Mr. W. A. Brooks observed that the work was one to which unqualified praise could be given. The only possible objection he could raise was that enough money had not been spent. The works ought to have been considerably larger. They were of national importance, and should have been executed at the national expense.

Dr. Pole observed that if the bar was natural solid ground, no doubt the cut would be permanent; but if, on the other hand, it was one of those bars so frequently formed at the mouths of rivers by deposit, was it not to be feared that the same causes which had produced the bar would, if they remained in operation, tend to silt up the newly-formed channel? He merely asked for information, as he had no doubt the subject had been well considered in all its bearings.

Mr. John Grant asked the Author if there was much difference in the expense per cubic yard of the blocks in front and the bags of concrete behind, and whether he had reason to believe that, if the front had been made with bags of concrete, the work would have been less sound. It appeared to him that the foundation was as sound as it could be made by any method. No doubt it looked better to have square blocks in front, but under water that could be of no moment. He also wished to ask whether it was essential to have such large blocks as the 100-ton blocks which were used for 200 feet of the length. He thought that the remaining length of 600 feet when completed must have been quite as sound as the part made of the larger blocks. If they were not absolutely necessary, there would of course be a considerable saving in the plant required for raising and fixing such large bodies. This special plant was in the present case required for setting only forty blocks. The early failure in putting in the concrete was probably due to the fact that sufficient allowance had not been made for the cement that would naturally get washed away. It was intended to be 1 in 6; a strong mixture, no doubt, could it have been depended upon to remain amongst the gravel and sand; but in water that could not be assumed. A considerable allowance should always be made for the loss of cement put in in such a way.

Mr. Redman said the Author had not alluded to one point of interest—the tidal velocities, more especially upon the ebb, through the outlet. Carlingford Lough was between 9 and 10 miles in length, and 2 miles in breadth; it had an average rise at spring tides of 16 feet, and there was a vast body of water, which might be represented by about 200,000,000 tons, passing out upon

the ebb. A large quantity of that water no doubt escaped at the outfall, which was 2 miles in width from high water to half ebb; but a large proportion would pass out from half ebb to low water, and the velocity of the ebb-current through the low-water channels would be considerable. In the Admiralty Chart the highest velocity assigned to the surface of the Lough was $2\frac{1}{2}$ knots an hour; and it was well known that the authorities were always wisely tenacious of giving information of that kind unless absolutely authentic. From the observations of Captain Beechey and others, the tidal currents in the Irish Channel in many places had been found to reach 4 knots an hour—notoriously so through the North Channel. In the Pentland Firth, and in the channels amongst the Orkneys, the velocities attained 7 or 8 knots an hour. The Admiralty Sailing Directions contained the caution not to attempt to enter Lough Carlingford except on the flood, or with a fair wind of sufficient force to overcome that of the ebb out of the Lough, showing how great the outset velocity was.

The oscillating gangway for foot-passengers was an ingenious adaptation of the parallel rule plan for the treads, and it was supplemented by a connecting movement between the upper bar of the railing and the balusters. Some years back he had drawn out the details of a landing of a similar kind for the lower reaches of the Thames, but it was only to be applied to the steps, and there was some hesitation in adopting it, lest the constant use of the gangways in the particular spot in question should render it dangerous to the foot-passengers, when incautiously using the staircase towards the top of a spring tide, when the treads would disappear, and accidents might occur. No doubt the great elevation in the present case obviated that objection. With regard to the support of the piles as fenders for steamers of great length coming alongside, he could quite enter into the feelings of the Author, who had no doubt adopted an ingenious and effectual mode of bracing the timbers. Some under his own supervision, where there was a rise of tide of 20 feet, the depth being 6 feet at low water, projected a considerable height above high water. They were isolated Memel sticks, and had been standing for thirty years, with powerful guy rods in front, mooring chains attached, and only two piles at the back, half the height of the front piles, with a diagonal, horizontal, and raking system of braces. He thought the arrangement adopted by the Author was a very good one.

Mr. Gilbert Redgrave said it appeared the original surface of the ground had to be largely made up in order that the goods and passenger station might be erected, and the Author had described

the difficulties experienced in building a great length of river wall, part of it in a considerable depth of water. The site was on a piece of land which might be taken to be nearly square. What then would be the objection to making tidal docks in lieu of an expensive river wall? Various sidings could have been brought alongside the docks, and the necessity for providing hydraulic machinery, and the rather complicated passages for loading and unloading, would have been avoided. The difficulty with reference to taking the passengers underneath the goods station would not have arisen, and the cattle and passenger traffic could have been kept wholly separate. The cost of constructing such docks would have been much smaller, he thought, than that of the river wall, and instead of being able to utilise only one side, vessels could be approached from all round. It would be interesting to have some further particulars respecting the deposit of concrete in bags. He wished to know whether the bags were sewn together, or made up in any way before they were placed. It would seem, if the bags were made whole, that after they were deposited the junction between two bags would have caused a line of imperfect jointing between the concrete, and so have given rise to difficulties.

Sir J. HAWKSHAW, Past-President, observed that he had not seen the site of the works, and he would not therefore suggest different arrangements in regard to the making of docks, or other matters which could only be well understood by those who had considered the case in point for a long time. He might say, generally, that any observations from persons called upon at a few minutes' notice to give opinions upon works of that sort, other things being equal, could not have the same authority as those of the engineer who had had to carry out the works, and who had therefore necessarily carefully considered his scheme. The Author had given, as might be expected, an intelligent account of an interesting work, and had brought two or three facts before the Institution which it would be useful to consider. With regard to the deposit of concrete in bags, there was no such difficulty as Mr. Redgrave apprehended. The operation had been carried out pretty extensively, and had been described before by Mr. Dyce Cay,[1] who, at Aberdeen, had deposited bags of concrete to a considerable extent. He had himself used concrete in bags, and had found no difficulty with reference to the jointing. If the bags were not quite filled nor the concrete made too hard, they were easily adjusted by divers, and by other processes, so that they could be packed close

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxix., p. 131.

together, and made very solid work. A curious illustration occurred in Holland some years ago. A sailing vessel laden with bags of cement foundered close to the Dutch coast; at low water she was got at, but it was two or three weeks before there was an opportunity of reaching the cement. The bags were taken carefully on shore, when it was found that the Portland cement in every bag had become solid and assumed the precise shape of the bag, representing almost every thread of the canvas which enveloped it, not only the weft but the woof could be traced, and the whole had to be broken up, and was used for macadamising a road. The water had percolated into the cement, which had become quite hard. This showed what could be done by using concrete in bags. There was no doubt that in many places it was an excellent method, and might be employed with effect. He thought that Mr. Barton had used it with judgment. With reference to putting concrete through water, he did not know how it was that Mr. Barton's effort had failed. He had put concrete through water in one case 70 feet deep. It required, however, two things: first, that the water through which the cement was put should be still, and excluded from the surrounding water; and, secondly, that the concrete should be made richer than usual, because it was necessary to allow for waste, which no doubt rendered it rather expensive. If the space could be inclosed, so as to prevent the water from flowing in and out, concrete could be sunk through water with perfect success. The southern end of Cannon Street bridge had been thus founded upon concrete. In that case square water-tight caissons were made, and the water being still, the concrete was lowered through it, and formed a sound foundation. Some of the cylinders in the Londonderry bridge had been treated in this way. In the case under discussion, perhaps the water was not perfectly still, and the cement might not have been quite sufficient. In the Mediterranean, walls had been built in that way for centuries, as might be seen at Genoa and Leghorn. The quay wall was divided into compartments; the space was lined with canvas; and white lime, which was obtained in the district, was mixed with pozzuolana only—no sand—and passed through water. Mr. Barton might probably have had recourse to large blocks with advantage. In some situations, walls might be built in that way with success. A remarkable instance might be seen at Dublin, where Mr. Stoney, who had read a Paper on the subject before the Institution,[1] had been using blocks 350 tons in weight. The

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxvii., p. 332.

work could not be well done in a rough sea; but under suitable circumstances the method might be adopted. A drawing of the dredger had not been given; but it must have been a good one to accomplish the work described. There was but a short time to work; and the difficulty of getting machinery to act when a vessel was oscillating in the waves was very great.

Captain CALVER said there was no question that the pressure of the ebb would be through the channel, and the only thing likely to diminish the depth in it would be a marginal, or littoral, drift across its outlet. If there were none, there was every chance of the depth being maintained without any expense.

Mr. BARTON, in reply, said that Cranfield Point practically extended underneath the water as far as Hoskyn Channel. The cut was not through a drift formation caused by the meeting of the ebb-tide and the current, the shoal was a part of the land, and, in fact, the action of the sea, for hundreds of years, had been to deepen the surface upon the bar. When operations were commenced there, the whole surface was coated with boulder-stones so close together that the action of the tide in deepening had evidently been stopped by them. They had accumulated gradually as the clay had been cut away, and had dropped down until they had formed a sort of armour over the surface of the bar. Cranfield Point above low water was itself wearing away by the action of the sea. Since the first cut had been made through the bar, three or four years ago, the action of the tide had been rather to deepen it. It had been always kept by the tide quite clear, and the soundings made from year to year had not shown any shallowing. The blocks in front of the quay wall had been more expensive than the bags of concrete at the back; not, however, in themselves, they were made in frames, and the cost of lowering them had been much the same as that of lowering the bags, but they had to be carefully set by divers, and on that account were more expensive. The expense of divers, where each stone had to be set, and inequalities to be removed, was a serious matter. He was inclined now to think that the bags might have been also used for the front, and in any similar case he should probably use them. The end, however, was much exposed, and on that account, and on account of the current, the large blocks were needed at that part. The velocity of the current at the entrance was about $4\frac{1}{2}$ knots, and it varied throughout the whole of the district from 4 to 5 knots. Through the old channel it was not so much. The fenders occasioned some difficulty, inasmuch as the landing-stage had to be left free to move up and down in an open space, a steamer would come alongside

against a fender unsupported to the extent of 20 feet: that difficulty had been met by making box beams with $\frac{3}{4}$-inch plates and heavy angle irons—three in the width of the paddle-box, and braced together with a series of horizontal and diagonal wrought-iron box beams. As to the question of tidal docks, the whole object of the arrangement at Greenore had been for the purpose of establishing a fixed hour daily steamboat service, which was of immense importance both for passengers and for cattle traffic; so that tidal docks would have been out of the question. The cattle trade from Ireland was very large. The development of the trade between Holyhead and Dublin had proved how enormously a trade would increase when there was a fixed hour service on which dependence could be placed. There was a nightly steamer from Greenore to Holyhead; the second year's traffic had been 50 per cent. more than the first year's, and every department of the trade was rapidly increasing.

The bags held the concrete pretty loosely; the bag was put into a wooden skip, and the concrete came from the mixer direct: the flaps of the canvas were brought across the top and sewn with a packing needle, in a minute or two; the skip was then lowered and the bag was let out.

Mr. Stephenson, President, observed that there were several localities as well adapted as Greenore for the coasting trade of the country. He agreed with Sir John Hawkshaw in thinking that Greenore Harbour was an exceedingly useful one, both as a commercial harbour and for the smaller coasting vessels. He thought that the current through the new cut ought to be considerably faster than that through the old channel; if so, the chances of silting must be less. If Mr. Barton could get a little more money to make it 5 or 6 feet deeper, it would enable vessels of 500 or 600 tons to run in at low water. A vessel drawing 10 feet of water would strike in 3 fathoms in a heavy sea, so that the place could not be a harbour of refuge for large vessels. He would also suggest that a light should be placed at the entrance of the channel, as it was a dangerous thing to attempt to hit the channel by running in with two lights in one inland. If that improvement were carried out, and the channel deepened, the harbour would be one of the best on that part of the coast.

Mr. W. D. Cay remarked, through the Secretary, that the Author had successfully built part of the rear of the quay wall with liquid concrete in bags. He trusted, however, that the remarks in the Paper, as well as those of Sir John Coode on the New

South Breakwater at Aberdeen,[1] were not made with the view of appropriating for the Author the credit of originating the idea of constructing submarine works with liquid concrete in bags. The idea was not of recent date, having been described in the specification of a patent (No. 4,710) granted to James Frost, a builder, of Finchley, Middlesex, in 1822, for "A new method of casting or constructing foundations, piers, walls, &c.," from which the following was an extract, viz.: "In constructing foundations, and walls, and piers, the parts of which may be under water, I mix the required cement with the before-mentioned hard and durable substances; I enclose the composition in bags lowered by tackle to the surface of the work, and there dispose them in a regularly stratified manner while the composition is in a soft state, and will take the impression of the preceding layer in strata, and thus form courses of a well-imbedded conglomerate rock." He believed his own employment of the system at Aberdeen to have been as nearly as possible contemporaneous with its adoption by the Author, the experimental bags, the success of which led him to use the system, having been deposited in June and July 1870, and the active use of the bags having been carried out in the spring of 1871. Further, the system, described in the discussion on the Aberdeen Breakwater, of depositing concrete in bags by means of a hopper barge, had proved satisfactory and economical; nearly 9,000 cubic yards having been deposited in that manner during the latter part of last summer at the North Pier Extension Works, Aberdeen, mostly in 50-ton bags, at a cost of 21*s.* per cubic yard for labour and materials; and the power of the work so built of resisting the sea appeared in this case to be greater than if it had been built of ordinary prismatic solid blocks of similar weight.

Mr. P. J. MESSENT remarked, through the Secretary, that he commenced using concrete in bags placed by divers under the foundation blocks of the walls of the North Pier at Tynemouth in 1865. He first, unsuccessfully, tried mixing concrete in a diving-bell. Then, having noticed some bags of cement caked into solid masses from having been accidentally wetted at sea, he tried the concrete in bags. In the first experiments the materials were mixed and filled into the bags dry, but on examining them it was found that they had sometimes caked on the outside before the water got to the middle. Afterwards the concrete was mixed and watered before being put into the bags. The proportions were

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxix., p. 158.

about 6 of gravel and sand to 1 of Portland cement. He had since used concrete in bags very extensively. When the great accident occurred to the piers from the violent storms in December, 1867, the repairs, both temporary and permanent, were largely carried out in this way by filling the hollow spaces in and under the hearting with concrete in bags placed and packed by divers.