

## Discussion.

The PRESIDENT, in moving a vote of thanks to the Authors for their interesting Papers, remarked that in the work at Barrow he had been compelled to take special interest, owing to the fact that a battleship had been kept in the dock and rendered unavailable for service for many months, in consequence of the accident to the pier-head. Instead of being delivered in August, 1900, the ship had not been received until May, 1901, and, in other circumstances, it might have been a serious matter that a completed battleship of a new type was prevented from entering on service by an accident to the dock-entrance. Of course, the accident could not have been foreseen; but the moral seemed to be that it was undesirable to leave ships inside an entrance that was to be altered, if they could be got out before the work was commenced. The President.

Mr. SAVILE mentioned that Sir John Aird had kindly sent for exhibition two models showing the strutting of the cofferdam before and after the accident. As the timber-work was rather complicated, the models might be of interest to the members. They explained the work better than any diagram would do. Mr. Savile.

Mr. HENDERSON remarked that it might seem an unusual thing to resort to rubble for the construction of a long wall to protect the dock-site. The engineers would not have thought of doing such a thing had it not been for the fact that  $\frac{1}{2}$  mile away, in the south-east corner of the harbour-works, a spit of sand ran out, which was dry at low water. East of this spit the water was 15 fathoms deep, and on the dock side only about 4 or 5 fathoms; the spit therefore afforded very considerable protection to the dock. Mr. Henderson.

Mr. FRANK STILEMAN mentioned that the docks at Barrow had been constructed in 1867 by his late father's firm, the original dock-entrance being 60 feet wide, capable of taking vessels of 6,000 tons or 7,000 tons, such as the second-class cruisers of the "Doris" class, built at Barrow. After that the Ramsden Dock had been constructed, giving an alternative entrance into the Walney Channel which was nearer to the sea by about  $1\frac{1}{2}$  mile. The entrances were 100 feet wide and 30 feet deep at high water of ordinary spring tides, and the passage was through the dock-entrance and the lock till the vessels arrived at the upper sill, having at that time 24 feet of water. H.M.S. "Powerful," then, he believed, the largest cruiser in the Navy. Mr. Stileman.

Mr. Stileman. excepting the "Terrible," had passed through that entrance safely. After taking over the works of the Naval Construction and Armament Company, Messrs. Vickers, Sons and Maxim had built several warships, including the "Vengeance" and the Japanese battleship "Mikasa," now Admiral Togo's flagship, which drew 27 feet 9 inches. This had necessitated the lowering of this dock-sill, or the flooding of the dock to an impossible extent. An arrangement had therefore been made, between the railway-company owning the docks and Messrs. Vickers, to lower this dock-sill, making it uniform with the remainder of the docks, and to deepen the Ramsden Dock all over to 30 feet; but not to deepen the Buccleuch Dock—except by a cut sufficient to form a passage from Messrs. Vickers's works to the dock-entrance—on account of the depth of the walls, built in 1869, not permitting that course. Messrs. Vickers's fitting-out berth had been deepened, however, so that they could accommodate alongside their quay, where there was a 100-ton crane and a 150-ton crane, vessels drawing 30 feet. Ships drawing 28 feet could now pass through those docks. In giving Mr. Savile permission to write his Paper, he had enjoined him to make it as explicit as possible, and to mention all the circumstances, for the benefit of those who might have to carry out work of similar character and dimensions. Troubles had been experienced, which, with considerable expenditure of money and time, had been overcome. Some of them, he considered, could not have been foreseen; and, at all events, he thought it would be admitted that the work had been carried out in a thoroughly satisfactory manner. The railway-company could never have undertaken the work of lowering the dock-sill if they had not had a second string to their bow in the Devonshire Dock entrance. All vessels had had to be passed through the entrance-basin of the Devonshire Dock, while little or no work could be done at the Ramsden Dock. Before beginning to lower the dock-sill, however, they had equipped the Ramsden Dock basin with four deep berths, which had enabled vessels of large tonnage to discharge part of their cargo. The vessels had then been passed through the Devonshire Dock entrance, either into the Devonshire Dock, or into the Ramsden Dock. With regard to karri piles, when H.M.S. "Euryalus" was lying in the dock, the quay caught fire, damaging the vessel. While the whole of the pitch-pine piles were destroyed, the karri piles were simply charred. As to having two entrances to a dock, within the last few months Messrs. Vickers, Sons and Maxim had asked his firm whether they could see their way to

widening—not deepening, because they were deep enough already Mr. Stileman. —the passages between the Ramsden and Buccleuch Docks, and the high-level bridge between the Buccleuch Dock and the Devonshire Dock, to a width of 100 feet. The present width of the passages was 80 feet, and H.M.S. “Dominion,” which had a beam of 78 feet, had passed through them. The motive for the suggestion to widen the passages was the fact that Messrs. Vickers had then been tendering for the new vessels for the Cunard Line, which were to have 85 feet beam. To carry out the proposed widening would, in all probability, necessitate opening the Devonshire Dock again; which further showed the advisability of having two entrances. The depth of water at Messrs. Vickers’s fitting-out berth had been made 3 feet more than in the cut, in order to allow for waste of water in carrying on the traffic through the locks. With regard to the accident to the foundations, both the old and the new borings had given ground for the belief that they would be perfectly safe, but unfortunately that had proved to be not so. The pier-head, previously composed of masonry, had been rebuilt in timber; that made a satisfactory pier-head, though probably not as good as masonry, because ships’ captains had not the same respect for a timber pier-head as they had for masonry. The caisson was to some extent a novelty, being flat-sided. After some experience had been gained, the caisson had been got across in less than 2 minutes. With the ends blocked it could not be hauled across in less than  $4\frac{1}{2}$  minutes: which showed the advantage of the open ends. It had been built by Messrs. Vickers at a cost of £9,000.

Mr. C. S. MEIK thought it was very desirable to have two Mr. Meik. entrances to every set of docks. Mr. Stileman had shown that they were absolutely necessary in the case of the Barrow Docks, and, although they had not been adopted in the Burntisland Docks, the original design had provided for an alternative entrance to the new dock by forming a connection between it and the old dock. True, the dock was only  $11\frac{1}{2}$  acres in extent; nevertheless, it was advisable to have a second entrance, and the time might come when the Commissioners would feel the necessity of it. The seaward surface of the embankment-wall had been purposely left rough, the blocks being deposited as they came out of the quarry, with the object of breaking up any swell, and preventing the sea from breaking over the parapet-wall. The same plan would be adopted in the new dock which was to be made at Swansea, where the wall was 3,000 yards long. The sand backing behind the seawall had formed a very efficient dam. No clay whatever had been used at the back of the wall for keeping the water out, yet the

Mr. Meik. quantity of water pumped from the dock had not been larger than could be dealt with by three pumps, and the bulk of the water had come from other sources than leakage through the sea-wall. Most of the walls of the dock were founded on whinstone rock, which underlay shales. That was fortunate, because in the west dock the foundations were very different; indeed, for a dock  $5\frac{1}{2}$  acres in extent they were extraordinary. At the north-west corner of the dock there was blaes, which was a sort of decomposed shale; then it changed to freestone, from freestone to hard clay, from hard clay to soft clay, from soft clay to whinstone, from whinstone to soft clay again, and finally the entrance was founded on freestone and shale. That was probably as wide a variety of foundations as had been met with in a dock of the size in question, the total length of the quay-walls being not more than 2,000 feet. With regard to the cement, Mr. Henderson had omitted to state the mesh of the sieve. It was 5,625 meshes to the inch; and with that mesh there had been a residue of 4.9 per cent., against a specified residue of 7.5 per cent. The specification had asked for a tensile strength of 400 lbs. per square inch after 7 days, but some of the cement had given as much as 560 lbs. He thought that specification might be looked upon as tolerably safe; but since 1898, when it was drawn up, his firm had seen fit to make the specification more stringent. He considered it was desirable that the specification should be made more stringent still; better and stronger cement than that could be obtained, and engineers should have it. There could be no doubt that fine grinding produced a very quick-setting cement. That might be a drawback, but it could be overcome either by aeration or by the addition of gypsum, which, in moderate quantities was, he thought, allowable; it was not an adulteration, as it had no deteriorating effect upon the cement. As was well known, an Engineering Standards Committee was now sitting, and among the things which it was intended to standardize was cement. If the Committee's standard specification, when arranged, limited in any way the tensile strength of cement, or its fineness, he thought it would be a mistake. In 1858 the Metropolitan Board of Works had asked for a cement in which the tensile strength of a briquette  $1\frac{1}{2}$  inch by  $1\frac{1}{2}$  inch was to be 400 lbs. per square inch after 7 days, equal to 177 lbs. per square inch. At the present day his firm were asking for a cement that would show 500 lbs. per square inch after 7 days. With regard to fineness, the Metropolitan Board of Works in 1858 had not imposed any other condition than that the cement should be ground "extremely fine." Now, his firm's

specification asked for 1 per cent. on a 5,776-mesh, and 20 per cent. Mr. Meik. residue on a 32,400-mesh sieve. If in 1858 a committee had issued a standard specification limiting the tensile strength of cement to 177 lbs. per square inch, engineers would probably not now have at their disposal such cement as they could obtain. In the discussion on the Paper from which he had quoted the specification of the Metropolitan Board of Works it was stated<sup>1</sup> that "during the preliminary experiments, objection was taken to the standard then proposed, and afterwards adopted, and it was strongly urged, that a standard of about 300 lbs., instead of 400 lbs., would be found, in practice, to be the highest attainable." It was fortunate that no Standards Committee of that date had fixed a standard specification for cement, and he hoped the present Committee would not lay down rules which would retard in any way the improvement of cement-manufacture. The cost of the Burntisland East Dock, including dock-entrance and sea-wall, was £316,000; the cost of the gates, engines, and hydraulic machinery, carried out by Sir W. G. Armstrong, Whitworth, and Co., was £35,000; the cost of the jetty and gangway outside the dock-entrance was £4,000; the engine-, boiler-, and accumulator-houses cost £5,700; the electric lighting, water-supply and sundries £7,000: making a total of £367,700.

Mr. WM. MATTHEWS (of Westminster) remarked that he could Mr. Matthews. promise, as Chairman of the Committee on Cement, that Mr. Meik should have every facility for explaining to the Committee his views on the subject, which would be carefully considered. With regard to the Ramsden Dock sill, he had on different occasions seen the work in course of execution after the accident; and he thought he had never seen a work of the size surrounded with so many difficulties, which difficulties had been grappled with both by engineers and contractors with great skill. The Institution was indebted to Mr. Savile for his full and frank description of the undertaking, and he was to be congratulated on having had charge of so interesting a work. About its details there were three or four points of interest. The first was the care exercised in dealing with the foundations of the new invert. Before cutting away the old invert in slices, Mr. Stileman had ascertained carefully where the good bottom existed, and where the bad bottom would be met with; and had dealt with the good places first, in order to limit the possible effects of the bad places. Thus, the area of the sill open at any one time had been considerably limited. Again, once a

<sup>1</sup> Minutes of Proceedings Inst. C.E., vol. xxv. p. 67.

Mr. Matthews. section had been opened in a bad spot, it was always dealt with uninterruptedly and sealed with concrete before it was left. The cast-iron sheeting had, no doubt, in this instance, made an excellent cut-off; but it did not follow that cast-iron sheeting could always be used with equal success in other cases. About 15 years ago, his firm had carried out some work at Hodbarrow, on the opposite side of the Duddon Estuary to Barrow, in ground similar to that described by Mr. Savile. There, using exactly the same kind of cast-iron sheeting as at Barrow, it had been found that, in consequence of boulders existing in the clay, the sheeting was, in some cases, broken, and its use had not been attended with success. In its place wrought-iron sheeting had been used successfully. They were now constructing, on the same ground, an embankment which would shut in about 170 acres of foreshore, and there steel sheeting was being used very extensively; there was a steel diaphragm  $\frac{7}{8}$  mile in length and 35 feet in height, with the exception of some small portions about 26 feet high. He was in hopes the work would be closed about July, 1904, and that an interesting description of it might be brought before the Institution. In regard to the difficulty of ascertaining the character of the bottom from borings, his experience tallied with Mr. Stileman's. In the case under discussion, Mr. Stileman had arrived at the conclusion that it would be prudent for him to proceed with the work in the manner which he had laid down. No doubt that would have been so, had the bottom been of the character which the borings had been considered to indicate. So far as they went, borings gave correct results; but it was possible that they might miss dangerous strata which might affect the whole character of the work. In the work at Hodbarrow to which he had referred, a series of borings had been made along the work. From three borings, at intervals of 600 feet, the engineers had been led to believe that a good clay bed existed at 7 feet below the surface. In carrying out the work, however, a dip of 40 feet between two borings had been found, and a dip of 20 feet between the other two borings, neither of which would have been expected from the results of the borings. He could therefore readily sympathize with the engineers in their difficulties at Barrow, which had really been due to the existence of an unknown seam of sand. The only point in Mr. Savile's Paper to which he wished to take exception was the statement that karri timber was not liable to be eaten by marine worms. That certainly was not correct so far as tropical waters were concerned. At Colombo, jarrah timber, which was supposed to resist the action of worms better than karri, was being used

for a cofferdam, and it had been found necessary to protect the Mr. Matthews. jarrah timber from worm-action, even for temporary use. One valuable characteristic of karri timber had been mentioned by Mr. Stileman, namely, its resistance to the action of fire. As far as Mr. Matthews knew, the only way of distinguishing between jarrah and karri, which were almost exactly alike, was by burning a small chip; jarrah yielded a black ash and karri a white. He considered that jarrah timber was certainly superior for sea-work, in respect of resisting the action of the *Teredo*.

Mr. BASIL P. ELLIS expressed his appreciation of Mr. Stileman's Mr. Ellis. remarks as to the execution of the work at Barrow. In extending the cofferdam after the fall of the pier-head it had been impossible to drive all the piles quite down to the clay, and therefore while the new invert was being put in, there had been a certain amount of risk of another blow. With that risk in view, it had been decided to sink alternate 12-foot squares, in chess-board fashion; and the work well illustrated the advantage, with a bad bottom of that sort, of exposing the smallest possible surface at a time. Only one square had given any serious difficulty, and that had been successfully dealt with, as described by the Author. The method was well worthy of being followed on other occasions, when similar difficulties were met with.

Mr. SAVILE, in reply, thanked Mr. Matthews for his appreci- Mr. Savile. ative remarks. Work giving such trouble as that experienced in the lowering of the Ramsden Dock sill was seldom met with, and he was glad to have had the opportunity of gaining experience in the execution of such a work. Mr. Matthews's statement that borings did not always give reliable information was borne out by the result at the Barrow Docks, even after further borings had been made. In front of the cast-iron sheet-piling four borings had been put down at first, which did not give concordant results. Borings had then been put down between these four, about 10 feet apart; and even then it had been hard to form an accurate idea of the foundation. Both Sir John Aird and Mr. Ellis must have been thankful when the work was finished, as until the water was let in there was always a possibility of further trouble. With regard to Mr. Ellis's remarks, there had not been much risk of water coming in under the cofferdam extension, because, although some of the timber piles had not been actually driven down to the clay, in every case where a timber pile was not so driven a set of three steel piles had been driven behind it down to the clay, so as to make the cut-off effective.

Mr. Henderson. Mr. HENDERSON, in reply, remarked that from the first he had felt sure that the sand embankment behind the sea-wall would be successful, as, when in the Clyde Trustees' Office, he had seen a long length of riverside quay-wall constructed behind an embankment of sand taken from the Queen's Dock excavations. The surface of the pitching of the wall had been left very rough for the reason mentioned by Mr. Meik. He understood that at the Swansea Docks, Messrs. Meik were about to construct a sea-wall with a sand embankment behind it, in the same manner as at Burntisland. The only difficulty met with in carrying out the work had been the water behind the dock-wall, and that had been overcome without any damage resulting.

The President. The PRESIDENT remarked that, lest there should be any misapprehension, he would add that the officials of the Admiralty had been well aware throughout that every endeavour was being made, by all concerned with the work at Barrow, to minimize the delay; and that nothing in the way of expense and effort was being spared by the engineers or the contractors to bring the "Vengeance" into service at the earliest possible date. With regard to Mr. Henderson's Paper, probably, in settling on the width of 60 feet at the entrance, provision had been made for either constructing another entrance or widening that one at no distant date, because the tendency in ship-construction certainly was towards increase of size. He never went to Barrow and looked at the dock-entrances without thinking of a principle which he was always urging on his friends who were dock-engineers, namely, that they were acting wisely in allowing a considerable margin beyond what they found to be absolutely necessary under conditions prevailing at the time of carrying out the work.<sup>1</sup>

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<sup>1</sup> Mr. Henderson has since explained that the trade of Burntisland is largely continental, and is likely to remain so, and it may be a long time before vessels in that trade will much exceed 50 feet in beam; so that the 60-foot entrance to the new East Dock should be ample for ordinary purposes. Reasonable probabilities only were considered in settling the width.—SEC. INST. C.E.