in the sense he had done. Mr. Shield corrected two of the errors in that passage when he admitted that the teredo was not a worm and that it had no head; and as for the third, the Author had consulted personally the leading marine biologists in this country, including those attached to the British Museum, and as they all agreed that two black teeth formed no part of the equipment of the teredo, he regretted his inability to alter his criticisms. He did not doubt that Mr. Shield had come across animals (not molluscs) answering to the description quoted, but in his opinion they were not teredo.

The Author.

In reply to Mr. Tait, the Author was not aware that before the original piers were built any suggestion of founding upon the shale was discussed, and unfortunately he had no information as to the amount, if any, actually subscribed by the Admiralty or granted as a result of the recommendation of the Royal Commission on Harbours of Refuge, towards the expense of carrying out the Tyne works. While admitting the correctness of Mr. Voisin's statement that, the cement remaining the same, the quality of concrete varied with the proportion of sand to gravel in the ballast, the Author would like to point out that in most river ballast—and certainly in that from the Tyne—all sizes of particle were found, from fine sand through every gradation up to stones 2 or 3 lbs. in weight, and it would in consequence be exceedingly difficult to differentiate between "sand" on the one hand and "gravel" on the other. He ventured to think, also, that in this particular case homogeneity of concrete could be secured by adequate inspection alone, and this without the additional cost which the grading of the ballast would have involved. As a proof of this he might add that on several occasions the side of a mould moved while the mould was being filled, thus necessitating subsequent dressing of the block in order to bring it back into shape. The block under such circumstances was dressed when ready for stacking, and in numerous cases the pebbles broke across rather than leave the matrix, although the concrete was only 7 days old. The Author thoroughly realized the danger of honeycombed concrete, and he thought it would be impossible to find any in the whole of the new work. Unfortunately the section of the pier varied so frequently that the cost per lineal foot which Mr. Voisin asked for could not be ascertained with accuracy, and the Author feared to include anything which might lead to error. With regard to Mr. Beard's question concerning the efficiency and nature of the composition used to prevent the concrete from adhering to the sides of the moulds, the efficiency was undoubted, but all the Author knew of the composition was that it was an emulsion: it was sold as "concrete oil," and from its comparatively low cost he would suggest that its constituents were of the nature of by-products.