

Discussion.

The PRESIDENT, in moving a vote of thanks to the Author for his interesting Paper, remarked that the Author was in Rangoon ; but that his successor at Dundee, Mr. J. Thompson, Jun., was present, and might like to make some observations on the works described in the Paper. The President.

Mr. JOHN THOMPSON, Jun., mentioned that the coal-hoist jetties had now been completed at a cost of about £17,000, including the hoist and the foundations. The extension of the Caledon ship-building yard had been commenced. It was about 500 feet in length and about 150 feet from the shore. It was constructed of 12-inch piles, 8 feet apart from centre to centre, and 12-inch by 6-inch sheet-piles, with rubble backing and tie-piles behind the main piles. With regard to the movement of the sandbanks, he had not had much opportunity for making observations since taking up the position of Engineer to the Port. The Author attributed the removal of the Middle Bank to the narrowing of the river owing to the harbour-improvements, and its re-formation to the erection of the Tay Bridge, which had so diminished the flow of the ebb-current below the bridge as to allow material brought down by it to be deposited over the area of the Middle Bank. That bank had been in existence in 1816, and consequently must have been formed from other causes than the erection of the Tay Bridge. He quite agreed with the Author that the erection of that bridge had increased the flow of the ebb-current, doubtless owing to the narrowing of the river. The Middle Bank was practically in the same position now as it had been then, but farther northward and eastward. If the increased velocity of the ebb-current due to the narrowing of the river was sufficient not only to carry the material held in suspension above the Middle Bank, but also to scour it away, he did not think that the erection of the Tay Bridge would sufficiently diminish the flow of the ebb-current to cause the material brought down from above the bridge to be deposited on the Middle Bank. He thought it would decrease the velocity above the bridge and tend to increase the deposits there ; and the slackening, for the same reason, of the flood-current as it approached the bridge would cause the material held in suspension on the flood-tide to be deposited over the area of the bank. From observations made by floats, the flood-current decreased Mr. Thompson.

Mr. Thompson. as it approached the Tay Bridge and increased after passing through it, and in the same way the ebb-current increased after passing through the bridge. Observations made by Mr. Cunningham had shown that there was not quite so much material in suspension on the flood-tide as on the ebb-tide; but there was a considerable amount, and he saw no reason why that material in suspension should not be deposited over the area of the Middle Bank now, as the tide slackened on approaching the Tay Bridge. Previously, no doubt, it had been deposited in Invergowrie Bay, farther west on the north bank. He thought the erection of the Tay Bridge was probably the cause of the re-formation of the bank, but not altogether for the reasons given by the Author.

Mr. Baggallay. Mr. H. C. BAGGALLAY thought there was no branch of civil engineering wherein practical experience was more important than in works connected with water. Theory was important, but practical experience was more so; and therefore he thought the Institution owed a debt of gratitude to any engineer who was good enough to present to it a Paper on works such as those described by the Author. The Paper was a little wanting in detail, and he thought some further information might be given as to the construction of the works. It was proposed to build a new wall in front of the existing berths on the north-east side, but nothing was said as to how the trade of the port was to be dealt with while that wall was under construction. It was mentioned in the Paper that the wall was to be of a permanent character, to replace the old timber wall: was it to be assumed that it was to be of concrete or of masonry? In dealing with a river with a strong current, and apparently with a bottom which was constantly shifting, anything like a cofferdam was a serious matter. In ordinary dock-work, in the dry, a timber quay could be built for about half the cost of a concrete or masonry wall, and there would be a greater difference when the work was carried out in a river where it was necessary to enclose it in some way. Therefore he thought some information as to how the work was to be carried out, and the trade of the port carried on in the meantime, would be interesting. With regard to the hydraulic installation, he congratulated the Author upon the very satisfactory performances of the jiggers. He had frequently kept a record of how many lifts cranes and other hydraulic machines made in discharging vessels. Of course it was more usual in dock-work where there were mixed cargoes to have cranes of about 30-cwt. capacity. These jiggers, however, being for a special purpose, dealt with only

5 cwt. The cranes in such ports as London, Liverpool, and Buenos Aires were usually 30-cwt. cranes, and he had found from observations on a large number, discharging different kinds of cargo, that they did not average more than thirty lifts per hour, or one lift in 2 minutes; whereas the jiggers could, when pressed, do about five lifts per minute, which was highly satisfactory. In the London Docks there were a number of jiggers, but they were not popular, as they did not answer well; that was probably due to the fact that the cargo to be dealt with was not always of the same kind. Where bales of jute weighing 400 lbs. were being unloaded continually, no doubt jiggers would be more useful. In the engine-house at Dundee there were two small accumulators. He had found small accumulators of little use; if an accumulator was to be used at all it should be a large one. An ordinary 30-cwt. crane hoisting to a good height used about 30 gallons of water at one haul, and the two accumulators mentioned in the Paper contained together only 50 gallons. It was a curious fact that, in dock-work, when the hydraulic installation was spread over a large area, accumulators were not wanted at all. Calculating what the expansion of the mains ought to be under the pressures given, it would be found that the expansion was something infinitesimal, one-thousandth or something very small. Whether it was due to the amount of air in the water or not, he did not know, but, as a matter of fact, constant pressure could be kept up without accumulators. Accumulators might be useful at distant points, but in those cases it was desirable that they should not be weighted up to the maximum pressure. If working at 700 lbs. per square inch they should not be weighted to more than, say, 600 lbs. per square inch, so that they might always be up. Generally, when there was a want of power, it occurred at a time when there had been a little falling-off owing to the over-use of capstans or machines taking a great deal of water, and the accumulators were found to be all down at the same moment; whereas, if the weight on the accumulators was kept low they were up until the pressure fell to, say, 600 lbs. per square inch. If weighted to the working-pressure they were always on the move, and that wore them at the top or bottom of the rams and caused them to leak; and if the glands were screwed tight they would not work at all when they came to the thicker part of the shaft. Therefore it was important that when accumulators moved they should move through as much of the stroke as possible, and not oscillate at the top or at the bottom. Although he had read Mr. Cunningham's Paper, he did not quite follow

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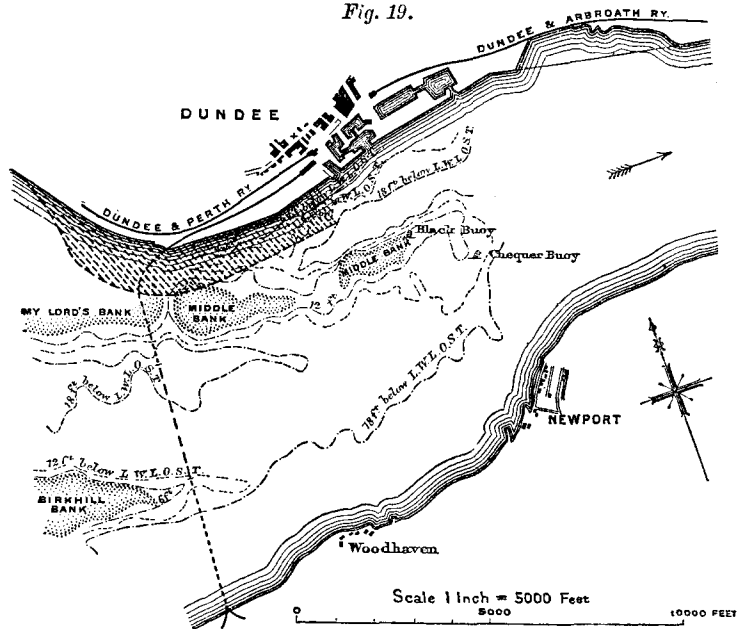
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Mr. Baggallay. the Author in his views as to the cause of the ballast and sand coming in front of the docks. It appeared that, long before the bridge was made, what was called the ballast bank had had a tendency to come in front of the port. The illustrations did not give sufficient data to enable an opinion to be formed as to the actual direction of the current, but apparently there had been a large increase of depth in the estuary generally. Mr. Cunningham showed that in the 50 years about 30,000,000 tons of sand and silt had been removed; and while a considerable portion of that had been caused by the bridge, a much larger portion had been scoured away long before the bridge was built.

Mr. Pilkington. Mr. WOODFORD PILKINGTON remarked that he wished to express his appreciation of the Paper, which formed an interesting sequel to that written by Mr. Cunningham, and gave a historical survey of the progress of the Port of Dundee under the direction of various engineers. Whoever had been responsible for designing the Victoria graving-dock had put in a very interesting example of a caisson closing with a hinge, which he thought had been at that time a novelty. Since then much progress had been made with sliding caissons, floating caissons, and travelling caissons, especially the remarkable invention of the late Mr. Kinipple, M. Inst. C.E., who had shown Mr. Pilkington some beautifully designed automatic caissons. Mr. Cunningham's Paper was an able analysis of the regime of the estuary, and what puzzled Mr. Pilkington was that such a Paper should have been written without its Author leaving behind him any record of the manner in which he would wish to carry on the work of regulating the estuary. The laws which governed silting and the formation of sandbanks and bars in an estuary such as that of the Tay had been a peculiar hobby of Mr. Pilkington's for some time. He considered that a sandbank in the middle of a stream, such as "My Lord's Bank" and the Middle Bank, was the result of two meeting currents. If it were possible to find out where the currents came from a shoal could be dealt with much more easily. An important example of the formation of sandbanks by the deflection of colliding currents was afforded by the Goodwin Sands. These sands had been, as was well known, originally an island, the top of which had been washed away gradually by the sea; but they were now quicksands maintained by the currents, one current coming from the direction of Germany and another coming down the English coast. These currents met and divided, with the consequence that the Goodwin Sands had been formed; and it was surprising how slightly those sands had altered in contour and dimensions. This arose from

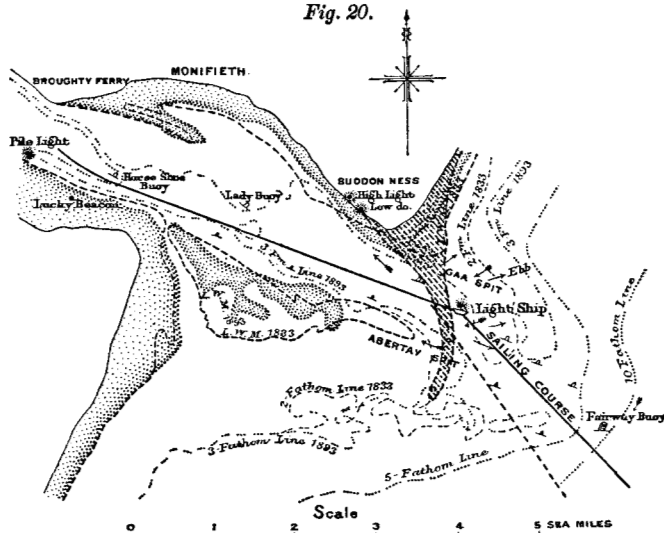
the currents, in again seeking the straight direction, meeting, the contained pointed oval being the permanent shape of the Goodwins. As was well known, cattle had fed on the sands some years ago, and there was no reason why they should not do so again if the sands were treated as the Admiralty had treated the mud-bank in Portsmouth Harbour called "H.M.S. Excellent." The plans in the Paper did not show the full length of the River Tay, but from the illustrations to Mr. Cunningham's Paper it appeared that there was one shoal by the Lady Buoy which was in the middle of the fairway—a shoal which must have been deposited

Fig. 19.



by the currents; and if it were removed it would never re-appear, there being no confluent currents in existence to cause its formation. That deposit had been formed of very large stones a long time ago. With regard to the Tay Bridge, in place of enlarging the spans of the bridge, which, on a curve having a radius of only 1,500 feet, would cause the bridge curve to be represented by a polygon of chord lines, so that the cross girders at the middle of each span would have to sail over considerably, and would require bracketing to support the curved rails, the effect of the piers could be overcome by advancing the line of the esplanade from the dock works and continuing it so as to intersect the bridge

Mr. Pilkington. at the end of the straight part across the river, the retaining-wall then curving in towards the shore, in the direction of Kingoodie, *Fig. 19*. This curved wall would act as a cushion and guide to the ebb current, which would wash away a large portion of My Lord's Bank and the Middle Bank. With regard to the removal of the bar, he suggested that this would be effected by a curved mole, or training-wall, and breakwater from below Buddon Ness, *Fig. 20*, passing inside the lightship and forming a mean of the curves of the littoral current lines of uniform soundings on the 5-fathom and 10-fathom lines. It was clear, from the description given by Mr. Cunningham and from the

Fig. 20.

results obtained, that the littoral current flowed always steadily from north to south; the effluent showed this from the permanent effort to follow it indicated by the sailing-course lines of 1833 and 1895 taking a permanent set south. The Abertay Spit as a centre of swing might disappear or remain, or alter in shape or in length, but need not be considered in designing the work, as an entrance 500 feet wide and having 35 feet at low water would be sufficient for any purpose. If that principle were carried out in the Tay estuary a curved junction would be made and the whole of the bar be removed; and instead of there being only about 14 feet of water over the bar at low water there would be 30 feet or 40 feet along the whole of the sailing-course.

Mr. S. G. HOMFRAY, in reference to the hydraulic machinery, Mr. Homfray. remarked that the jiggers had been designed for the special work of lifting bales of jute, which were hauled up in rapid succession. The lift was merely a vertical one to the top of the gangway, and then the bales were slid ashore. The jiggers worked at the speed mentioned by the Author, and it was quite a different thing from working mixed cargoes with a swinging crane. They were most successful where there was no crane, as the men in the docks could never be persuaded to work jiggers when they could use a crane, the latter being a much easier method for them, although it did not work at the same speed. The 30-cwt. crane was very suitable for the goods that came into large British ports, and he had on several occasions timed 30-cwt. cranes making two lifts per minute. With regard to the size of the accumulators, the first accumulator had been put down for a very small engine. A second engine had been added, and another small accumulator had been put down to give the power: the whole formed quite a small installation. It had not been necessary to add largely to the accumulator-power for the sake of the jiggers, because, as Mr. Baggallay had mentioned, it was possible to do without accumulators. When a sufficiently large plant was worked, and where there were a number of machines lifting rapidly and constantly, the continual draft on the engine did away with the necessity for a large amount of accumulator-power, the accumulators being little more than equalisers. He thought, however, that even Mr. Baggallay, favourable as he was to large accumulators, would be satisfied that the coal-hoist was fairly equipped with an accumulator having a ram 20 inches in diameter and 35 feet stroke. With regard to the loading of outlying accumulators, Mr. Baggallay could not be contradicted in saying that it was an advantage that they should be loaded to a lower pressure, but what that pressure was to be depended entirely on the draft on the accumulator from the machines near, and could be settled only by experiment. The outlying accumulators should be practically always up, and should make a stroke only when a large quantity of water was drawn from the mains.

Mr. F. E. WENTWORTH-SHEILDS remarked that the Author had Mr. Went- given two interesting drawings of retaining-walls, a solid masonry worth-Sheilds. wall, and a timber wharfing; but he did not mention in either case what the foundation was. The masonry wall appeared to be an exceedingly massive one, the thickness of the base being equal to quite one-half of its height, but the foundations appeared

Mr. Wentworth-Sheilds.

to be shallow—only 3 feet 6 inches below the bottom of the dock—and it would be interesting to know on what the wall was founded, and whether any movement had been noticed in it. A somewhat similar wall had been built by the late Mr. Alfred Giles, Past-President Inst. C.E., at Southampton, and had been described in the Proceedings.¹ A certain length of it had moved. The foundations had been 6 feet in the ground, but the whole wall had slipped forward, due to the fact that it had been on what might be described as a very slippery, weak clay. The timber wharfing mentioned in the Paper appeared to be of a light character, and one that most dock-engineers would hesitate to erect, except on some exceedingly stable foundation; and it would be desirable to know into what the piles were driven, and whether there had been any settlement or forward movement. In regard to the neat and ingenious gate-caisson he also wished to know what method was used for opening and shutting it, and how long the operation occupied.

Mr. Napier.

Mr. R. T. NAPIER mentioned that he had crossed the old Tay Bridge a fortnight before it fell, and the new bridge for the first time in August 1901, and he had naturally looked on the scene with interest. If he was not mistaken, he had noticed that the piers of the old bridge were still in existence in the river-bed. If the current flowed at right angles to the bridge, the piers would probably not be any additional obstruction, as the spans of the new bridge were the same as those of the old bridge, but otherwise they might be. In fact the matter would be complicated by the old piers being allowed to remain. If they were really there he would like to know whether there was any intention to remove them.

Mr. Shelford.

Mr. W. SHELFORD thought it was possible to come to some important conclusions with regard to the movement of the shoals. The main thing was that in the Tay there had always been a middle sand, and that middle sand had asserted itself, though not always in the same position. The forces at work were generally, and to a large extent, similar to those in other rivers on the east coast. The prevailing north-easterly wind drove the flood-tide with considerable force against the shore of any river on the east coast, and the flood-tide then turned due west and flowed up the estuary. On its return the ebb-tide sought the shortest cut to the sea, flowing down the north side and making another channel; and the space between the two channels was generally called the middle sand. On the Humber, which was a good example of the east coast rivers, the same state of things was observed. Looking back at charts

¹ Minutes of Proceedings Inst. C.E., vol. lxx. p. 171.

200 years old it would be found that the middle sand was invariably there, although not always in the same place, and it was always due to the causes he had mentioned. If the surveys were extended and the charts made more complete, he thought it would be seen that the theory he set up was correct. All other matters, such as the building of the Tay Bridge, and other obstructions, were subsidiary.

Mr. G. F. DEACON considered that it was quite impossible to draw any conclusions without full information as to the estuary and a little more information as to the land water. Mr. Shelford's observations might be applied not only to the rivers on the east coast, but to some of the rivers on the west coast of England. There was an analogy, for example, between the Tay and the Mersey, the Mersey being an estuary running south-east, and the Tay an estuary of much the same size running south-west. In both cases the flood-current hugged the concave shore—Birkenhead in the one case and Dundee in the other—and in both, the ebb-tide took a straighter path, the cause and effect being the same. With regard to particular banks, much had been done by the straightening or curving of the shore on the Dundee side, and if the plan dated 1816 was compared with that dated 1900 the effect was obvious. Although the Middle Bank still remained, it was a much smaller bank, and the velocities had been increased considerably, with the result that the average depths shown by the sections had also been increased. He suggested the Paper should have added to it the figure of the inner estuary in order that it might be better understood, and also a little more of the mouth of the river.¹

The PRESIDENT explained that the report of the discussion would be sent to the Author, who would be asked to reply in writing, but Mr. Thompson might at once be able to give some information as to certain matters of fact which had been commented on. It was stated at the beginning of the Paper that protection had to be provided for vessels against the gales in the Tay, and perhaps Mr. Thompson could say whether the vessels lying against the quay-walls without any such protection suffered at all in times of heavy weather.

Mr. J. THOMPSON, Jun., mentioned that no details of the proposed sea-wall had yet been prepared, but it was proposed that it should be built of concrete in short lengths of 200 feet or 300 feet at a time. The foundation of the Victoria Dock walls was rock, and the timber wharfing was on stiff clay. There had been no perceptible

¹ A plan of the estuary of the Tay is given in Mr. Cunningham's Paper, above referred to; Minutes of Proceedings, Inst. C.E., vol. cxx. (Plate 6).—SEC. INST. C.E.

Mr. Thompson. movement in either case. He did not think there was any intention to remove the foundations of the old Tay Bridge. Large vessels were not affected in any way by gales, but the trawlers suffered. There had been no case of any vessel breaking adrift or damaging herself. On the average it took about 10 minutes to open the gate and 5 minutes to close it. The extra time taken in opening the gate was owing to the water in the air-tight compartment having to be displaced by means of an air-pump. This took on the average about 5 minutes. Under the most unfavourable conditions the time necessary for opening the gates was 13 minutes, and under the most favourable conditions 7 minutes.

The Author. The AUTHOR remarked, in writing, that, as the present engineer to the port had been present at the meeting when the Paper was read and had kindly replied to several of the questions raised, there was not much to add in reply to the discussion. The movement of sandbanks in an estuary was a subject on which it was almost impossible to find two engineers who thought alike, but the theories advanced in the Paper would, he hoped, serve as suggestions to others studying a similar subject. In connection with the Tay it was true, as remarked by several members, that there had always been a Middle Bank, but there were certain other facts which could not well be controverted. First, concurrently with the works of the port, the Middle Bank had decreased until in 1885 it had practically ceased to exist. Secondly, the bank had reasserted itself after the building of the new bridge and the whole of the river-bed in the vicinity and up to the line of the navigation-spans had begun to silt up; the inference from these facts being that the piers of the old and new bridges combined formed a groyne which obstructed the tidal currents and allowed sand to collect. With reference to Mr. Baggallay's remarks, the ballast bank should not be confounded in any way with the Middle Bank; the former was a distinct mass, formed below a projecting spur of land and had long since been entirely removed. In answer to the questions put by Mr. Wentworth-Sheilds, the piles in the timber wharf had been driven down to a very stiff clay. It was desirable to have the front of the market as near as possible to the river-front, and therefore it had been decided to limit the rows of piles to two, the back row also serving as foundations for the iron columns supporting the market-roof. He had recognised at the time that by this design the stability of the structure would depend almost entirely on the strength of the iron tie-rods, and these had been made very numerous and had been attached to the wharf with great care, the landward ends being embedded in blocks of concrete. Particular attention had

also been paid to the filling and hand-packing of stone pitching. The Author. The gate-caisson was opened and shut by means of chains attached to hand-power winches. Most of the piers of the old Tay Bridge were still in existence. A strong desire had been expressed by the Harbour Trustees to have them all removed before the building of the new bridge was commenced, but on the representations of the railway engineers that the foundations of the new bridge would be imperilled by their removal, they had been allowed to remain, on the railway company agreeing to place and maintain a light on each pier.

Correspondence.

Mr. T. JOHNSTONE BOURNE remarked that it would be interesting Mr. Bourne. if the Author could give for the several critical periods at which increase of accommodation had proved necessary, viz., 1829, 1848, 1865, 1876 and 1891, the tonnage of goods, inward and outward, dealt with per lineal yard of quay. The length of quays at those dates was given in the Paper, as were also the dimensions of the locks controlling the size of the vessels using the port; and the completion of the figures as suggested should show the increase of efficiency of unit length of quay as the average size of vessels increased. The shed-accommodation appeared to be about 8·6 square yards per lineal yard of quay, which seemed a low ratio, especially as the transit-sheds were of one floor only, which must serve for both export and import, and as there were no railway lines on the face of the quay. The design of the landing-wharf (*Figs. 9*) appeared to be of an eminently economical character. Perhaps the Author would state the nature of the material in which the piling was driven, and of the filling; and whether the anchor-rods occurred at every frame: also whether the anchor-block was continuous along the back of the quay. The figures given for the maximum and the average rate of discharge by hydraulic jiggers seemed to prove them to be as efficient as electric cranes for the kind of work required at Dundee, and their first cost was probably less.

Mr. W. DYCE CAY observed that the section of the north wharf Mr. Cay. of the tidal basin for trawlers was the same as that of a wharf he had designed and erected in 1875 for herring-fishing boats at