Discussion.

The President. The PRESIDENT, in moving a vote of thanks to the Author, observed that the Paper was one of a type not often accepted for reading at The Institution, as it dealt with a possible work for which no definite design had been adopted, and in fact all the information necessary for making the design was not yet available. The objection to Papers of the kind was obvious. In the present case, however, it was felt that the Paper dealt with a link between two important parts of the Empire, and that it ought to be accepted for reading, as a good discussion on the subject might possibly have an important effect on the future of the work. He was sure the members would be only too pleased if they could help in any way towards the elucidation of the difficulties which were apparent in some of the proposals described in the Paper. The information given by the Author as to the effect of the monsoons and the currents was of great interest.

The Author. The AUTHOR remarked that when quite a youth he visited the Middle Level drain near King's Lynn, while the dam, necessary in consequence of the failure of the St. Germains sluice, was being built, and he had always retained a lively recollection of the difficulty—which had been fully described by Sir John Hawkshaw [1]—of closing altogether a water-channel in which the current was rapid. There, of course, the alternating current was solely due to the tides, whereas at Adam's Bridge it was due to the monsoons; but the cases did not seem to him to be wholly dissimilar in character. It was upon that recollection that his proposals for dealing with Adam's Bridge were to a large extent based. He naturally felt a great interest in the matter, and when he became aware that the proposals of Mr. Lewis—who, in common with so many members of The Institution, had sacrificed his life for his country, having died at Gallipoli—differed so widely from his own, he was induced to propose a Paper on the question, the more especially as Mr. Lewis had suggested that half the cost of his scheme should be borne by the Ceylon Government, for whom the Author's firm acted as consulting engineers. He was therefore grateful to the President and Council for breaking through their

[1] Minutes of Proceedings Inst. C.E., vol. xxii, p. 497.

rule and permitting a Paper to be read and discussed on a work which was at present merely projected. With regard to *Fig. 6*, he had to make one or two explanations. Another drawing accompanying Mr. Lewis's report showed a rolled steel joist attached by one of its flanges to the back of each pile to serve as a guide for slipping the slabs down. For a 16-inch slab the joist would probably require to be 18 inches by 7 inches, assuming that British standard sections were used. Even then, to allow 16-inch slabs to slide down readily some little shaping at their ends would be necessary. If the piles penetrated, as he believed they were intended to do, 12 feet into the sea-bed, the weight of the longest would be about $10\frac{3}{4}$ tons, and if each 18-inch by 7-inch joist extended to the bottom of the lowest slab, its weight would be about $1\frac{1}{2}$ ton, so that the pile with the joist attached would weigh a good deal and would not be an easy thing to pitch. He was not at all clear how or at what stage of the work the 2-inch double-cable chains, which seemed to him to be excessively strong, were to be attached to the piles, in view of the fact that it was necessary they should pass through the slabs. The 1-inch plate shown in *Fig. 6*, 3 feet by 16 inches, evidently formed part of the connection of these chains to the piles, but he was not sure whether that plate was intended to be embedded in the pile or to be outside the pile; at all events, he did not quite see how the chains were intended to be connected with it. The Author.

Mr. V. E. DE BROË remarked that, being connected with the South Indian Railway Company, he had read the Paper with great interest. He had followed the various estimates which had been submitted from time to time, and was thoroughly familiar with the history of the matter. Leaving the financial prospects of the scheme out of the question, and dealing with it from an engineering point of view solely, there were two points that appeared to require further consideration. The first was undoubtedly the question whether to give waterway or not. That, to his mind, was more a harbour-engineer's than a railway-engineer's question. As a railway-engineer he had had a good deal of experience in dealing with rivers in India and had dealt with very extensive training-works, but his harbour experience was limited to having been a Port Trustee in Karachi for some years, though not in charge of the works. It was a very open question, which the harbour-engineer ought to settle before the railway-engineer attempted a design, whether Mr. Lewis's idea of trusting to silting up was sound, or whether the Author's idea that waterways must be given should be adopted. The second point of importance was that Mr. de Broë.

Mr. de Broë. of alignment. Mr. Lewis's alignment went boldly across the "pot-holes," as he called them. When the design came home Mr. de Broë was asked to look into it, and it struck him that a sinuous line avoiding pot-holes might have saved the very deep piling shown in *Fig. 6*. Forty feet was a great depth, and there would be considerable difficulty in getting such piles in, because they had to be got in accurately to within an inch in order to receive the slabs. The exact pitching of such piles would be a matter of great difficulty. If the pot-holes could be avoided by curving round them, and if a depth of 6 feet or 8 feet could be obtained by a sinuous line, it seemed to him that such an alignment should be sought. He had attempted, from the drawings which had been sent home, to plot a sinuous line on the chart, but the soundings given were not sufficient guide, and he had written to India for more soundings. For proper consideration an engineer required cross sections on Mr. Lewis's centre-line and soundings up- and down-stream for at least 500 or 600 feet, at close intervals. When it was possible to plot cross sections it would be known how the thing stood. Whether it was possible to alter the alignment and avoid the pot-holes he did not know, but he had great doubt as to the extent of the pot-holes. Some of them were described as 500 feet long, and if they were of that length perhaps Mr. Lewis had made a mistake in calling them pot-holes; they appeared to be more like channels. When the cross sections were received he would be in a better position to criticize Mr. Lewis's design reasonably. He agreed with the Author that to attempt the cross section of viaduct shown in *Fig. 6* in a depth of 40 feet of water would be a very difficult matter. Another point was that a wave-breaker would be a good thing outside the piers; whatever section was settled, good long wave-breakers up-stream and down-stream would be of great advantage.

Mr. Shelford. Mr. F. SHELFORD felt a little diffident in joining in the discussion because he had never seen the site, but about 22 years ago the scheme was rather to the fore, and connected with it were the names of the Author, the late Sir William Shelford, and the late Sir George Bruce. He had inherited a bundle of papers containing plans and other information as to Adam's Bridge, which lately he had sent to the dustbin, feeling convinced that if a bridge was ever built between India and Ceylon he himself would not be associated with it. He was not sure that the Author would either, although he trusted he might be wrong. If ever the bridge was constructed, it would be built by the Government of India or the Government of Ceylon on the departmental system, and some engineer yet unborn

would have the credit. He wanted to join issue with the Author on a fundamental point in the Paper. He might be mistaken, but he believed the Author was completely wrong with regard to the current across the site of the bridge. He hoped the Author in his reply would give some information as to whether the bridge was really required or not. India and Ceylon had their ports from which traffic came and went, but what was the interchange traffic between the island and India? Adam's Bridge, he believed, was due to the presence of a ridge of rock, between India and the island of Ceylon, which acted as a submerged weir. The tides running along the shores of India and the island picked up sand, which was deposited by the water in the lee of the submerged weir. It was easy to see that the sand once deposited would be washed backwards and forwards from north to south and thus cause the sand beds. The conditions were such as to cause complete instability; what was an island one day was a hole the next, and what was a channel one year became an island the next. With regard to the currents, as everybody knew, the tide was caused by the moon; the moon travelled from east to west along the equator more or less, and the water was heaped up at the equator and flowed north and south, and caused tides all over the world. In the case of Adam's Bridge the tide was flowing north, and on the south side of Adam's Bridge the tide was practically unobstructed in the Gulf of Mannar. Deep water existed there. On the east side of the island the tide had to go a little farther and pass through shallow water called Palk Straits. It was clear that high water on the south side of the ridge would occur long before high water on the north side of the ridge. That result, of course, was complicated by the occurrence of the monsoons. In considering the question of a bridge across the site, the engineer would have to make up his mind whether he would let the water through or stop it and let it silt the sand up. Clearly it was a case where the currents could be stopped. He would like to know why the Author said that "it would be advisable to provide openings at all places where the depth of water exceeded 3 feet, because to encroach further on the channels would entail serious acceleration of the current, coupled with greater scour." The Author said practically the same thing on p. 294, and assumed that the more the channel was obstructed and the further the bridge was constructed from the two ends, the greater would the velocity of the current become. In Mr. Shelford's view there were no such conditions at all. When cutting off a piece of the sea and enclosing it for reclamation—as exemplified by a very interesting work carried out by the President's firm some years

Mr. Shelford.

Mr. Shelford. ago at Hodbarrow[1]—a certain quantity of water had to pass in and out of an opening at every tide, and, the narrower the opening, the worse the current became. But at Adam's Bridge there was no definite quantity of water to pass over the ridge, and there was no occasion for water to pass over. If four-fifths of the waterway were obstructed and one-fifth allowed to remain open, the conditions would not be affected; there would be nothing to increase the current through the remaining fifth. The waterway might even be blocked to the extent of $\frac{99}{100}$ and there would be nothing to make the water run faster through the other $\frac{1}{100}$. A current of water through a channel was due to the head, and there would be nothing to alter the head in the construction of a bridge. That seemed to him to be a very important point, because if it were possible to build the bridge across without any great difficulties from increased current, an expensive scheme would be done away with to a large extent and it would be possible to fall back on a simpler scheme. It was necessary to know more about the site before the methods to be adopted and the materials to be used could be dealt with.

Mr. Ward. Mr. H. T. S. WARD remarked that he had known Adam's Bridge more or less since 1876. It seemed to him that the question raised by Mr. Shelford was whether the bridge should be solid or perforated. When the south-west wind blew there was a current going north, and when the north-east wind blew there was a current going south, and the tide was out of it altogether. Really it was only the monsoons that had any effect. The first thing to do, if it were desired to keep a navigable channel open, would be to put a lock in the Pamban Pass, and it did not seem to him a difficult thing to make a lock in 10 feet of water. There was no doubt that the blocking-up of the few water-passages would not affect the level of the ocean above or below it in any way, if it were treated as a bund. He thought the Author said that the slope on either side was 1 in 628, and it was comparatively easy to make a sandbank safe at that slope. The pot-holes extended probably 500 feet, and there was a bank of 40 feet high, the greatest depth there. The slope might be 10 to 1 outside, and sand could be put there with the aid of a sand pump or sand dredger, and form a bund across the narrow opening. He did not consider that piles were necessary at all. He believed that once the openings were closed one way or the other they would probably silt themselves up. He did not think there was any difficulty about it with the present

[1] H. S. Bidwell, "The Outer Barrier, Hodbarrow Iron Mines, Millom, Cumberland." Minutes of Proceedings Inst. C.E., vol. clxv, p. 156.

appliances for sand dredging and sand pumping, Much labour would not be wanted, as the work could be done almost entirely by machinery. Mr. Shadbolt's scheme was a good one if rubble could be obtained. The information was inadequate to frame any satisfactory estimate, but he thought the principle was to fill up with sand and make a sandbank. With regard to the permanency of the sandbank, he remembered that on the south-east coast of Ceylon at Hambantota the sand encroached on the village to such an extent that it buried a number of houses there, and the only way that could be stopped was by planting a coarse grass that grew in the sand and Palmyra palms, and then the burying of the village ceased. Mr. Ward.

Mr. J. S. BERESFORD understood that the slope of 1 in 628 was the bed slope from the crest of Adam's Bridge up and down stream. [The AUTHOR assented.] The velocity of the currents was considerable, and as the width of the deep channels was also considerable, the volume of water that passed could not be small. If that volume of water were stopped altogether there would be some rise in the water-level. With regard to pot-holes, he did not think they could exist with such a quantity of silt-laden water flowing, and he believed they must be continuations of channels, not pot-holes. With regard to construction, it was a very difficult job to divert a large and deep running stream in sand. He had had to do with a great deal of such work in India and Egypt and had found a difference of level of 18 inches to offer very considerable difficulties. Even with plenty of rough rubble, stone could not be thrown on sand before the bed had been protected in some way. He had had some difficult cases of closing branches on the Nile where the current ran at 6 or 7 feet per second and the depth was 13 feet. It was only possible to close there with rubble, and carpets of sail-cloth 400 or 500 feet long and 70 feet wide had to be put down first from a bridge of boats anchored up-stream. That was an expensive arrangement, but it succeeded, the whole object being to protect the bed from scour during construction. Something of the same kind would have to be done at Adam's Bridge in stopping the stream. The pile arrangement suggested by Mr. Lewis seemed, at first view, a sort of groyne for reclamation, and he could not imagine the piles being got in easily and the slabs being lowered to the proper level. He thought the pile arrangement would hardly be practicable in the many deep places shown on Mr. Lewis's survey, unless the concrete slabs were omitted and the water allowed to pass freely, the bed being pitched with rubble. It seemed to him the only thing to be done was gradually Mr. Beresford.

Mr. Beresford. to stop the current altogether, if the work was ever carried out. In India, where the river Ganges, above Hardwar, with a rough boulder bed, had to be diverted annually, this was done by means of open wooden cribs, which were put right across the stream from derrick boats: enough stone was put in to keep the cribs from being washed away, and then the stone was gradually thrown in, working up to one level, and the main flow thus stopped. At Adam's Bridge there would have to be some protection such as sail-cloth in great carpets, as was used in Egypt, or mattresses of some kind, although the latter were not always satisfactory. The construction of so long a line would be very difficult. With reference to doing the work from both ends, he did not think the partial stopping of the flow in so wide a section would increase the current very much elsewhere. It would depend greatly on the extra head due to the water-surface slope and velocity of approach up-stream. In dealing with sandbanks protected by rubble he had always found that it could be done, provided the sand were covered with an inverted filter—gravel first, then rough ballast, and then stone. In that way, by judiciously arranging the size of the pitching, they had succeeded in India in making banks which were quite permanent. Ten miles of bridge seemed a very large undertaking, and perhaps if the Author's plan were carried out, the length might be diminished very considerably, as on the Punjab rivers, by using Bell bunds. The flow would be concentrated, and the amount of bridging thus reduced.

Mr. Preston. Mr. S. PRESTON said the first thing that had struck him was the rather elementary nature of the surveys, the best survey that had been produced being one made 80 years ago. In a question like that under discussion, a survey 80 years old might be considered out of date. Of the other two surveys put forward, one was simply a line with no information north or south at all, and the other (the Author's), although a little more elaborate, did not contain much detail. Speaking as an irrigation engineer of some standing in India, where surveys were made with very great detail, he had been much struck by the want of detailed information given in the Paper. It was the irony of fate that Sir Charles Hutton Gregory should have advised a rather small Government like that of Ceylon to make its railways of the 5-foot 6-inch Indian standard gauge, and that the powerful and wealthy Indian Government should not have brought its broad-gauge railways within 150 miles, in a direct line, of Rameswaram, where a junction between the two systems could take place. The Author had not said whether it was intended to make any broad-gauge connection

on the Indian side. It was noticed that Mr. Shadbolt had made an estimate for a broad-gauge line—there being no broad-gauge line on the Indian side—while Mr. Lewis had made an estimate for the metre gauge. Was it the intention of the Indian Government to make a broad-gauge connection? Because, if so, it meant at least adding 170 or 180 miles to the length of broad-gauge railway that would have to be laid. The Author might also have given some information as to material. It seemed difficult to form any opinion as to whether the embankment should be made right across, quite apart from the question of currents and the necessity for keeping the waterways open, or whether it would be better to make, as the Author suggested, partly embankment and partly bridges. If it was an embankment, it must depend entirely on material, and the Author had said nothing as to the material that would be available. According to Mr. Lewis, rubble would have to be brought about 120 miles, but the question was whether it was obtainable in any quantity. It was essential in any scheme to know what materials were available. Mr. Preston.

Mr. R. St. George Moore said the Author proposed openings and an embankment. He had produced sections and criticized the embankment proposed by Mr. Shadbolt and the embankment proposed by Mr. Lewis, but he had only said that his own embankment was to have stone ends. Therefore it would be valuable to have the details of the embankment that he proposed. Mr. Moore.

*** The Author's reply to the Discussion is printed at p. 326.

Correspondence.

Mr. Robert C. Bristow remarked that, having had some years experience in dealing with constructional work in a tideway, and over sandy deposits, he would like, in the first place, to congratulate the Author upon his complete and lucid presentment of the subject. It seemed fairly obvious that the existing sandy deposit which formed the half-submerged "Adam's Bridge," maintained its position as a whole, notwithstanding alternate monsoons from the north-east and south-west, each of which replaced, somewhere on the bank, material which the previous one had displaced. Further, it was clear that openings in the sandbanks had been formed approximately in the naturally suitable positions for the Mr. Bristow.