Correspondence.

Mr. Binns Mr. ASA BINNS congratulated both the engineer and the contractor on the magnificent national work described in the Paper. It was interesting to note that the project was discussed for 5 years by three Royal Commissions; it was played with for 25 years during the construction of the old Admiralty Pier; it was practically forgotten for another 25 years, and it was not until the passage of the Naval Works Loan Act of 1895 that the matter was seriously taken up. The works were then designed in 2 years and carried to completion by the contractor in 12 years. The total cost of the works was little more than half that of the latest battleship, and the service rendered during the war was obviously of incalculable benefit. It was at least doubtful if the Port of London would have had free access through the Channel during the period of the war had it not been for the services rendered by Dover Harbour.

With regard to the design, it was noteworthy that, whereas the old Admiralty Pier was constructed of blocks weighing 7 or 8 tons, the new works had employed throughout blocks weighing about 40 tons. He regarded that as of great importance for the permanence of the works and the reduction of maintenance-costs. As to the execution of the works by the contractor, it was difficult to express adequately admiration for the masterly layout of the plant. The daring and enterprise shown in the adoption of staging and Goliath cranes, as compared with the alternative of building overend with Titan cranes, had probably made all the difference between a harbour finished and serviceable before the war and an unfinished work open to enemy attack. The contractor's plant and staging must have cost several hundred thousand pounds, and it would be interesting to know whether advances had been made to cover some portion of the value of that plant before the measured permanent work began to give some reasonable return on the outlay. There were obviously few contractors who could afford to sink such a large amount of capital in plant for which the return was to be spread over a period of about 10 years in the payment for the permanent work. The Author stated that usually 18 to 20 gallons of water were used per mixing for concrete mixers of 1 cubic yard capacity. Mr. Binns had found in practice over a long period a variation of as much as 33 per cent. in the quantity of water used, but the average with ballast concrete had worked out at ⅝ gallon of water per cubic foot of concrete, or 18 gallons of water per cubic yard. Concrete mixers were supposed to be regulated to give a uniform supply per mixing, but none of those in ordinary use accomplished that. He had suggested to makers that it was a point which required improvement. Workmen would invariably tend to use more water than was desirable, with a view to reduce the labour of trimming into position and ramming in the work. An excess of water was highly prejudicial to the quality of the concrete. The Author's note in Appendix II with regard to the mixing of two qualities of cement varying greatly in setting-time was of great interest. The initial and final setting-times of cement as determined by the tests prescribed in the British Standard specification were no doubt an indication of the initial setting-time of the concrete made with the cement. They were not, however, so far as he had been able to discover, an indication of the final setting or crystallization of the concrete, which had to take place before the shutters could be removed. That hardening of the concrete to enable shutters to be removed was of great importance to the contractor, and he had known a contractor to prefer slow-setting cement to medium-setting, because the former enabled him safely to remove the shutters after a shorter period than the latter. Mr. Binns had never been able to discover a reason for the provision of a medium-setting cement in the British Standard specification. He could only imagine that it arose from the British love of compromise, and personally he would be glad to see it abandoned, or absorbed within the limits of the slow-setting quality. **Mr. Binns**

Mr. G. WOULFE BRENAN thought further information on the following points would be interesting and useful. The staging consisted of groups of piles 100 feet long, which were driven into the sea bottom. Owing to the large scantling—up to 20 inches square—the driving of the piles must have been a matter of some difficulty, and he would be glad to find in the Author's reply a description of the method used and of the depth driven into the marl or clay before the chalk was reached; also if any further precautions were taken, such as blasting a hole in the chalk and wedging up the piles to secure them. The statement in Appendix II as to the mixing of quick- and slow-setting cements was interesting, as in the course of carrying out harbour-works old stock and fresh cement had frequently to be mixed together. It was not stated to what extent gypsum was actually used in the making of the concrete blocks. **Mr. Brenan.**

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Mr Dyce Cay. Mr. W. Dyce Cay considered that some beneficial improvements might be made in the general design. For instance, the Prince of Wales's Pier blocked the western entrance by standing in its centre only 1,500 feet from its mouth. The improvement he would suggest would be the extension of the Admiralty Pier by an additional 1,000 feet in a slightly trumpet-mouthed line. That would give vessels going into the Admiralty Harbour a flatter curve on which to swing round to starboard, and would reduce the wave-motion in the anchorage. With regard to the 650-foot entrance between the East Arm and the South Breakwater, there might be some reason for it connected with naval strategy of which he was ignorant, but, otherwise, he thought it disadvantageous, as it increased the silting and wave-motion inside. Those defects could be obviated, and fresh tidal water run through the harbour every tide, if the gap were built up solid to, say, 1 or 2 feet above half-tide level, over which the tidal flow would pass, as over a weir; when required, a bridge could be carried along the weir, connecting the works at the two ends. He did not think Dover suitable for a Royal dockyard. It would not be so easily protected as Portsmouth or Rosyth, and there was not sufficient level ground. It appeared, however, to have rendered great service in the recent war as, inter alia, a base for the Dover Patrol. Referring to the execution of the work, he did not consider the bag joggles workmanlike as described on p. 60. He believed those used below low water would never set hard unless taken out of the water and dried. That accounted in some degree for the effect of the collision of a large liner in November, 1907, mentioned on p. 65, when a length of 80 feet of the South Breakwater was moved 4 feet inwards and had to be taken down and rebuilt. He preferred the system he had used for the round head of the south breakwater at Aberdeen. He formed the joggle as part of the block, of the whole height of it, and semicircular in horizontal cross section, and a corresponding groove to receive it was cast in the adjoining block. Those end blocks, weighing, say, 25 tons each, were set by mason divers without difficulty, when lowered to them by Goliath cranes from the sea-staging. The current, of which he had personal experience, was about 1 knot per hour. He did not think the rail cramps referred to in the "General Description of Works" would be tightly held when plunged below water-level in a bath of 2-to-1 cement mortar, which would not set hard. The system of block building used at Dover would not be so suitable in ports exposed to ocean seas and greater depths of water, not being sufficiently massive.

Sir Whately Eliot.

Sir WHATELY ELIOT remarked that it was evident that the project for a harbour at Dover was one which had received attention for centuries, but, with the exception of the Admiralty Pier, had not been put into execution until recently. After about 500 years of consideration, and with the experience that had been gained in the construction of harbour-works generally, it would naturally be expected that something approaching perfection both in design and construction would be obtained. He thought such an expectation had in a great measure been fulfilled in the work now completed. He had no hesitation in expressing that opinion, as he had spent many of the best years of his life in the construction of piers and breakwaters in exposed positions, and could therefore realize the difficulties to be met with and overcome in carrying out such works. He had been afforded opportunities of visiting the Dover works during their construction, and had been much impressed with the solid and substantial nature of the permanent work, and also with the excellent arrangements and machinery employed in carrying out the work. He would specially allude to the staging, which was such a great improvement upon what was generally met with in connection with sea-works. Staging in exposed position had always been a source of anxiety, being liable to damage. In late years, in many cases where circumstances permitted, staging had been abandoned in favour of long-armed Titan cranes, working and setting blocks from the end of the completed portion of the breakwater under construction. In the case of Dover, where time was of importance, to expedite the work staging was adopted of a type which had evidently proved very successful, judging by the small amount of damage sustained and the rapidity with which the block-setting had been carried out. The staging also made it possible to use diving-bells for preparing the foundations in advance of the block-setting. He could remember a similar method of preparing foundations by means of diving-bells in the construction of the Tyne piers on which he had been engaged about 50 years ago; the bells were smaller than those used at Dover and the staging and travellers were of a lighter description. He could quite endorse what the Author said with regard to the value of the time and care spent in setting the foundation courses. The operation of setting the blocks and the other details of the work had been so carefully described in the Paper that it was quite easy to follow the whole process of construction. The protecting apron of concrete blocks along the sea-face of the works was a very necessary provision. He had seen much damage caused by the neglect of that precaution, for the downward scour from the impact of a wave against a vertical wall was most destructive. He

Sir Whately Eliot. noticed that Messent mixers were used for the concrete. He thought it would be hard to beat those mixers, both as to the quality and quantity of their output. The working of the concrete-mixing plant by electric power showed great enterprise and deserved the success which evidently was attained. It was interesting to find that the circulation of the tidal water within the area of the harbour proved generally satisfactory and fulfilled the anticipated result of the positions of the entrance, and that the amount of silting was not more than had been expected. The Paper formed a most useful and interesting record of the construction of a magnificent naval harbour —a truly national work.

Mr. Hindmarsh. Mr. R. F. Hindmarsh asked the Author to describe the method of taking current-observations at a depth of 15 feet below the surface; also to state whether any cracks had developed in any of the Dover breakwaters, and, if so, the method, if any, of dealing with them. The apron blocks were only 3 feet 6 inches in depth and, as 40-ton blocks 6 feet in depth had been disturbed at a depth of 20 to 25 feet below low water at the Tyne breakwaters, it would be interesting to know whether any disturbance of the apron blocks at Dover had occurred. With regard to the granite facing on the breakwaters, it was stated that the facing blocks on either side were of granite, from the top to a depth of 3 feet below low water of ordinary spring-tides. In view of the fact that recent similar breakwaters had been completely faced on both sides with granite blocks, perhaps the Author would state whether he considered that to be necessary, and whether any abrasion of the unfaced blocks in the Dover breakwaters had taken place since their construction. With regard to the surface of the promenade on the Admiralty Pier Extension, which was finished with Seyssel asphalt, that had been in use on the promenade of the North Pier, Tynemouth, for over 10 years, but owing to repeated damage by heavy seas and the heavy cost of consequent repairs, the Tyne Commissioners had recently decided not to repair the surface but to replace it when damaged by concrete paving, which it was thought would be more satisfactory. It would be of interest to know whether any difficulty had been experienced at Dover in maintaining the asphalt paving. Referring to the timber fendering on the harbour side of the East Arm at Dover, a considerable amount of fendering was fixed, during the war and at the request of the Admiralty, to certain masonry quay-walls on the Tyne. The Admiralty were recommended to fix a system of vertical and horizontal fenders, but would only agree to vertical without horizontal timbers. Experience had shown, however, that the vertical and horizontal system of fendering would have been much more satisfactory, although, of course, considerably more expensive in the first place. Would the Author say whether it was found necessary to embody in the concrete blocks timber bearing-pieces for the heads of the T-headed lewis-bars to rest upon when lifting the blocks ? Mr. Hindmarsh.

Mr. J. C. LARMINIE considered Mr. Wilson's Paper a model of terse perspicuity. He would like to know, however, why, in that particular instance, the ordinary form of *pierres perdues* foundations was rejected in favour of the more elaborate and perfectly designed staging. Possibly a staging would in any case have been essential to permit of so many Goliaths working at the same time, and it might have been considered easier and more economical to fix the staging piles in the chalky sea-bed than in a mass of *pierres perdues*. Again, in regard to the extension of the Admiralty Pier, Fig. 1, Plate 1, was to so small a scale that it appeared that where the new work joined or started from the old turret head, the line of the new wall was almost a tangent to the curve of the turret. In any case, no bond or connection of any kind appeared to have been formed between the new and the old work. Also it was stated that further shoreward the space between the new retaining-wall and the old pier was filled with chalk. The starting of the East Breakwater, being from the shore, was comparatively a simple operation, but that of the South Breakwater could have been by no means so easy. Presumably the staging had been continued right across the 740-foot opening contemplated for the eastern entrance. The adjustment of the width of that opening and of the southern entrance, judged in the light of circulation through the harbour, appeared to have been very successful. However, with a strong flood-tide running, the approach to the southern entrance must be difficult, as the Admiralty Pier Extension, acting like a groyne, would be certain to cause a strong impinging sweep along the face of the South Breakwater. Would this account for the intentional swinging of the incoming boat from Calais and her entering the harbour stern foremost, as happened when he last crossed ? It would appear that the curve of the South Breakwater, being formed in 60-foot straight sections, necessitated the ends of each section being formed radially. It would be interesting to learn whether the formation of the harbour had caused any shoaling or erosion along the sea face of the East Breakwater or Admiralty Pier, such as frequently followed the construction of works of the kind. With an ebb-tide running it looked as though two opposing swirls might be set up in the harbour, unless the flow through the eastern entrance was great enough to overpower that through the south entrance, Mr. Larminie.

Mr. Mitchell. Mr. JAMES MITCHELL considered that the works described reflected great credit both on the engineers and on the contractors. The general plan of the harbour appeared to be admirably adapted to its purpose, while the massive sections of the breakwaters, the great weight of the blocks, the system of dowelling, the depth of the foundations below the sea-bed, and the apron of concrete blocks, seemed to ensure the stability and endurance of the works, even in their very exposed position. The extraordinary rate of construction was a tribute to the wisdom of the contractors in providing sea-staging and machinery on such an ample scale, to the excellence of their organization, and to their unremitting effort. The change from sailing to self-propelled vessels had, of course, modified the bearing of the question of the advisability of having more than one entrance to a harbour. There could be little doubt that, apart from the feasibility—even for a self-propelled vessel—of taking one entrance rather than another, in certain states of the sea or the tide, the question of the effect of currents inside the harbour upon the movement of silt was one of very great importance and complexity. Although swell inside a harbour was a great drawback, it was well to keep in view the fact that it had the advantage of disturbing silt which the currents otherwise would be unable to move. Anyone who had watched from a pier-head the passage of a vessel into harbour, while a strong current was running past the entrance, must have been struck by the coolness and judgment involved in the sudden and drastic changes of helm necessary to avoid disaster as the bow of the vessel passed out of the current while the stern was still under its influence, the danger being accentuated in a heavy sea when the direction of travel of the waves happened to coincide with that of the current. Both the width and lie of a harbour-entrance involved many factors, the resulting design being necessarily a compromise, chiefly affected by the necessity for providing sufficient sea-room for vessels entering or leaving the harbour, while at the same time producing still water inside for the convenient handling of vessels. The advantage of being able to turn a vessel while entering a harbour, so as to avoid crossing the direction of travel of a current or wave at right angles and without having virtually to narrow the entrance by passing through it obliquely, was very great. The lie of the western and more exposed entrance of Dover Harbour, although dominated by the position of the Commercial Harbour, seemed to be very well adapted to meet the circumstances referred to—circumstances which, in tidal seas, were inseparable from an entrance necessarily situated so far seawards and so far beyond the general coastline. The use at Dover of sea-staging (permitting the simultaneous working of several cranes), rather than of a single Titan crane, was interesting. The use of the "single Titan" method of construction had no doubt been largely influenced by serious losses due to the damage of sea-stagings, but the chief deciding question was undoubtedly that of the amount of preparation required by the breakwater foundations, the general rate of progress of the finished structure being governed by the rate at which those could be completed. Where the amount of preparation required was considerable, there was a strong case for the use of staging, which permitted various portions of the structure to be proceeded with simultaneously. The great strength of some of the sea-stagings built in recent years, as compared with those employed on some of the older breakwaters, was very remarkable. The information as to the relative fields occupied in the works by helmet divers and diving-bell men was interesting, and, in the strong currents met with at Dover, the large and heavy diving-bells employed must have greatly facilitated the work of levelling the foundations. Mr. Mitchell.

Sir Francis Spring.

Sir FRANCIS SPRING, K.C.I.E., remarked that, as an engineer who for the last 15 years had been in administrative and executive control of work of a character similar to that described, he wished to express his appreciation of the Paper and of the valuable experience embodied in it. He had pleasant recollections of a fine summer day spent at the Dover works with Mr. A. G. Vaughan-Lee in or about the year 1906. Also during the last 10 or 12 years he had heard a good deal about them, and doubtless also was indebted to them for many useful details, because of his association with Mr. H. H. G. Mitchell, M. Inst. C.E., his successor at Madras, who at one time was a young assistant engineer on some part of the Dover Works. As members acquainted with Sir Francis Spring's own Paper[1] would be aware, the structure of the Dover breakwaters differed from that of the Madras structure in three main respects : first, in its having been built in horizontal layers instead of in forward sloping slice-work with a 1 in 4 batter ; secondly, in its being founded on, or slightly in, the hard channel flint and chalk sea-bed, instead of on a carpet of rubble stone 180 feet wide and 15 feet thick ; and thirdly, in the absence from the Dover breakwater of the mass of pell-mell 30-ton blocks forming a seaward protection at Madras. Of those three main differences the first was, of course, due directly to the second, and all three to the absence, in the case of the sea-bed at Madras, of any kind of hard stratum such as had been found at Dover. In the method of construction, also, the two works differed

[1] Minutes of Proceedings Inst. C.E., vol. cxc, p. 89.

Sir Francis Spring. essentially, for though Messrs. Pearson's block-setting plant was suitable enough, in spite of its great cost, for the 9,000 linear feet and more that had to be built at Dover, it would have been very extravagant to have used it for Madras, where, in all, only about 2,650 linear feet of blockwork required to be built. As noted in the Paper above referred to, a single Titan crane used at the scar end of the Madras structure sufficed to secure an average progress of 575 linear feet per annum, of which 114 feet was done in 1 month —or at the average rate, in a year, if only monsoon conditions did not prevent its continuance, of 1,368 feet forward. Sir Francis had never used a diving-bell, but had, on one occasion, been greatly interested in finding a derelict bell, to the best of his recollection about 15 feet by 6 feet, and 6 feet high, with its glass windows still in place, at Paumben, between India and Ceylon, where presumably it had been used many years before for the excavation of a small channel in the shallow bar between the mainland and Rameswaram Island, since spanned by a Scherzer lift-bridge, for the passage of small coasting craft.

The joggles described in Mr. Wilson's Paper were all right, passing as they did only half-way down each horizontal block where used. But at Madras five joggle-grooves, or "chimneys," passed right through from top to bottom between successive "slices," a height of 40 feet. The five chimneys were supposed to be filled with bags of wet concrete rammed down from the top by a long and heavy rammer. But an engineer, or a foreman, could not invariably be present when a chimney had to be filled, and a bag might stick and refuse to go down, and there had since seemed reason to believe that if a bag did not yield to the rammer it might sometimes have been left where it stuck, and the rest of the chimney might have been filled to the top without chance of discovery of the omission. Later, when certain horizontal blockwork came to be done—as described in a later Paper[1]—Sir Francis insisted on the joggles of each course being filled, as was done at Dover, before the next course of blocks was laid. As to the granite-faced blocks used at Dover, he had made many such blocks in Madras for use at places liable to exceptionally rough treatment. Incidentally it might be mentioned that the granite walls, one or two per block, saved quite an appreciable amount of timber for moulds, a consideration in days of dear timber. Granite being the only species of stone available in Madras no question of its cost for such a purpose as block-facing would arise. His experience was that the adhesion

[1] Minutes of Proceedings Inst. C.E., vol. ccx.

Sir Francis Spring.

of the granite facing to the concrete at the back of it was faultless. Of course, projecting into the concrete filling, a due proportion of long header stones had been used. He considered the Author was to be envied in being able to secure greenheart for fenders. At Madras jarrah had to be used for that purpose, but near the water-line the life of this timber was short, perhaps 8 or 10 years, so full of timber-eating seaworms were the tropical waters. The life of iron or steel straps, bolts and nuts for holding fenders in place was not much longer than that of the timber, because of corrosion; and it remained to discover a means of holding in place timber fenders in the tropics, so as to allow of the easy removal and replacement not only of the timber but of its fastenings. On p. 56 the Author referred to the scarfing of the staging-piles. His own experience had been that the best method of scarfing heavy timber for vertical loads was to square up the two ends to be joined, butt them together, but not half-check them, and then to strap them with four old rails laid flat on the four sides of the timber, with bolts going through from rail-web to rail-web. Only half rails were required for such strappings, and the join appeared to be stronger than the pile itself.

A very important question was the effect of the two open entrances on the surface roughness of the sea within the enclosed 600 acres. His experience of the smaller Madras 200-acre area was that so long as only 20 feet of the old, now closed, harbour-entrance remained unclosed, they did not get rid of a certain troublesome wave which had run along the inside of the breakwater ever since the harbour was built. The closing of the final few feet of the opening had the effect of causing the wave to cease immediately. But even with only a single entrance, and that protected by a sheltering arm, there were two wave troubles: one, the formation of wind waves, possibly 2 or 3 feet from trough to crest, such as were inevitable in any unsheltered reservoir of water of a like area, and secondly, a certain "range" which caused movement in vessels lying at the quays during a few days in a year. Of those two wave troubles the first might be observed in any of the thousands of artificial irrigation reservoirs, locally called "tanks," scattered throughout the Madras Presidency, many of them hundreds of acres in extent. The earthen embankments forming the down-stream side of such tanks must practically always be pitched with stone to prevent erosion by the wind waves. Waves of that character, though undoubtedly troublesome, were not found in Madras to interfere with the transfer of cargo between ship's side and quays or lighters, or to cause vessels of ordinary sea-going size to roll

Sir Francis Spring. unduly. The other kind of water movement, usually called "range," had little or no effect on vessels at anchor, but undoubtedly at Madras gave trouble to vessels at quays, by causing them to bring what might prove to be a breaking stress on their own lines and on the Port Authority's springs. That range was found to be specially troublesome within the 11-acre boat-basin which had an entrance only 80 feet wide, nearly a mile from the single harbour-entrance. In that basin all small craft congregated when bad-weather signals were hoisted, from the Port's own 1,000-ton vessels downwards; and sometimes there had been a good deal of anxiety, particularly at night time when the crews of small craft were perhaps absent, because of the surging due to the range referred to. Therefore, though unfamiliar with the tides and waves of the Straits of Dover, he could understand that quite troublesome seas might be generated within the 600-acre area through the 650- and 740-foot entrances, in view of troubles of a like nature, though of less magnitude perhaps, arising out of the single 400-foot entrance of the 200-acre harbour.

As regarded the question of circulation of the enclosed waters, his experience had been that in this respect the second entrance might have advantages. For, in the smaller harbour, and especially in the boat-basin, there was a distinct lack of circulation with a 3-foot tide. He would not, however, for the sake of better circulation alone, willingly put up with the disadvantages, in the form of wave troubles, due to a second entrance.

It was not, of course, to be expected that the writer of a Paper on a work carried out, under his professional supervision, not "departmentally" but through the medium of a firm of contractors, should be in a position to offer any very detailed figures of costs. That such must necessarily be the case had already been recognized more than once by Sir Francis Spring in Papers read before the Institution. The great contractor had not gained much footing in India. Indeed, during nearly 50 years of railway and marine work Sir Francis had not himself had the advantage of his intervention, but, like most Indian engineers, had carried out his work as if he himself were a contractor's agent in close touch with the hire of labour and the purchase of material. Each method of working had its advantages and disadvantages, and one of the advantages of the Indian "departmental" system was that the writer of a works Paper could usually offer to the profession, as well as to future estimators of the cost of similar work, figures of cost in gross and in detail, such as, in the other class of work, were known only to—or at least might only be revealed by—the contractor. The excellent Indian system of accounts and of State audit made it easy, for any engineer willing to take advantage of it, to offer to the profession unit costs of work which could not but be valuable to others engaged in work of a similar character, after due allowance for differences of conditions. A search through Mr. Wilson's Paper revealed the fact that, beyond the mention, near the end, of a total expenditure of £3,500,000—which might or might not have run to £390 per linear foot of finished breakwater—no mention was made of any costs at all. But regrettable as such omission might be, it must doubtless be recognized as inevitable under the circumstances of an otherwise most interesting Paper. Sir Francis Spring.

The AUTHOR, in reply, desired to express his thanks to the various correspondents who had so courteously forwarded remarks upon the Paper. He agreed with Mr. Asa Binns as to the advantage of heavy blocks, inasmuch as they not only ensured greater stability to the work, but also, in connection with suitable plant for handling them, conduced to rapidity of construction. No advance was made to the contractors in respect of plant generally, though some allowance was made on account of the large quantity of timber delivered for the purpose of staging and other matters. He entirely endorsed Mr. Binns's opinion with regard to the excellence of the contractors' plant, and in particular with regard to the staging, which, he believed, was one of the heaviest temporary stagings ever erected. With regard to the quantity of water used in mixing concrete, that varied considerably with the nature of the material and the weather conditions, the 18 to 20 gallons mentioned in the Paper being a general average throughout the work. The Author was also inclined to agree with Mr. Binns's suggestion that the provision of a medium-setting cement in the British Standard specification might possibly be dispensed with without material disadvantage. The stage-piles were all driven by an ordinary free-falling monkey, operated by a Lidgerwood winch, and the penetration averaged, say, 12 to 15 feet into the sea-bed. At the inner end of the East Arm, where the piles were driven into the bare chalk, the penetration was not quite so much. No gypsum was added to the cement after manufacture. With regard to Mr. Dyce Cay's remarks as to the disadvantage of the eastern entrance on account of its encouraging silting and wave-motion, the Author was quite satisfied that the effect of the entrance had been, as anticipated, in the opposite direction—that was to say, it had encouraged circulation in the harbour, which had undoubtedly reduced the silting. Any wave-motion in the harbour would also tend to reduce silting. Mr. Cay's object in building a sort of weir The Author.

The Author. across the entrance was not clear. As to the suitability of Dover for a dockyard, it had never been the intention to use it for such a purpose. The bag joggles had proved in every way satisfactory, and in many cases where, for one reason or another, any had had to be removed, they were found to have set perfectly hard. The movement of a large portion of the head of the South Breakwater *en bloc* when struck by the steamer, appeared to the Author to be convincing proof of the excellence and value of the joggling. The Author failed to see how Mr. Cay could find evidence of the inefficiency of the joggling in that movement. Mr. Cay affirmed that the system of block building used at Dover would not be sufficiently massive to resist ocean seas. It might be pointed out that at Peterhead an exactly similar system of construction had been used with complete success, the work being exposed to some of the heaviest seas known. Sir Whately Eliot's remarks were very interesting, especially coming from one who had had such wide experience in heavy sea-work. With regard to his remarks on the use of Messent mixers, the actual mixing of the concrete by them was exceedingly efficient and satisfactory, but in the Author's opinion the more recent type of mixer, where the materials could be inserted through the trunnion without stopping the rotation of the mixer, had an advantage over the type where the machine had to be stopped for recharging each time. Mr. Hindmarsh asked how the current-observations at a depth of 15 feet below the surface were taken. The arrangement was a very simple one. A triangular vane, weighted so as to hang vertically, was attached by a line 15 feet long to the bottom of a float. So far as the Author was aware only one crack, obviously due to settlement, had occurred in the Admiralty Pier Extension, but that was only of slight extent and did not exceed about $\frac{1}{4}$ inch or $\frac{1}{2}$ inch in width. The usual slight contraction cracks, of course, occurred at intervals throughout the various works. No apron blocks had been disturbed by the sea. In the Author's opinion there would have been no advantage in facing the blocks below low water with granite. No trouble had been experienced with the Seyssel asphalt promenade. When inspected recently it was in perfect condition, and had required no maintenance. With regard to the fendering, the horizontal members were of great assistance in staying the vertical members, and were certainly to be recommended. In all cases timber bearing-blocks were put into the concrete blocks for the T-headed lewis bars to rest upon when lifting.

The question of using *pierres perdues* foundations was considered, but it was found that the depth at which the top of such a mound should be placed so as to secure it against disturbance by wave-action approximated so nearly to the natural sea-bed level that there would be no object in adopting that method of construction. The blockwork of the breakwaters was therefore carried down to sea-bed and the foundations were prepared in the manner described. In carrying out the extension of the Admiralty Pier, an efficient bond was arranged for between the new work and the old. The scale of the plan given in Fig. 1, Plate 1, was too small to show the detail. The staging of the East Breakwater was continued right across the opening to the South Breakwater, as described in the Paper. With regard to Mr. Larminie's remarks as to the mail-boats, it was a frequent practice to turn those boats round before entering the harbour, though it was not invariably done. In forming the straight sections of work around the curved portion of the South Breakwater, it was clear that the ends of each straight portion would be formed radially. So far as the Author was aware, neither shoaling nor erosion had taken place along the eastward face of the East Breakwater or the Admiralty Pier. As a general statement it might be said that during the ebb the tide entered the harbour by the eastern entrance and flowed out through the western entrance. The Author agreed with Mr. Mitchell that such disturbance as would inevitably take place in such a large harbour during gales, would have the effect of disturbing the silt and enabling it to be removed by the currents. There was no doubt that the large and heavy diving-bells employed had greatly facilitated the carrying-out of the work. The Author was much interested in Sir Francis Spring's remarks, especially in view of his experience at Madras. Although exposed to heavy seas, the weight of the seas at Dover would be small as compared with the heavy monsoon swells experienced at Madras, so that a special wave-breaker of pell-mell blocks on the seaward side of the work was not necessary. Sir Francis Spring was envious of the use of greenheart for fenders at Dover. It was not clear why they could not equally well be obtained at Madras. With regard to the method of scarfing staging-piles, at Dover the scarf consisted of a halved joint 4 feet long with two 1-inch fish-plates 8 feet long on either side of the pile, the whole being securely bolted together. This had proved thoroughly satisfactory. Sir Francis's remarks with regard to the wave disturbance at Madras were of great interest. In large harbours such disturbance could not be avoided, and there was no doubt that, as suggested by him, the eastern entrance had been of great advantage in the matter of circulation. Rectangular joggles filled with concrete bags, between the courses of the sloping bond, passing from top to bottom of the work, were adopted by the late

The Author.

The Author. Sir John Coode in connection with the South-West Breakw at Colombo, commenced about 35 years ago. The Author not aware of any special difficulties having been experiencec connection with that work. Sir Francis referred to a probable of the work at Dover as being £390 per linear foot. That figur had presumably obtained by taking the round figure of £3,500,(and dividing it by the length of work constructed. The total s however, included many other items besides the actual length breakwater and wall built, the cost of which would not ave nearly so much as the figure mentioned.

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25 November, 1919.

Sir JOHN PURSER GRIFFITH, M.A.I., President, in the Chair.

A lecture, entitled "Some Aspects of Metropolitan Road and I Transit," by Henry Herman Gordon, B.A., Assoc. M. Inst. C was delivered and discussed.

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2 December, 1919.

Sir JOHN PURSER GRIFFITH, M.A.I., President, in the Chair.

The Council reported that they had recently transferred to class of

Members.

THOMAS BOWYER BOWER.

And had admitted as

Students.

JOHN GEORGE ARTHUR.
IVON ARTHUR BAILEY.
DAVID ROSS BALFOUR.
ROBERT WALTON BALL.
ROBERT ARTHUR BLUMHARDT.
PHILIP LEA BOLTON.
LESLIE BOWN.
DAVID CHARLES BOWSER.
ALFRED LISTER BRIGGS.
EDWIN BUTLER.
GEORGE LESTER CARPENTER.
HORATIO JOHN COLLINS, *M.C.*
JAMES CRUIKSHANK.
CLEMENT HENRY CRUTTWELL.
WILLIAM GOULD DAVIES.
CECIL GORDON DAY.
ARNOLD FIELDER DOWNER.
JOSEPH EDGAR DUMBLETON.
GEOFFREY HENDER STUART EL
LOVELL STRANGE EATON ELLIS
ANSELM FITZPATRICK.
FRANK FOULGER.
HUGH COWAN FRASER, *M.C.*
IAN FRASER.
HAROLD COWASJEE GOOCH.
RICHARD HENRY HALL.
GEORGE BRIAN HERSEY.
NORMAN KENNETH HOLMES.
JOHN HUNTER.
HERBERT JOHN JACKSON.