

### Discussion.

Sir CLEMENT HINDLEY said that he was very glad of the opportunity of expressing his satisfaction at the completion of the interesting harbour work at Vizagapatam, and he would like to congratulate the Authors on the way in which they had presented their account of the work. He was in a position to give some information on the way in which the harbour works at Vizagapatam came to be constructed. In an earlier discussion before The Institution, he had mentioned the difficulties which engineers often encountered in dealing with human factors before they began their material work ; the Bengal—Nagpur Railway, having proposed the construction of a harbour at Vizagapatam, had for years to face all kinds of opposition and difficulties. It was only right, therefore, that a tribute should be paid to the tenacity and foresight of Sir Trevredyn Wynne, who was almost the creator of the Bengal—Nagpur Railway, in continually bringing before the public and the Government the necessity for developing that port. Until the construction of Vizagapatam harbour the thousand miles of coast from Calcutta to Madras had only small, so-called ports where merchandise and passengers had to be landed in surf-boats. The Bengal—Nagpur Railway, running from Calcutta to the Central Provinces, and being one of the main railways converging on Calcutta, had within its territory an area of 80,000 square miles, with practically no road or railway communications and with no harbour facilities ; for many years, therefore, they urged the construction of a railway from Raipur to Vizianagram (the city near the port) and the development of Vizagapatam harbour. They suggested numerous schemes and financial proposals, but always there were constitutional and other difficulties, and in the main it was easy to understand how they arose. Vizagapatam was in the Madras Presidency ; the seat of the Government was a very long way away, and naturally very little interest was taken, particularly as those in control at Madras feared the competition of the new port. The Bengal—Nagpur Railway, being centered on Calcutta, could not get any support from those at Calcutta for the creation of another port within measurable distance of the port of Calcutta. The railway therefore struggled on in vain. Constitutional changes took place in 1919, under which the Government of India assumed control of the major ports and left the minor ports to the provincial Governments ; that again complicated matters, because Vizagapatam had no one to take an interest in it. When the vital question of improving the

Sir Clement  
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railway communications of India came to be considered, however, the gap seemed to be one which ought to be filled up, and so it came about that the railway project for a line from Raipur to Vizianagram, coupled with the development of the port at Vizagapatam, was taken up again. It was found that the only way to develop that port was to create it, by an Act of the Central Government, a major port, so that funds from the Central Government could be applied for its development; its control was placed in the hands of the Railway Board, as that was the only technical department under the Government of India which seemed to be capable of looking after it. It would be seen that that was the only way, having regard to the constitutional position and to the way in which funds could be provided, by which any progress could be made at all.

Mr. Ash had credited him with being responsible for major decisions in the earlier stages. He had been in some measure responsible for the decision to start work on the port, and for the appointment of Mr. Ash in succession to Mr. Cartwright Reid, the Engineer-in-Chief who had commenced the work. The Railway Board had taken over from the Bengal—Nagpur Railway the whole staff and plant engaged on the work, and the General Manager of the Bengal—Nagpur Railway was appointed as administrator. He wanted to disclaim, therefore, any credit, or the reverse, for other major decisions in the early stages, as the work was done on the basis of the project which had been prepared by the Bengal—Nagpur Railway. The confidence which the Government of India placed in Mr. Ash had been most fully justified, for no one who read the Paper could fail to realize that Mr. Ash had converted the harbour scheme into a most practical and economical one.

Sir Clement was particularly interested in Mr. Ash's discussion of the very difficult problem of the littoral drift. Mr. Cartwright Reid, who had been on the spot for a good many years, had made a long series of hydrographic surveys which seemed to indicate that there was no great danger, at any rate, in attempting to dredge the channel and then awaiting further developments, but it was obvious from the experience of Mr. Ash after the channel had been dredged that the littoral drift was considerable and would have to be dealt with. He thought that the method of building the breakwater by sinking two tramp-steamers was most ingenious, and it was probably the only way in which it could have been completed in the time available.

Sir Leopold  
Savile.

Sir LEOPOLD SAVILE said that on two occasions he had been brought in touch with the scheme described. In 1916 he was asked by Sir John Wolfe Barry and Partners to investigate a proposed scheme, and, after spending some time on the site, he assisted in the drafting of their report. As was stated in the Paper, that report was

the first to suggest placing the harbour inland, and he thought that credit should be given to Sir John Wolfe Barry's partner, Mr. A. G. Lyster, Past-President Inst. C.E., who, he believed, was the first to make that suggestion. The scheme as finally carried out differed in many respects from that proposed in the report made by Sir John Wolfe Barry and Partners, but the inland location of the harbour had been adhered to, although the lay-out was modified to a very considerable extent. In Sir John's report two breakwaters were shown, protecting the channel from being silted up by the littoral drift, but in the scheme adopted those breakwaters were omitted, as it was then considered that, once the channel had been dredged across the bar, it could be maintained by the ebb and flow of the tide, assisted by a moderate amount of dredging. So far as he was aware, it was not realized that that was impracticable until about a year before the port was due to be opened. Mr. Ash accordingly was faced with the problem of providing the necessary protection in the short time available, to avoid deferring the opening for one or more years while a breakwater of the normal type was being constructed. It was then that he conceived the idea of forming an island breakwater by sinking two ships and supporting them by sufficient rubble to protect them against the monsoon, and of forming a silt trap which could be dredged by a dredger working under the protection of that breakwater. It was at that stage that Sir Leopold was again concerned with the scheme, when his firm was consulted as to its practicability. It was not an easy matter on which to give an opinion, but in finally supporting the scheme they were influenced, among other things, by the following considerations:—

(1) That a delay of a year or more would entail a considerable loss to the revenue of the port. (2) That Mr. Ash's proposal was the only one that could be carried out in the time available. (3) That, given a minimum amount of protection by rubble backing, as finally agreed to, it was not considered that the normal monsoon swell would do any really serious damage. (4) That, Sir Leopold having known both Mr. Ash and Mr. Rattenbury when they had been with him at the Admiralty, his firm felt certain that all that was humanly possible would be done to ensure the success of the scheme. He thought that the greatest credit was due to the Authors and to their staff for the successful opening of the port and maintenance of the channel during the monsoon of 1933, and for the fact that a cyclone in the following November did no serious damage to the breakwater.

Mr. M. F-G. WILSON remarked that he was especially interested in the Paper because in 1909 his late partner, Sir William Matthews, Past-President Inst. C.E., made an exhaustive report on the harbour and examined four or five projects which had been put forward.

Sir Leopold Savile.

Mr. Wilson.

One of them had been proposed before the troubles due to sand travel at Madras had occurred, but the others were of later dates, and all insisted that there was certain to be a travel along the coast and that it would have to be dealt with. He was surprised, therefore, to see from the Paper that the consensus of opinion at a later date was that the experience at Madras was not likely to be repeated at Vizagapatam. There were many examples of littoral drift of the kind met with at Vizagapatam. Stable beaches did not constitute evidence that there was no travel of sand ; for example, there had been a stable bar at the mouth of the Mersey for many years, but the movement of the sand became apparent directly dredging was begun, and he believed that about 500 million tons had been removed since dredging had been commenced. The way in which the sand travel at Vizagapatam was dealt with, once its magnitude was realized, appeared to have been very satisfactory, the small breakwater made by sinking two ships forming a lee under which the sand could be dredged. The practical effect of the dredging was to lift the sand which was travelling down the coast across the harbour entrance and pass it along.

The breakwater seemed to him to be rather short for its purpose, and it might have to be lengthened later on ; however, so far it seemed to have been very successful. He noted that dredging had been carried out in a swell of 4 to 5 feet. In dredging on a bar at Lagos it had been found that a swell of 3 feet was quite as much as was comfortable. What surprised him, however, was the small amount of damage done to the loose rubble of the breakwater. The section shown in Fig. 9, Plate 3, looked quite inadequate for its purpose, but evidently it had stood exceedingly well for its first season. He imagined, however, that much of it would probably be washed away in future, and that it would require to be constantly fed with fresh stone. The south-west breakwater at Colombo, which was exposed to the same monsoon, was founded on a rubble mound with a large rubble apron in front ; much of that apron was washed away by each monsoon, and had to be made up again in the fine season. That action had gone on for many years, until eventually it was decided to cover the apron with concrete blocks as wave-breakers. That work was expensive, but was quite successful, and he would not be at all surprised if similar measures had to be taken at Vizagapatam before very long.

With regard to the inner works, he was interested to note that Mr. Ash had discarded the original plan of building what were described in the Paper as "arms" and "tongues," which he took to mean a series of comparatively short jetties. Such a method would have been extravagant, as the ends of the jetties and the

spaces between them had to be filled in with at least the equivalent <sup>Mr. Wilson.</sup> of a quay wall, whilst they could not be used as such. Moreover, if the jetties did not correspond to the lengths of the ships any space left over was wasted, whereas with continuous quays that difficulty could, within limits, be overcome by moving the vessels along the quay and berthing them as required so as to economize space. The principal objection to a long quay having the usual sheds was the difficulty of providing access to the railways along the water side of the sheds. In the present case access was to be provided where the angles occurred in the quays, which was a good arrangement; but the quays were very long, and he would not be at all surprised if it were found when they came to be worked that more access was required at different places, so that one or two sheds would have to be sacrificed. The Authors had adopted monoliths for the wall. Presumably they were driven to do so by the local conditions, as the ground was soft and swampy and there would have been difficulty in sinking trenches, but the cross section as determined by monolith construction was not economical for a heavy retaining-wall. Apparently, however, they were sunk very successfully, and it would be interesting to know how nearly they came to their correct positions.

Mr. K. A. WOLFE BARRY said that his firm had watched the <sup>Mr. Wolfe Barry.</sup> development of Vizagapatam with the utmost interest. Many reports had in the past been made by many engineers, but his was the first firm, he thought, to make the definite recommendation that an inland harbour should be developed in preference to an outside harbour of the Madras type. That report was made to the Bengal—Nagpur Railway in 1914, when his father, Sir John Wolfe Barry, and Mr. A. G. Lyster were still alive, and not in 1921, as might be thought from the Paper. After the War, however, finance became very difficult, and as the development of the port became urgent the Government of India took it over from the railway, and his firm had no further active interest in the matter. In their report to the Bengal—Nagpur Railway, his firm drew attention to the similarity of conditions between Durban and Vizagapatam—both having narrow entrances with almost unlimited tidal basins behind them. The information then available with regard to littoral drift was very vague indeed, but it was not expected to be serious. The report, however, stated clearly that maintenance dredging would have to be done, but it was hoped that a valuable increase of scour might be developed by increasing the tidal capacity behind the entrances, as had been done with very good effect at Durban. It was certainly not anticipated that an accretion of nearly one million tons per annum would have to be faced, but, even if it had been, he was quite sure, from the many conversations which he had had with his father and with Mr. Lyster,

Mr. Wolfe  
Barry.

that they would not have altered their recommendation to form an inland harbour. In their original scheme, as Sir Leopold Savile had pointed out, they showed two breakwaters, one on each side of the entrance, at right angles to the shore, with an indication that they would probably have to be extended in the course of time. It was obvious, however, that the method adopted and described in the Paper for overcoming the difficulty of accretion was much better. It was most ingenious in its construction and design, and well deserved the success which it was evidently achieving.

Mr Du-Plat-  
Taylor.

Mr. F. M. G. DU-PLAT-TAYLOR remarked that Mr. Ash stated that the foreshore to the northward of the breakwater was to be restored or maintained by pumping sand upon it. The physical conditions at Durban were very similar; in consequence of the extension of the breakwaters, and particularly of the south breakwater, which extended 2,200 feet beyond the Bluff, the beach in front of the town had been completely denuded of sand, and the low-water mark had travelled inshore at the worst place about 200 feet, many buildings immediately behind the promenade being endangered by that denudation. Since Mr. Ash's visit the authorities at Durban had called in Mr. Nijhoff, a member of the South African Harbour Commission, who had investigated the matter and proposed to pump dredged sand over the north pier and on to the foreshore, in much the same way as that proposed at Vizagapatam. Mr. Nijhoff estimated that 700,000 cubic yards of sand would be required to restore the foreshore to its former condition, and proposed to retain it there by constructing groynes to extend 400 feet below the low-water mark of spring tides.

It was stated that poor concrete was used in the floor of the graving dock at Vizagapatam so as to relieve under-pressure by leakage. He did not think that that was a very good expedient; he would much prefer to make the floor of good solid concrete and to put in vertical stoneware drainpipes with the sockets uppermost, each socket being plugged with concrete. If any under-pressure should appear, the plug would be blown out, and it could easily be restored.

One of the most useful parts of the Paper was the Table showing the wear on pumps, pipes and other equipment used in the suction-dredging, as that was one of the most serious problems of such work. He understood that some experiments had recently been made in Holland in lining dredging pumps and pipes with indiarubber; unfortunately it had not so far been a success, owing to the difficulty of securing the lining, but if that difficulty could be overcome he believed that it would solve the problem.

Mr. Anderson.

Mr. A. L. ANDERSON remarked that engineers would realize the difficulties which those in authority must have had when they had

to decide on the detailed lay-out of the harbour. He did not think **Mr. Anderson.** the Authors claimed that the lay-out of the harbour was ideal, but he was sure that, given the peculiar conditions with which they had to deal, the resulting harbour was probably as good and effective as any that could have been designed. To those who might at any time be called upon to sink ships as a measure of protection, not necessarily against drifting sand, the scuttling of the ships for the island break-water was very interesting. The Authors had framed their Paper in such a modest and lucid manner that it might give the impression that that was a very simple proceeding, but he was assured by those who were in a position to know that it was by no means easy. The Authors had one advantage that they had plenty of stone ready to fill the ships and surround them. The Admiralty authorities would, he thought, rather support Mr. Wilson's suggestion that if a larger type of block had been used outside it would have saved maintenance in the future. The Authors' project was very bold; he thought it was novel, and he was delighted that it had been so successful. He was glad to see that the Authors had adopted a co-ordinate survey. At the naval base at Singapore a similar system had been employed, and during the past few years it had been immensely valuable, saving time and considerably reducing the length of wireless messages between Singapore and England.

The Authors were very fortunate in having been able to carry out the reclamation with sand, as the Admiralty had found clay to be most unsatisfactory; it never seemed to stop settling. He noticed that single-storey transit-sheds were adopted, provided with a truck-loading platform, but the Paper did not state whether that platform was at the floor-level of the shed or not. At Singapore very large single-storey transit-sheds had been adopted, and the Stores Department of the Admiralty had asked that there should be no break from the floor of the shed to the truck-loading platform, so that hand-trucks could be pushed from the floor on to the railway-truck. It might sometimes be possible to sink the railway beneath the floor-level of the shed, but at Singapore the floor of the shed had to be sloped up to the truck-loading platform level. The sheds at Singapore were 225 feet wide (instead of 200 feet, as at Vizagapatam) and it was not thought that the slope on the sheds would cause any difficulty. It would certainly enable materials and so on to be handled quickly with no lifting into the trucks. He did not claim that the idea was original, for he thought that Mr. Wentworth-Sheilds had adopted it for the transit-sheds at Southampton, which had been very successful.

**Mr. E. J. BUCKTON**, referring firstly to the general lay-out of the **Mr. Buckton.** harbour, said that Sir Frederick Palmer, who was consulted in 1926,

Mr. Buckton. had favoured the adoption of two long docks, one running more or less on the site of the northern basin of the accepted plan, and the other to the west of but parallel with it, the rail and road approaches from the north being more or less the same for both those parallel docks. The heads of the two proposed docks on the accepted plan were nearly 2 miles apart, and Sir Frederick contended that such a lay-out would not lend itself to easy administration. It had to be borne in mind that the scheme as prepared was a very extensive one, and that the final stage might never be reached. In Sir Frederick's lay-out he felt that it would not matter very much whether a small length of dock were first opened, and then gradually extended, or not, but with the official scheme he felt that it would be necessary to bifurcate the traffic about 2 miles away to approach the areas, or to have a great many temporary approaches which would have to be altered as the extensions were made.

Sir Frederick expressed his personal view as early as 1926 that the entrance could not be maintained without protection. He did not suggest the kind or extent of the protection which would have to be provided, as he did not know enough about the site.

Mr. Ash's proposals in 1932 for the protection of the entrance-channel were referred to his firm, and they were in general agreement with Mr. Ash on all points but one, namely, that Mr. Ash held a more favourable opinion of the sunken ships as a nucleus for the breakwater than they did. Ships sunk for such a purpose had been used before, and could not be said to have proved an unqualified success. A good many years ago, when repairing one of the Tyne piers, a ship was filled with concrete and sunk to form a temporary breakwater protecting the reconstruction works from heavy seas. It answered its purpose; not much of the ship was left, but the lower part of the concrete was discovered 2 years ago, well bedded in the sand and having changed its position considerably. A more important instance was in New South Wales, where there were three wrecks at a dangerous part of the coast near the entrance to a harbour. To form a breakwater it was decided to sink two more ships to close the gap, and to cover them with rubble. Those who had been concerned with that work had differing opinions as to its success, though he believed that the engineer responsible was satisfied with it. Ships scuttled on a sandy bottom subject to wave-action invariably broke their backs and ultimately went to pieces; although that was a fairly definite statement, most people who had had experience with ships going ashore would support it. To prevent a ship going to pieces it had to be practically covered with rubble, and the stones had to be larger than would be necessary for a rubble breakwater without a ship as a nucleus. That might not be obvious, but he thought that it would

be found to be true. The steel wall buried inside the breakwater Mr. Buckton. really weakened it ; if the plate were not there, the water would work through, but the plate acted as a cut-off and the waves were blocked and had to get away in some other manner, tending to displace the rubble. Mr. Ash agreed with his firm that a breakwater of rubble alone would be better than a breakwater of scuttled ships protected by rubble, and it was found that an all-rubble breakwater could be constructed in two seasons. At that time trade was very bad ; the new harbour could only have got such trade as it could draw from other Indian ports, and it was thought worth while to refer to India to find out whether the authorities there would be prepared to delay the opening of the harbour by one season so as to permit of an all-rubble breakwater being built. Sir Leopold Savile, in referring to the question a little earlier, had said that one of his reasons for supporting the scheme was that he was convinced that one year's delay would mean a very considerable loss. His own firm felt that, taking the problem as a whole, that could not be so. The time to build harbours was during a slump, and the time to open them was as a boom developed. The operating costs of a harbour were great, and it was difficult to meet them out of revenue, even when trade was good. The authorities, however, could not agree to delay. He did not know their reasons, but he did not think that at that time, when trade was so bad, a loss would have been involved to the country as a whole. There might have been a loss to a provincial government, and he did not know how the work was being financed, but at any rate it had to go on. Since the breakwater had to be provided in one season, there was no alternative to Mr. Ash's suggestion of scuttling two ships. The best service which his own firm could do was to suggest strengthening the proposed breakwater by using more and larger rubble, but Mr. Ash considered at the time that that was not possible ; it was expected to be difficult to get large stones in sufficient quantities from the quarries. However, he noticed that the breakwater at the end of the first season had been made considerably stronger than that originally submitted to his firm for consideration ; in fact, it was nearly as strong as the strengthened section which they proposed. It seemed that the quarry conditions proved more favourable than was at first expected, and apparently Mr. Ash was able to obtain more than double the minimum quantity of stone on which he could reckon before the breakwater was constructed. The exceptionally heavy stone discovered was of great value in constructing a breakwater, as the effectiveness of stone increased rapidly with increasing specific gravity. It had at one time been assumed that 3-ton blocks would be the largest available, but it had proved possible to get almost any size of block, and the stone had

Mr. Buckton. had to be broken down to suit the cranes available. Instead of the expected 3-ton maximum, 8-ton blocks were actually used. The breakwater was very severely tested by a cyclone, and, although it suffered heavily, it stood the test. The ravages of storms would have to be made good, and heavy maintenance had to be expected until the hulls were broken down or were covered with large rubble or blocks. He considered that the final cost would be appreciably higher than if an ordinary rubble breakwater had been made in the first place. The sinking of the ships was probably the only possible solution of the problem ; it was certainly most ingenious, and every credit was due to Mr. Ash for it, but he thought that it was not a suitable method of constructing permanent breakwaters and should not be copied except in an emergency.

Mr. Gedye. Mr. N. G. GEDYE remarked that in recent years The Institution had had very valuable Papers on dredging and littoral drift from three Indian ports, Madras,<sup>1</sup> Cochin<sup>2</sup> and now Vizagapatam. He could not recall any other series of Papers coming from one part of the world which contained so much useful and detailed information on sand-travel and on the dredging and pumping of sand by suction-dredgers.

Mr. Rattenbury had stated on p. 255 that wave-heights up to 21 feet had been registered in the offing, and that unmeasured waves had been estimated to be from 25 to 30 feet in height. It would add to the value of the figures and records given if the Authors could state the depth of water and distance from the shore of the place where those records were usually made, as the form and height of an unbroken wave near the shore were affected very greatly by the slope of the sea-bed and the rapid decrease in the depth of water. It was also stated that the troughs of waves which occurred in bad weather might be as much as 8 feet below mean sea-level. That record would be made more useful if the corresponding height above mean sea-level could also be given ; probably they were the 21-foot waves which were mentioned on the same page. With regard to the sand-travel, paragraph (f) on p. 256 clearly referred to the sea-bed as well as the actual foreshore, but it would be interesting to know whether the Authors had any information as to the limiting depth of water in which definite littoral drift was found to take place. Perhaps the depth of water corresponding to the limit of the 300-foot belt might be given.

Mr. Rattenbury mentioned that it was possible to dredge in seas with wave-heights up to a maximum of 4 to 5 feet, but that pipe-line

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<sup>1</sup> Sir Francis Spring, "Coastal Sand-Travel near Madras Harbour." Minutes of Proceedings Inst. C.E., vol. xciv (1913), p. 153.

<sup>2</sup> R. C. Bristow, "Cochin Harbour Works." Minutes of Proceedings Inst. C.E., vol. 230 (1930), p. 40.

work was impossible in rough weather. It would be interesting if Mr. Gedye. information could be given as to the maximum wave-heights when pipe-line discharge was possible. Dredging by sea-going hopper suction-dredgers could, of course, be carried on with waves of much greater height than those with which it would be safe to attempt the working of a floating pipe-line.

Reference was made in the Paper to various methods by which the stone was transported and discharged on to the breakwater, and he would like to ask whether the Authors had used any flat-decked scows, which were frequently employed in England where weather and other conditions were suitable. In replenishing the breakwater at Brixham during the last few years it had been found convenient to carry stones up to 10 tons (which was the limiting load of the available crane) across the harbour on a scow and to dump them at high water with the greatest ease and speed. The Paper referred to hopper-barges used for depositing stone, and he would like to ask whether side-door hoppers had been employed. For the periodical replenishment of the rubble mound of the South Pier at Tynemouth a large amount of stone was dumped from side-door hopper-barges, which had the advantage of being able to move into a depth of water over the mound which was very little more than the depth of the craft, as the hopper-doors were hinged at the top, so that no part of the barge was below keel-level while discharging the stone. The normal practice, if it was desired to keep the stones well up on the flank of the breakwater, was to discharge one side and then to turn the barge round and discharge the other.

It would be interesting to know what was the normal ebb flow through the narrows at the harbour at spring tides, apart from any abnormal ebb due to land water.

Mr. W. C. ASH, in reply, wished first of all to express the thanks Mr. Ash. of his colleague and himself for the very kind remarks which had been made about their Paper.

It seemed to have occasioned a certain amount of surprise that those concerned with the work were not well aware at the time that the project was put into execution that sand-travel did exist. It would be agreed, he thought, that it was not an easy matter to be quite certain whether the sand of a beach was travelling or not; the sections would probably be quite constant, or would exhibit no greater variation than might be expected from seasonal changes and from disturbances, so that a survey of that kind was of no help at all. At the same time, certain indications were available. Actually at Vizagapatam sand-travel could be seen during the monsoon whenever the wave-height was more than 3 or 4 feet. He attributed the travel which took place on that coast chiefly to the

Mr. Ash.

obliquity of the wave-action to the general line of the beach, and he thought that most people who had studied the matter would agree with him. The movement could be observed on that coast as on many others, though it was not easy to account for the continuity of the travel at every stretch of the coast. It seemed to him, therefore, when he got there that there was no reason at all why Vizagapatam should be immune. Moreover, whenever there had been a period of bad weather it had been possible actually to see the sand, obviously in considerable volume, travelling past the hill which was on the southern side of the entrance, known as the Dolphin's Nose, and he had similarly stood on the bluff at Durban and watched the sand travelling towards the "sand trap"; from a height of several hundred feet it could be seen perfectly clearly.

The determination of the approximate amount of sand-travel, however, was a very different matter, and the ideas which were entertained at the time when the scheme was undertaken varied a good deal. He had considered it necessary to spend at least a year in making observations and forming general conclusions before he would venture to offer any sort of opinion whatever; he kept silent for at least a season, but after that he did get rather alarmed at the fact, as it seemed to him, that the authorities concerned were confronted by a really serious problem and were making no provision for it, not having in their estimates any money for a breakwater or protective work of any kind. But even after experience had supported the conclusions formed and an idea of the seasonal volume of travel had been obtained, a great deal of investigation had been necessary before a scheme for dealing with the problem could be put forward, and that process had occupied considerable time. He agreed with Mr. Wolfe Barry that the idea of an inside harbour was justified, irrespectively of the existence of the littoral drift. He was convinced that certain investigators had formed an exaggerated idea of the value of the tidal scour at Vizagapatam. It would, in conjunction with two parallel breakwaters, have afforded but little relief. He doubted whether it was a very potent factor at Durban in maintaining the depths which were needed for the liners which visited that port.

One question of detail which had arisen was that of the swell in which dredging could be done. Probably his colleague would have more to say on that point. They had recorded in the Paper that they could and did dredge outside in a swell of about 5 feet, but of course a great deal of difference was made by the conditions under which the dredging was done. As had been remarked in the discussion, it was one thing to be dredging with a pipe-line and another to be dredging into a hopper, but with the flexible suction used they were

able to dredge with a fair degree of safety by hopping in a 5-foot Mr. Ash. swell. The pipe-line, of course, was not used in such a swell. When he was making investigations at Durban he found that hopper-dredging was carried out there in a swell of 9 or 10 feet, but that was absolutely necessary at times to keep the harbour open. He was very anxious indeed not to have to repeat those conditions at Vizagapatam. At Durban the dredging was done on the weather side of the harbour, where the sand-trap was situated, but he was convinced that at Vizagapatam it was necessary to have a lee, and that was one of the essential parts of the scheme.

Reference had been made to the difficulty of getting rail access on an "arm-and-tongue" lay-out. It was admittedly a difficulty, but he thought that it would not be very serious in the lay-out which had been adopted at Vizagapatam, because of the frequent breaks. It was true that there was a length of twelve berths on each side from the northern to the southern end of the Northern Basin, but there were kinks in the alignment of the quays, and at such places a connecting line could be taken from the running line at the back of the sheds to the quayside lines. The lay-out possible at those points had been studied in detail, and he did not think a great deal of quay-wall would be lost in getting the railway connections.

He was especially interested in the particulars which Mr. Du-Plat-Taylor gave with regard to facts which had come to light at Durban since he himself had made some investigations there. It now appeared that the question of the protection of the town was becoming more serious than it had appeared to be at the time when he was there, though there had even then been some anxiety. He thought it was obvious that if the littoral drift along a coast were interrupted, then, since the wave-action would continue just the same, erosion would occur. The authorities at Vizagapatam were afraid of that, as would be gathered from the Paper, but perhaps their fears were a little exaggerated, because he gathered from the latest information that the beach now appeared to be becoming a little congested. *Fig. 3* (p. 247), showing the working model, could be used to illustrate the point. A considerable volume of dredged sand had been dumped on the stretch of beach shown in the north-west corner of the diagram. The direction of the swell being, during the south-west monsoon, roughly parallel to the breakwater, it would be seen that the beach was to some extent in the lee of the breakwater. Also, a shoal had been created by sand dumped in the sea to the north of the channel, and that further modified the wave-action on the beach. The result was that the beach was becoming rather overloaded, but he thought the future solution would be to do a greater part of the dredging in the channel by

Mr. Ash.

hopping and to discharge it out to sea, where it would eventually disappear to the northward. Similar conditions applied at Durban, but he had been given to understand when he was there that there was relatively a larger return of sand during the periods when there were northerly winds; an appreciable proportion of the sand dumped at sea to the north of the harbour was, he had been informed, brought back by the return action of the swell and helped to keep the beach replenished to some extent; otherwise the erosion of the beach would have been very much more serious than it actually was.

Mr. Anderson had remarked that the lay-out at Vizagapatam was far from ideal. He was not quite sure whether Mr. Anderson was referring to the port as a whole, including the entrance and the inner scheme, or to the inner scheme alone. If Mr. Anderson referred to the whole scheme the Authors would be in agreement with him, but they had had to take certain physical facts into account. There was, for instance, an awkward bend in the channel which could not be avoided because of the position of the hills. Inside, however, there was a swamp of several thousand acres, and if the inside lay-out was not good it was the engineers' own fault, because there was very little to condition the planning of the harbour. They had to arrange, of course, for railway-access in accordance with the present alignment of railways up the coast, but, apart from that, they had had almost complete liberty. They had endeavoured to take advantage of all the factors which were in their favour, and they were to blame if the inside lay-out was unsuitable. He admitted that the bend in the channel was an undesirable feature and had proved troublesome in practice, but that was the fault of Nature. Mr. Buckton's reference to a supposed disadvantage in railway communication during the period of construction of the northern arm appeared to be based on a misapprehension of the order of procedure. There would, in practice, have been very little difference during that phase whether Sir Frederick Palmer's straight Eastern Dock or the Authors' Northern Basin had been adopted. Extension of the produce berths would probably take place first in a northerly direction along the eastern quay. On completion of these, there would be the same choice under each scheme regarding the location of further extensions, but if the adopted scheme were followed, developments would thereafter begin at the northern end of the western quay and proceed southward. There would thus be no need for the numerous temporary connections referred to. Regarding the position at a later stage, when the development of the Western Arm would be in progress, extension would normally take place along the northern quay, in a westerly direction. By that time, the magnitude of the Port would naturally call for a certain degree of decentralization in

administration, and it appeared to be of more importance so to plan <sup>Mr. Ash.</sup> the Port as to take full advantage of the physical conditions than to make it conform to hypothetical needs of that nature.

Mr. Buckton had referred to the discussion which took place before the scheme for the breakwater was embarked upon. In making his remarks he had assumed that the issue between the breakwater as constructed and a more orthodox type of breakwater rested upon a hypothetical delay of one season. It was true that a delay of one season had been referred to in those discussions, but personally he had never believed in that time-estimate; he considered that it would have required many more seasons. Having now carried out the work by the adopted method, and being able to view matters in retrospect, he was quite convinced that they would still be building the breakwater if they had not chosen some such scheme as that which was actually executed. If reference were made to Figs. 14, Plate 3, it would be noticed that about amidships on the lee-side of the two scuttled vessels there were two spurs indicated by the darker lines. A stage had eventually been reached in the construction at which all material had to be handled at the 10-ton derrick crane, which was, roughly speaking, between the two ships. When unfavourable weather conditions set in, that was the only place at which they could handle blocks on to the breakwater. The spur on the right-hand side out to sea had to be put there to enable craft to get in at all. The swell was so constant and so strong nearly all the year round at Vizagapatam that it was necessary to have protection for any vessels from which cargo had to be unloaded, to avoid running very great risk of the collapse of the crane. They had needed every bit of protection which the nature of the scheme had enabled them to secure, and it was greater than any other sort of scheme could have afforded. The two ships at the breakwater were roughly parallel to the swell for the greater part of the year, but the waves diffracted around the two ends and caused a good deal of commotion, even on the lee-side. If they had had to start from one spot only by sinking a caisson or getting a start in some other way, and had had to bring all the stone to that one place, he did not think they would have made any appreciable progress for a long time; construction would have been very slow, and he was convinced that the breakwater would not have been functioning yet. Although, therefore, there had been talk of a delay of one season, and although the Government had been given to understand that that might be the extent of the delay, he was sure that that figure had no actual reference to facts, and that the work would actually have taken several years, during which time the entrance to the harbour could not have been kept open.

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He agreed that, as a matter of principle, bigger blocks might be thought to be necessary in front of a steel wall than in a simple random block-work mound, but the Authors had not, in actual practice, observed any evidence of the kind of wave-action which would necessitate specially heavy boulders. The breakwater was, after all, on a similar basis to others in which there was a core of slice-work covered on the weather side by blocks. The Authors had also been favoured in certain respects, to one of which Mr. Buckton had referred, namely, the very high specific gravity of the stone. They had stone weighing very nearly 200 pounds per cubic foot, and, since the weight of the stone in water had to be considered, their scheme had a great advantage as compared, for instance, with any scheme involving concrete blocks. His colleague would probably have something to say with regard to that, because Mr. Rattenbury had been at Vizagapatam for some time since he himself had left, and knew more about the behaviour of the breakwater during the last one or two monsoons; he could therefore speak regarding the necessity for renewals or for further building-up of the breakwater. So far, however, there seemed to be very little evidence that high maintenance-costs would have to be incurred. He agreed with Mr. Buckton that during discussions on the scheme he had given conservative estimates as to the tonnage and size of the boulders which would be placed in position during the first "calm" season. Nothing had occurred to indicate that the work would not have been quite secure during the first monsoon had it been possible to give no more protection than that covered by the estimate of minimum tonnage of stone to be dumped. But, naturally, having undertaken the work, the Authors had made every endeavour to provide the utmost degree of security, irrespective of former anticipations.

The width of the zone of sand-travel had been mentioned. He had stated in the Paper that he had come to the conclusion that it was limited to a strip of about 600 feet, and Mr. Rattenbury in his part of the Paper had put the width at a lower figure. It could not, of course, be stated with precision. Some light was shown on the subject by the fact that at the end of the first monsoon only 3 per cent. of the deposit from the littoral drift was found to have taken place outside the zone of the breakwater; thus, for every 100 tons which had been driven by the monsoon along that coast, 97 had passed in through the gap, and only 3 had managed by some means or other to find its way outside. That gap was 600 feet wide, and his own belief, based on observations, was that the 3 per cent. could be mainly accounted for by sand which had been punched up into suspension by the wave-action during the half-dozen or more storms

which took place during a monsoon, when sand could be seen in suspension for at least a mile out to sea. A slight amount of accretion in the channel would therefore be expected, even beyond the range of the protective work. Mr. Ash.

Mr. O. B. RATTENBURY, who also replied, said that doubt had been expressed as to whether the length of the breakwater and the area of the trap were sufficient. He had been at Vizagapatam for two seasons since the establishment of the breakwater, and there was no evidence at present that its length was insufficient. It had been possible to clear the trap every year in the calm season and to extend its area; when the drift set in during the monsoon the dredger could get in to the trap at intervals between the rough-weather periods, and there had been no difficulty in keeping it sufficiently clear of siltation. He did not think that the extension of the length of the breakwater would help in any way, because the sand-travel took place only within 400 or 500 feet of the shore, whereas the breakwater extended about 1,800 feet from the shore. Mr. Rattenbury.

With regard to the weight of the stone protection, the breakwater was really completed in March last, involving about a year's work since the Paper was written. On the weather side there were stones of up to 8 or 9 tons in weight extending for more than half the length of the breakwater from its outer end and also round that end, and considering the high specific gravity of the stone he doubted very much whether a great deal of trouble would be experienced in maintenance afterwards. He looked on the breakwater as completed, except for the possible effects of some unforeseen and very heavy storm. In the 2 years since the breakwater had been in position there was no evidence that a single stone had been moved, except during one storm. During the first year, at which time the protecting stone on the outside of the breakwater was small—from 1 to 3 tons individual weight—a cyclonic storm occurred in November and the weather-side stone was undercut, disappearing below water-level over a stretch of from 300 to 400 feet along the outer face. That stone had been replaced by heavy stone, and in the last two years none had been moved at all. It had to be remembered that the recent addition of 8-ton blocks of high specific gravity was equivalent to providing ordinary concrete wavebreakers of 30 tons individual weight. Experience so far indicated that maintenance would not be required except after the occurrence of a direct hit from a cyclone, such as might occur once in 20 years.

He did not agree with Mr. Buckton that the steel core formed by the ships was a disadvantage. The suggested movement of the stone due to recoil of waves did not occur. Possibly that was due

Mr. Rattenbury. to the high specific gravity of the stone used. Actually, heavy storms breaking more or less at right angles to the face of the breakwater caused no movement of stone whatever. In the storm which did cause damage to the breakwater, before the heavier wavebreakers had been placed, the waves broke at an angle to the face and the damage was due to the undermining action of a powerful wave running along the face of the breakwater. The steelwork was not likely to disintegrate below low water, and disintegration above had been provided for by building a masonry facing-wall back and front and by covering the deck and hatches with a considerable thickness of concrete.

A question had been asked regarding the accuracy with which the monoliths on the quay-wall were sunk, and to what extent they deviated from their intended positions. The upper wall had been corbelled out 9 inches from the face aimed at when putting the monoliths down; there was no monolith which projected beyond 9 inches, and in most cases they were within 2 or 3 inches of the vertical. There was a good deal of trouble in correcting some of them as they sank; they would tend to go as much as 18 inches or 2 feet out of line either way, but it had been possible to correct that either by grabbing or by kentledge, or on one or two occasions by pumping, and no great trouble was experienced.

The floor of the graving-dock was really the natural rock, and all that had been done was to level it and put about 3 inches of concrete over it. The Authors considered that it was better to use a porous concrete, so as to have no floor-lifting trouble; had watertight concrete been used, a much greater thickness would have been necessary and the cost would have been much greater. The arrangement had proved quite satisfactory.

He had heard of the suggestion of lining the dredging-pumps and adjoining pipes with rubber, but, as far as he had been able to find out, a rubber lining, though not suffering much wear from the sand, was liable to be damaged by stones cutting it up. A considerable quantity of boulders had to pass through the pumps at various times, and it was understood that rubber would not stand up to that. He did not consider that the use of rubber would be as satisfactory as the welding which was in fact adopted. Welding was used to such an extent at Vizagapatam that it was difficult to say what the life of a pump would be, because the wear was made good every two or three months by building-up. Recently he had lined the casings with steel strips fitted in position and welded together, which had been found to be satisfactory and cheaper.

In reply to Mr. Anderson, the floors of the transit-sheds at Vizagapatam sloped from the wharf up to truck-floor level. Up to the

present time goods were carried from shed to truck or *vice versa* Mr. Rattenbury on the heads of coolies, and for that method of carriage it would have been better to have the railway-platform 2 or 3 feet below the truck-floor. It was expected, however, that hand-trolleys would come into use as trade developed, and the design was made on that assumption.

The wave-heights were measured in the outer channel at 6,000 E., which was about 3,000 feet from the shore, and the depth of the water there was 24 or 25 feet. The measurements were always taken at one particular point; a series of waves was taken each time, and it was found that on the average about one-third of the wave-height was below the mean sea-level and about two-thirds above it, so that a trough 8 feet deep below mean sea-level at the time would represent a wave of 24 feet from crest to trough.

With regard to dredging in rough water with waves ranging up to 4 or 5 feet in height, he thought that Mr. Ash had forgotten that they did actually dredge in waves of that height with the floating pipe-line connected to the shore. The first portion of the pipe-line was sheltered by the dredger, and the rest of it ran inwards away from the rough sea, so that the pipe-line was not exposed to waves as severe as those. The pipe-line had actually worked in a swell of up to 5 feet. Choppy waves upset the pipe-line much more than a steady swell, but, on the other hand, dredging was much more difficult and dangerous in a heavy swell than in a choppy sea.

Side-door hopper-barges and flats were not used for depositing stone at the breakwater. The ships provided a core over 50 feet wide for the breakwater, and the rest of the stone over the slopes of the breakwater was deposited up to an average height of 9 feet below low water by bottom-door hopper-barges and country boats as described. The 300-ton hopper-barge deposited stones up to 8 tons in weight to that height on the exposed face. Above that height the heavier stone was loaded on to the ship by the centre crane and unloaded by the same crane on the weather face, being then drawn along the ships by ships' derricks and tipped over the side. It was also transported by railway to the ends of the ships, where cranes deposited it in position. In the completed work there were wave-breakers of 5 to 8 tons in weight level with the ships' decks, extending the whole length of the breakwater and round the ends. The top width of that bank of wave-breakers was about 20 feet, and the slope about 2 to 1 down to a depth of 9 to 10 feet below water. The greater part of that bank could not have been deposited from side-hoppers or deck-lighters, owing to its height.

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\* \* \* The Correspondence will be published later.—SEC. INST. C.E.