Discussion.

The President. The PRESIDENT, in moving the vote of thanks, remarked that, as the three Papers dealt with harbour works situated in different parts of the globe, it was thought they would afford a useful opportunity for comparative observations. The Paper by Mr. Bristow dealt mainly with dredging operations, with special reference to pipe-line dredging, and contained a large amount of very useful statistical information. He had been much struck by the general remarks appearing towards the end of Mr. Williams's Paper on Lyttelton harbour, in which the Author emphasized the advisability of not using permanent material in works where an alteration was likely to be required in course of time owing to development or some other cause. The Author stated that a saving of about 33 per cent. had been effected by the use of timber instead of concrete, which would be sufficient, at the end of 25 years at compound interest, to provide for the entire reconstruction of the works. The Paper by Mr. Hindmarsh, describing a riverside quay served by railway and road, and fully equipped, was a very useful record of modern practice.

Mr. Palmer. Mr. FREDERICK PALMER, Past-President, congratulated Mr. Hindmarsh on the successful accomplishment of a rather difficult work. Those who had had experience of works of that nature, including what he might call the putting of new wine into old bottles, would know the risk of dealing with old structures and depending partly upon them for support of the new construction. Mr. Hindmarsh had discussed with him some of the proposals, but Mr. Palmer had really had very little to say, and nothing at all in the way of criticism, regarding them, because they had been so admirably adapted to bring about the desired end. The old quay-wall had settled very much soon after it was built 50 years ago, and it was, and always had been, in a state bordering upon instability; so much so, that it had been impossible to dredge deeper than 14 feet outside. Mr. Hindmarsh's problem had been to make a berth for vessels drawing 30 feet. He had done that excellently, thanks not only to his own ability, but, as he would be the first to acknowledge, also to the selection of a firm of contractors who had carried out the work extraordinarily well. Mr. Palmer had inspected the work on one or two occasions, and he had been very much impressed with the way in which it had been arranged and planned. A matter of detail

Mr. Palmer

was the difficulty experienced in the past in arriving at a definite loading of tie-rods. In the case described, however, it had been possible to get a definite tension ; the rods had been tightened in the ordinary way, and afterwards, with the aid of the extensometer as explained on p. 27, it had been possible to tighten them by the coupling shown in Figs. 3, Plate 2, so as to give a definite tension of 20 tons on each tie-rod. The wall was therefore held back by a definitely known force approximating to 500 tons.

He had been brought into contact with the Cochin scheme in 1924, when he was appointed by the Secretary of State for India as Chairman of the Committee which had to deal with the question whether the work should be carried out. That Committee met on several occasions and was extremely fortunate in having Mr. Bristow as a collaborator. It was very largely due to the complete confidence Mr. Bristow had had in the successful accomplishment of the dredging of the channel across the bar, and also in the possibility of maintaining it, that the Committee had been able to recommend the Government of Madras to proceed with the work. It was a bold conception to dredge a channel across a continuous bar running along the coast. The channel was about 3 miles long, but the results had more than justified the confidence which Mr. Bristow expressed. An extraordinary feature of the work was the extremely low cost of carrying it out. The cost of the second season's dredging in the open sea, where the work was interrupted for eight months every year by monsoon conditions, was 2*d.* per cubic yard on a quantity of 2¼ million cubic yards, in round figures. Mr. Bristow also gave figures for the record month (December, 1928) when the total quantity removed during the month was 1,355,000 cubic yards, and the cost £5,800, or about 1*d.* per cubic yard. That cost, of course, included only the small repairs carried out during the month. The total quantity dredged was practically 10 million cubic yards, and the cost was about £127,000, or 3·1*d.* per cubic yard. He could not recall any work of that magnitude that had been carried out at so low a rate. Further, it had been completed in an exceedingly short time. It would be interesting to know the total cost, including the administrative charges, interest, and depreciation. If one took the rate of interest as 5 per cent., and the depreciation as high as 15 per cent. per annum, the costs would still remain extraordinarily low. He felt that he must very heartily congratulate Mr. Bristow not only on his excellent Paper, but also on the more than excellent work he had achieved. The scheme had been under contemplation, as Mr. Bristow said, for nearly 70 years, and it was entirely due to his initiative, and to the confidence he had

Mr. Palmer. been able to instil into the Government, that at long last that great work had been carried out, and carried out in a manner which must commend itself to anyone who read the Paper.

Sir Cyril Kirkpatrick. Sir CYRIL KIRKPATRICK remarked that 20 years or so ago he had to deal with the Norwegian traffic on the Tyne, and he congratulated Mr. Hindmarsh on having succeeded in taking that traffic from the Newcastle Corporation quays to North Shields. The business was increasing, and larger ships were being used. It was possible now to give excellent facilities to passengers, whereby the train could go direct to the passenger-station alongside the quay, in contrast to the old days when the passengers had to go to the Central station, Newcastle, and make the journey to the Newcastle Corporation quay by cab; and that must have a considerable bearing on the future of that traffic. Mr. Hindmarsh had been very bold in taking the slice out by the dredger before driving the piling. Sir Cyril Kirkpatrick had seen the work shortly before it was finished, and he was pleased that it had been successfully completed by Mr. Hindmarsh, whose predecessor, the late Mr. James Walker, M. Inst. C.E., had been very nervous about the old river-wall at that site. The new work seemed to be substantial and well carried out. Undoubtedly it had been a difficult undertaking, and there were three different kinds of foundation structure. Was Mr. Hindmarsh in a position to give some idea of the cost of the work? It was perhaps not of much use to include the cost of the motor-road and the coal-hoist; but a figure for the cost per square foot of the various types of quay would be helpful. He would appreciate more information about the piling. A Paper[1] by Mr. H. A. Reed, M. Inst. C.E., was one of the most reliable and valuable records in the Proceedings of The Institution on the subject of piling; and it seemed that Mr. Hindmarsh might have data which would supplement that information. They should relate particularly to the load carried, more especially on the cruciform piles, the formula used, and the factor of safety adopted. Some driving diagrams would be very useful, and would yield further data concerning the correct formula for pile-driving. Had any difficulty been found in working with a grab in a column as small as 2 feet 9 inches in diameter?

Sir Leopold Savile. Sir LEOPOLD SAVILE remarked that in 1917 he was asked by Messrs. Sir John Wolfe Barry and Partners to go to Cochin to collect information on which a report could be based. He spent some time there with Mr. G. E. Browning, M. Inst. C.E., who was engineer to the Cochin State at the time, and he was given a great

[1] Minutes of Proceedings Inst. C.E., vol. 221 (1926), p. 67.

deal of information about various reports previously made on the harbour. After studying the various aspects of the problems on the site, he communicated the results to the late Mr. A. G. Lyster, Past-President Inst. C.E., a partner in the firm, who made a report based on that information. There were certain differences between the recommendations made then and the work actually carried out by Mr. Bristow. There had been two main problems. The first was the protection of the strip of land between the sea and the large lagoon, which at one or two places was only 50 or 60 yards wide. It was essential to maintain that strip of land, because the effect of any considerable improvement in the harbour and its entrance would be very largely destroyed if at any time the strip of land were seriously breached. The recommendation made by Mr. Lyster with regard to the protection of the foreshore, in view of the fact that the drift of the sand was northward practically for the whole length, was to put groynes out from the shore and connect them at their bases. Something of that nature, he gathered from the Paper, had been done, but although the sand had accumulated as expected with the northern current, when the monsoon came the waves were parallel to the coast, the sand between the groynes had been washed away, and the work had been largely destroyed. The arrangements which Mr. Bristow described for getting over that difficulty by building diagonal banks of stone were ingenious, and he did not remember having seen them carried out elsewhere. If they had really consolidated that portion of the coast, Mr. Bristow was to be congratulated on a valuable piece of work, which had made practicable the main part of the development of the harbour, namely the dredging. The whole problem of the dredging had been discussed for about 70 or 80 years; the question was not so much whether it was possible to dredge a channel through the bar, but how much such a channel would silt during the monsoon, and whether it would be possible to maintain it at a reasonable cost. With the development of larger dredgers, many of the difficulties foreseen in the early reports could be overcome. The line of the channel as adopted now was very largely that recommended by Mr. Lyster, the principal difference being that Mr. Lyster had recommended that the south side at least should be revetted, the object of the revetment being to reduce the volume of dredging required. It would be interesting to learn why that proposal had been dropped and the silting-shelves made. Those, he gathered, were not so much silting-banks as banks that collected on both sides of the channel material washed in from the south. Mr. Bristow's completion of the work, based on the findings of Mr. Palmer's Committee,

Sir Leopold Savile.

Sir Leopold Savile. was evidently a fine performance. The question that now remained was how much dredging would be required in order to maintain the channel. At any rate, the large suction dredger would have to be kept for use during and after the monsoon. Whether the port could afford the maintenance of a dredger of that size depended on the extent of the increase of trade. In the original report it was recommended that railway connections should be made, involving, he understood, the building of a viaduct across the harbour, and it would be of interest to know whether that part of the scheme had been abandoned. The existing jetties and piers were on the sea side of the backwater, and all cargo that came into or left the port had to be lightered between the mainland and the ships, whereas if the channel were extended across the backwater and wharfs were made on the mainland and connected with the railway system, cargo could be taken on board and landed direct, without the use of lighters. The dry dock made for the dredging craft seemed to be of a very expensive type for its size, and it might have been cheaper to have had a small floating dock.

Mr. Brims. Mr. C. W. BRIMS remarked that he was glad of the opportunity of thanking Mr. Palmer for his kind reference to the work of his firm on the Tyne Commission quay. There was not much that a contractor could say with regard to the work, beyond congratulating Mr. Hindmarsh on the way in which he had gone about it, when he found it necessary to make a very drastic alteration after the work had been begun. In a scheme representing roughly £250,000, when once the contractor had got his plant on the spot and had formed his plan of operations, it was a very serious thing to interfere with him. Mr. Hindmarsh might have adopted the attitude of insisting to the full on such rights as were found in the legal clauses of every specification. But he had done nothing of the sort; he had taken the contractors into his counsels, and they had been as interested as himself in arriving at a solution. The change had involved founding much deeper than originally intended for more than half the job, but the quay had been ready in time after all. Although the cruciform piles had entailed a good deal of thought and special plant, the contractors had been able to work in all the plant they had on the site. His thanks were also due to Mr. Hindmarsh for adopting the contractors' suggestion as to the method of construction, including travelling stagings working with an overhang on to the next row of piles. That was the only extra plant they had required. They had been able to complete the work, certainly at an increased cost, but at a lower cost than would have been involved had Mr. Palmer not been

consulted. He had blue-pencilled one item which Mr. Brims thought, though risky, a good one; but he was bound to confess now that Mr. Palmer was right. In the long run, thanks to the cordial co-operation of Mr. Hindmarsh, it had been possible to complete the work to the entire satisfaction of the Commissioners, while the contractors had obtained reflected glory in the shape of $3\frac{1}{2}$ months' bonus for finishing before their time. Mr. Brims.

Mr. G. E. W. CRUTTWELL remarked that he had been very gratified, on reading Mr. Bristow's Paper, to find that the direction of the entrance-channel suggested in his firm's report had proved to be about right, namely almost due west. He was gratified also to read the kind remarks in the Paper about the advice given in that report. Mr. Bristow was to be congratulated on having had this scheme adopted, as there had been very adverse reports stating that no such channel could be cut across a bar in an open sea, with the monsoon blocking it up each year. Mr. Bristow was one of the very few men in India who had believed in the scheme, and his arguments, as Mr. Palmer had stated, had convinced the Advisory Committee of which Mr. Cruttwell had had the honour to be a member. He agreed with Mr. Palmer about the very low cost of the dredging. He supposed that the administrative charges and the interest on the capital for the dredging plant would not amount to more than as much again as the prices given in the Paper. If that were so, the inclusive price would range from *2d.* to *7d.* per cubic yard—a very remarkable result for such a deep channel in so exposed a situation. He imagined that one reason why those costs were so low was the bonus system adopted. He doubted whether it would have been possible to get the men to work 20 hours out of the 24 without that bonus. In figures given in Papers presented to The Institution, the cost of dredging per ton was often given on the basis of barge measurement. All Mr. Bristow's quantities, on the other hand, were based on measurement in situ, which sometimes came only to half the barge measurement. On the average, the barge measurement would be 60 per cent. more than the in-situ measurement. Mr. Cruttwell

Mr. ASA BINNS observed that Mr. Williams's Paper on Lyttelton harbour gave an interesting account of a quarter of a century's work in harbour development. The cross section of the jetty (Fig. 4, Plate 1) showed that there was no cross bracing except the raking piles. Were they adequate to prevent undue oscillation of the jetty when a ship came alongside? He noticed also that Mr. Williams had adopted 5-ton cranes on the jetties. In the Port of London a very large proportion of the loads hoisted from ships' holds weighed less than 30 cwt., and he would have thought that a Mr. Binns.

Mr. Birns. 2-ton crane would have been sufficient, the heavier loads being raised with the assistance of the ship's derricks. A 5-ton crane was heavier and more expensive to maintain, and it was not so quick in handling, owing to its greater inertia. He was glad to see the paragraph to which the President had referred, on the wisdom or otherwise of building permanent works. The British tradition was all in favour of heavy, massive, expensive construction. He might take two illustrations from the experience of the Port of London. St. Katherine dock was constructed by Telford at a cost of more than £3,000,000 and opened just over 100 years ago. It was a magnificent dock, equipped with massive warehouses. As far as shipping was concerned, however, it had been obsolete for half a century. It had no railway access, and had it not been for the substantial character of the fabric, he thought that economic forces would long ago have resulted in some drastic improvement. But the very fact that it was so substantial resulted in its continued use. It still did very good work, but it could not possibly do it in the most economical way. Another instance was provided by the large sums spent during the war by the Port of London Authority in improving their cold-storage accommodation, which had been filled to overflowing during the war. But the improvement of transport in every direction since the war had resulted in a diminution of warehousing of every description, including cold storage. The result was that to-day the Port was able to accommodate all the goods requiring cold storage in the stores that had been available before the war. That was a case where possibly the short view and cheaper construction would have been wiser. He did not know whether it was due to the war and to succeeding financial stringency, but he was now asked to build more frequently for a life of 30 years than for an indefinite period.

With regard to Mr. Hindmarsh's Paper, he had been present on the opening day at the Tyne Commission quay, and he had greatly admired the accommodation provided. The electrically-operated pumps were so arranged that they started and stopped with some amount of shock at very frequent intervals. It appeared to him that that was not the best principle for electrically-operated pumps. It would be preferable to copy the old steam-pump, which crawled when there was a small demand and was capable of quick action when there was a large demand. Recently the Port of London had installed hydraulic pumps having a speed-variation from 30 per cent. of the maximum speed upwards. Oregon piles had been used for permanent work on the Tyne Commission quay. That was an innovation, and perhaps Mr. Hindmarsh would say why he had

adopted Oregon pine in that work. In the Port of London pitch-pine was still used for permanent piling. He had been assured recently that some of the railway-companies were experimenting with Oregon sleepers. If that was the case, it would be interesting to know the result of their experience. Mr. Binns.

With regard to Mr. Bristow's Paper, it appeared that Mr. Bristow had wrested success from failure by close attention to detail and by securing the co-operation of his staff. The plant was barely adequate to ensure success, and it was due to Mr. Bristow that it had been achieved. The use of " Ferrocrete " for the emergency repairs on the suction side of the sand-pump seemed to be a tribute to his versatility as well as to the material he had adopted for such an unusual purpose.

Mr. H. J. FEREDAY congratulated Mr. Williams on the good fight he had made at Lyttelton against very adverse circumstances, and on the measure of success he had attained by simple means. It looked as if the geological formation underlying that harbour would make it very difficult to increase the depth of dredging and at the same time stabilize the bed. Attempts to secure stability did not seem to have been successful up to now; he looked forward to further information, and hoped that some measure would be adopted that would accomplish what was needed. Mr. Williams had no faith in the foundations on clay, and on p. 14 he said that the history of the successive sinkings of the outer part of the mole showed that it was not safe to assume that a condition of stability had ever been reached in works standing on a deep clay bottom. That seemed rather contrary to the general opinion, because there were so many cases where bridge-piers and buildings had been founded on clay and had remained perfectly safe. He would like to take that opportunity of giving a concrete example of the bearing-pressure of clay. In 1923 Mr. Palmer and he tested the bed of clay under the river Hooghly at Calcutta—a bed which extended not only under the river but also under its banks, and probably under the whole of Calcutta. Cylinders 6 feet in diameter were sunk on each side by open dredging, on the Calcutta side down to 110 feet, and on the Howrah side to 90 feet below the river-banks. When those cylinders were sealed in the clay and the water was pumped out, Mr. Palmer and he went down to examine the clay and took sample cubes which were hermetically sealed in tin cases. The cylinders were concreted and loaded, and taking into account the skin-friction it was found that 16 tons per square foot on the Calcutta side and 12 tons per square foot on the Howrah side produced by the loads was borne without sinking movement. He had made a considerable number of tests with that clay during the last 6 years. Perfect Mr. Fereday.

Mr. Fereday. cubes of definite dimensions that had been kept in water for 2 years showed no effect except slight discoloration of the water, the edges of the cubes being as sharp as at the beginning of the test. Those cubes had then been slowly dried for a period of 6 months, and afterwards water had been allowed to soak slowly into them until they reverted to the original state, in which they were found in the river-bed. That had been done six times, and the material had always returned to the same density and the same shape. That was a very thorough test of clay. The colloids in that clay were very tenacious, and could hardly be washed away; in fact several washings from the clay showed no residue on evaporation. The colloidal quality of the clay was the determining factor in its stability. He had looked up many works on the subject, but they were more useful to the chemist and the soil-analyser than to the engineer; more tests and examinations of clay would be very useful.

Mr. Gueritte. Mr. T. J. GUERITTE observed that he had been closely associated with Mr. Hindmarsh in the matter of the design of the reinforced-concrete parts of the Tyne Commission quay. Although the quay was mainly of reinforced concrete, it had been decided to use steel sheet piles. Under the circumstances that had been a wise decision. At the time it had been felt that, as the old quay-wall at the back had sunk 2 feet 6 inches, it would be well to avoid undue vibration during piling. The life of steel sheet piling was uncertain, and, as mentioned in the Paper, the piles had been thoroughly cleaned and given two coats of bituminous solution. It would be interesting to learn how that treatment had stood the test of time, and whether there were any signs of corrosion. The concrete piles had been allowed to mature for 83 days before driving. That was a very long time, and possibly the piles had not been required earlier; for generally 4 weeks was enough for ordinary Portland cement, while, for special brands of cement, 10 days was quite common. A rather unusual mixture of concrete had been used, namely, Portland cement, sand, whinstone, and screened Tyne gravel. It was well known that the crushing-resistance of concrete made of whinstone exceeded that of concrete made of Tyne pebbles; but, when the two were mixed, a still stronger concrete was obtained. The improvement due to mixing round smooth river pebbles with whinstone had been demonstrated on the works at the new Berwick-on-Tweed bridge, a year or two before the construction of the Tyne quay. The whinstone in itself was rather too gritty, and the same probably applied to granite. The addition of round pebbles, so to speak, lubricated the mixture. The concrete not only became much stronger but also much less porous. It was mentioned in the Paper

that two kinds of sand were used, namely, coarse sand and fine sea sand. That mixture ensured a very non-porous concrete. A good deal of the trouble that had been experienced in earlier reinforced concrete had been due to the fact that crushed granite or crushed whinstone had been used because it was believed that it would be stronger on that account, while in fact the material did not last so well, because it was less impervious to sea-water. It was mentioned in the Paper that the lengthening of concrete piles had been found almost impossible, the joints always giving way. In his opinion that had been due not so much to the difficulty of lengthening the pile in itself, but to the fact that, owing to the circumstances of the case, the pile was standing unsupported in the middle of the river and was subject to vibration caused by the constant and fairly heavy river traffic. He thought it had been a very wise course under the circumstances to adopt rolled steel joists for the long piles. He was certain that under other conditions reinforced-concrete piles even 80 or 90 feet in length could have been driven well, but in the present case it had been better to run no risk and, in view of the plant available, to use the steel piles. The slight loosening of the riveting was to be expected, and it had to be taken into account in deciding upon the number of piles. The piles seemed to have had rather varied sets. One of them had a set of $2\frac{1}{2}$ inches for 30 blows and was loaded to 52 tons. He took it that the pile weighed about 8 tons, so that according to the normal formula it should have been able to carry 60 or 70 tons. A test-load of 50 tons was not much indication of the real bearing-capacity. A settlement of $\frac{1}{8}$ inch had taken place. Had the test been carried out before the concrete was placed round the pile? It might be that for a pile 84 feet long a settlement of $\frac{1}{8}$ inch was due to slight bending or even to the normal strain of the pile. Another pile had a set of only $6\frac{1}{2}$ inches for 30 blows, which indicated, according to the formula, a very low bearing-power. The new departure in the method of connecting the piling with the columns and bracings had solved fairly well the difficulty of minimizing concreting in situ near low-water level. Mr. Gueritte.

Mr. WILLIAMS, in reply, expressed his thanks for the kind reception accorded to his Paper. He appreciated the notice by the President and by Mr. Binns of his remarks on the advisability or otherwise of constructing in permanent materials. The only permanent construction in Lyttelton was the graving-dock, which had become obsolete owing to the increase in the size of vessels from overseas trading to the port. The bracing of the jetties had been done away with for the reasons given on p. 12, and the jetties Mr. Williams.

Mr. Williams. were less subject to oscillation now than formerly, when they were braced in the ordinary way, and no inconvenience was experienced from the bumping of ships. With regard to the choice of 5-ton cranes, it was well recognized that the majority of loads lifted were less than 30 cwt., and 2-ton cranes would therefore do most of the work; but, owing to the large span of the gantries, and the necessary heights and lengths of the jibs, the difference in cost between 2- and 5-ton cranes would not be very great, and the difference in speed of handling was negligible. The 5-ton cranes at Lyttelton had two speeds, a high speed for loads less than 2 tons, and a lower speed for loads exceeding 2 tons. Quite a number of lifts of more than 5 tons had been made by those cranes, sometimes by two cranes working together, as the shipowners preferred to use the wharf-cranes rather than fit up the ship's special heavy-lift derricks. The arguments for lighter cranes mentioned by Mr. Binns had been pressed on the Author by members of the Lyttelton Harbour Board, and in response to that pressure the 3-ton cranes had been installed on No. 7 jetty. But experience indicated that in weight, cost, and ease of handling the reduction in power was disappointing, and 5-ton cranes had been adopted as standard for the port. They were practically as handy as the less powerful ones, and were able to handle large grabs for discharging bulk cargoes. With regard to the instability of the harbour-bed due to the geological formation, referred to by Mr. Fereday, the axiom that saturated clay had no angle of repose applied to Lyttelton harbour, and whenever any substantial change was made in the conditions of comparative stability, by deeper dredging, or imposition of extra load on structures resting on the clay bed of the harbour, there would be movement in the process of readjustment of balance. But it was not expected that any such movement would be sufficient to cause injury to any of the structures; and, in his opinion, any attempt to stabilize the bed would cost more than would be justified by any advantages to be gained.

Mr. Hindmarsh. Mr. HINDMARSH, in reply, remarked that he was very glad that Mr. Palmer had mentioned the work of the contractors. The work had been done in 20 months, which, considering the difficulties and the magnitude of the operations, was a very creditable performance. With regard to Sir Cyril Kirkpatrick's remarks, the object of making these new provisions was to keep Norwegian traffic in the Tyne. The passenger facilities at Newcastle Quay were not very good, and there was a risk that the Tyne might lose the trade altogether. The total cost of the work described was about £300,000; and if at any time a member desired details of cost, he

would be willing to furnish them. The greatest total load on the piles was about 52 tons, but any pile that had had a poor final set had been tested to ensure that it was adequate to carry the full load. No serious difficulty had been experienced in grabbing out the small cylinders. The material in them to be removed by grab had been mostly soft; such hard material as had had to be removed had been broken up by means of a special tool with steel teeth. The concrete round the steel pile was only intended to protect the steel, and was not designed to carry any of the load. He had used Oregon piles because he could not get any pitch-pine long enough, and he thought the Oregon timber would be satisfactory, as it was sheathed with copper. He was certain that the timber would be broken away by ships long before it was eaten away by worms. When recently inspected the bituminous coating on the steel sheeting was in good condition. When the steel required cleaning it would be painted to low-water level. He hoped it would be possible to keep the sheeting in good condition for a long time. He was glad to hear Mr. Gueritte say that he approved of the cruciform piles. In all the circumstances Mr. Hindmarsh had thought that steel would be better than reinforced concrete for such long piles. The curing period of 83 days for the concrete piles did seem long. However, the contractors had had plenty of time in hand, and he had allowed as long as possible. He agreed with Mr. Gueritte's explanation of the cause of the failure of the joints in the reinforced-concrete piles. When the steel piles had been tested by loading, the tests had been carried out before encasing the piles in concrete. The contractor had been instructed to supply steel piles in three different lengths, namely, 75, 80, and 85 feet. The final set of the longer piles had usually been satisfactory, but the final set of the 75-foot piles had seldom been better than 3 inches for 30 blows with a 3-ton steam-hammer and a 4-foot 6-inch stroke. The two tests cited had been made on piles 75 feet long, the pile with a final set of 6½ inches having been loaded with 72 tons with a maximum settlement of 0·03 foot.

Mr. Hindmarsh.

Mr. BRISTOW, in reply, expressed his appreciation of the kind remarks made about the work for which he had been responsible. But the result was really due to the energy and devotion of his staff; while the work of the two consulting committees had been of the greatest value to him. He felt that Mr. Palmer had generously overestimated the share which he, the Author, had contributed to the findings of those committees. With regard to Sir Leopold Savile's questions, the timber groynes had arrested a certain quantity of sand and mud that was travelling up the coast. But the monsoon burst

Mr. Bristow.

Mr. Bristow. parallel to the shore, and the groynes were then unable to prevent the material from being grabbed back by the sea. The stone groynes overlapping each other in echelon fashion resisted successfully the "frontal attack" of the monsoon. The revetting of the outer bar had been considered in great detail, and many practical objections had been urged. So long as sand and mud were the only materials to be dealt with, successful maintenance dredging would be possible in the limited time available. But if masses of rock were swept into the channel by the fury of the monsoon, this maintenance dredging, necessarily through a pipe-line, would be very difficult. Another point was that over a large portion of the channel the ground was in soft mud, which would not support stone revetting. The silting-shelves were merely intended to keep the silting as far as possible out of the channel proper, thereby allowing ships to pass more freely during the periods of maintenance dredging. Railway connections with the mainland and the development of the reclamation were part of the next stage of the scheme now under consideration by the Government. He was rather surprised that Sir Leopold Savile had questioned the economic aspect of the dock. The cost was 2*s*. per cubic foot for the basin content, and 9*d*. per cubic foot for the total content, including the machinery. The whole dock had only cost £28,000. Apart from the first cost of a floating dock, it would probably have cost £10,000 to tow it to Cochin. Moreover, in corrosive waters, such as were found in the East, the cost of maintenance of a floating dock would be out of all proportion greater than the cost of maintenance of an ordinary concrete dock. It had been suggested by Mr. Binns that the dredger was hardly big enough for the job. In Mr. Bristow's opinion, however, the dredger had proved itself quite suitable. But, apart from that, when the work was begun there was only about 9 feet of water on the bar, and he had made a point of requiring that whatever dredger was employed should be able to float over the bar at any state of the tide. Now that the work was done a larger dredger was not wanted for maintenance purposes. The question of the bonus had been referred to by Mr. Cruttwell. The job would never have been done if a handsome bonus had not been paid to the men. They had worked 12 or 13 hours at a stretch, and had sometimes made two or even three times as much money by their bonus as by their wages. It was a great nervous strain to superintend such a job as this in the East, and it was a relief to feel that the men employed had the keenest possible personal interest in getting it done. Not only did that ensure a good hourly output, but the men looked ahead and always contrived to reduce stoppages on account of breakdowns and other

Mr. Bristow.

contingencies. With regard to costs it was necessary to add about 19 per cent. for overhead charges, plus sinking-fund and interest on the graving-dock, the machinery workshops, the dredger and pipe-line, and their attendant craft—tugs, barges, etc. The total over-all figure of 20 per cent. per annum mentioned by Mr. Palmer would not be very far out. Although the average cost of the dredging was 2·75 annas (3·1*d.*) per cubic yard in situ, the cost of the reclamation work was appreciably higher than the work outside. Taking the average, however, it could be said that the total cost of dredging was about 5 annas or 5·6*d.* per cubic yard in situ. The successful maintenance of the channel seemed now to be assured. In 1929 dredging was begun in the first week of December and was finished in 5 weeks. He had estimated that maintenance might take 2 to 3 months per annum, but it now seemed probable that that could be reduced considerably. He desired to acknowledge the valuable help of Sir John Russell, Director of the Rothamsted Experimental Station, for the information given on the composition of the sands. It would be extremely useful if in Papers dealing with dredging definite information was given about the material concerned.