

Discussion.

Mr. Bruce Bell. Mr. ROBERT BRUCE BELL observed that he had been engaged in the design and construction of slip-docks for the last thirty-six years. The inventor of the slip-dock was the late Mr. Thomas Morton, as the Authors had stated, and the main features of the slip-dock remained much as he had left them. The first actual change was made upon the purchase-machinery or hauling power. The original machinery consisted of spur-gearing, driven by manual power, horses, or the steam-engine. The change was the substitution of the hydraulic ram for the spur-gearred winch, but the Authors were mistaken in ascribing this invention to Mr. Morton, who died many years before. The invention was that of Mr. Daniel Miller, M. Inst. C.E., and was patented by him in 1849. The first application of it was on the slip-dock constructed by Mr. Miller and himself at Kelvinhaugh, on the Clyde, in the year 1850, the hydraulic machinery and cradle being made by Messrs. Samuel and Hugh Morton. This slip had taken up vessels of 1,000 tons. The length of stroke of the ram was 15 feet; the pumps were driven by a 30-HP. engine. Shortly after the completion of the Kelvinhaugh slip-dock, another dock, with hydraulic purchase for vessels of 1,500 tons, was laid down at Melbourne for the Colonial Government, and about twenty-six years ago a large hydraulic purchase was designed and constructed for the Russian Government for war-vessels of 2,000 tons, and another slip of equal size was sent to the Mauritius; but the largest hydraulic purchase on Miller's patent was that made for the Egyptian Government for war-ships of 3,000 tons. The stroke was 15 feet in length, the ram 18 inches in diameter, the weight of the cylinder 17 tons, that of the ram 5 tons, and the side-rods were each 5 inches in diameter. Various other slip-docks on this principle had been constructed with various lengths of rams, but the handiest length of stroke appeared to be 10 feet; the rods were whipped out of place by a crane, worked by steam or hydraulic power, and stacked at once; a couple of men were all that were required for fleeting the rods, and no such expenditure of time as that stated by the Authors should be necessary in a properly arranged dock. No separate engine was required for hauling up the empty cradle, this being done by gearing attached to the hydraulic apparatus; various modifications had been made upon the hydraulic apparatus since it was originally designed by Mr. Miller.

In the description of the mode of relieving the cradle from the Mr. Bruce Bell. ship in order to take up another vessel astern, the Authors observed that this was "an improvement which had been introduced of late years," and they went on to state that the transverse arms, "instead of being permanently fixed, are hinged at their outer ends to the side-ribs, and are thus capable of being swung round parallel with the side-ribs, upon which they rest when in this position," and they then described the process of relieving the cradle. He could not say whether Mr. Thomas Morton originally fixed the arms in a permanent manner, but he could say that he had never seen one of Morton's cradles with arms so fixed; and he knew that in the cradle furnished by Messrs. S. & H. Morton for the slip-dock constructed by him at Stornoway, thirty-six years ago, the arms were not so fixed, and that he relieved the cradle in precisely the same manner as described by the Authors (with the exception of swivelling the arms and lifting with hydraulic presses), and lowered it astern to take up another ship. In fact, all Morton's cradles, long before this time, were relieved in this manner. As regarded the swivelling of the arms, and the introduction of hydraulic presses to relieve the keel, both systems had been in use on the Clyde for upwards of thirty years. The first set of these swivels were fitted upon the cradle of the Kelvinhaugh slip thirty-three years ago; the cradle was also fitted with a set of Scott's keel-blocks, which could be all started at one lift, one connecting-pipe passing through the whole set; thus the ship was eased up bodily by a single pump. In view of this he could hardly see how the mode of relieving the cradle as described could be claimed as "an improvement introduced of late years." Another improvement which had been made upon slipways by himself was the provision of gates, by which a shorter length of slipway was required. The great length of slipway extending under water, and consequently valueless, was one of the chief drawbacks of a slip-dock. The first design for a dock on this system was made for the Nelson slip-graving dock at Rotherhithe on the Thames in 1854, and was constructed in the following year. Another novel feature in this dock was the form of the ways, which in place of being laid on a straight incline were laid upon a curved incline, the bottom of the cradle being shaped to the same curve, the ways concave and the bottom of the cradle convex. The reason for introducing these modifications was, 1st. For the adoption of gates. The shortness of the available length of ground, laid out at the requisite inclination, brought the level of high-water up to the door of the purchase-house; gates were therefore put in at the river line,

Mr. Bruce Bell. which were shut, as in a graving dock, after the vessel had been hauled up, and the water had ebbed. 2nd. For adopting a curved line, in place of a straight line of vertical inclination, was to avoid the great cost of sinking into the bed of the Thames to the depth required for the extreme end of a straight incline, and the certainty of constant deposit of mud at such a depth. It might be asked why not have made a graving dock at once? The answer to this was the expense of excavation, and the constant expense, at every opening of the dock, of clearing out the mud brought in from the river, and the cost of pumping, all of which evils were avoided in the dock as designed. This dock was unique of its kind, both in design and cost, the latter having been about £5,000. At high water the tide came up to the purchase-house door, and the total length of the slipway was only 356 feet. On the ordinary mode of construction it must have been 500 feet at least. Another dock, combining the dry-dock and slip-dock, was that constructed at Meadowside on the Clyde. It was laid on a straight incline, and had ample room above high-water mark; but to gain the use of some of the submerged portion of slipway, a chamber for the reception of a caisson was placed a little above the low-water line. This slip received vessels of 1,500 tons. The cost of this dock was about £18,000, that of Kelvinhaugh Dock was about £10,000. Complete plans for a graving slip-dock with caisson were made in 1859, and were sent to Stettin to be erected by a Prussian engineer. For a long time after the introduction of slip-docks, the vessels for which they were intended not exceeding probably 300 or 400 tons, and the beaches upon which they were laid (principally on the east coast) having a good range of tide, rendered the laying of the ways a comparatively easy operation by tidal work; but when larger ships came to be provided for, and slip-docks to be built on the Clyde with a range of only 9 or 10 feet of tide, the work of laying the outer end of the ways became difficult. The construction of a cofferdam was too serious a matter to contemplate, and in the first slip-docks constructed on the Clyde, those for Messrs. Barclay, Curle & Co., about forty years ago, the lower ends of the ways were laid upon a long platform of timber, as described by the Authors, and were sunk upon a bed prepared for them by dredging. This was also done with the Kelvinhaugh slip, the platform being about 300 feet long, but in some of the larger slips since made in the Clyde and elsewhere, a much stronger frame-work of timber was required; and in the case of the Meadowside slip, the bed had first to be piled, and the pile-heads cut off to the required line by sawing under water, and the frame-work set on

top of them. The best foundation for the upper end of the large slip-docks where not water-borne, and in fact for the whole of the slipway if made within a cofferdam, was ashlar stones set continuously upon solid masonry or concrete, and the cast-iron rails laid upon them without any timber intervening, the rails accurately fitted to the stone and bedded on flannel soaked in tar. The action upon the rails being a continuous steady motion by rollers of small diameter, closely set together, required a firm unyielding foundation. Mr. Bruce Bell.

The advantages and disadvantages of a slip-dock as compared with a dry-dock were less cost, better circulation of air around the vessel, better light, and no pumping for leakage. Against greater length of ground occupied, the larger amount of scaffolding required, and the great depth to which the after end required to be sunk beyond what was necessary for the draught of vessel. Where ground was of little value, and ample length could be obtained without inconvenience, the great length required for slipway was of little consequence; but where ground was valuable, and powers could not be got to project the slipway into the harbour or river, it became a more serious consideration. In the case of a dry-dock the only portion of the works unavailable for dock-floor was the entrance and gate chamber, not many feet in all. But in the case of a slip-dock a very large extent of dock-floor was rendered valueless. For example, supposing a slip were required for vessels 300 feet in length, such a vessel could be trimmed with ballast so as to have only 11 feet depth of water at the bow, about 3 feet more were required for the cradle and keel-blocks, or 14 feet in all, as depth of water on the rails, at a point 300 feet from the extremity of the slipway. The inclination of the ways would be 1 in 18; this would give $14 \times 18 = 252$ feet of slipway covered with water in advance of this point, which, in addition to the 300 feet, made 552 feet in all covered by water. Of this 50 feet might be gained by allowing the vessel to overhang at both ends, and telescoping the steering pieces as the Authors suggested, but it still left 500 feet covered with water, and valueless as dock-floor. It was true that part of this was generally utilised by allowing the last vessel docked to remain on the cradle to be operated upon by tide work. The choice, therefore, between these two forms of dock depended much upon local circumstances and the means at command. In order to gain additional surface of dock-floor, vessels requiring extensive repairs had in some cases been removed bodily to one side of the slipway. Messrs. Barclay, Curle & Co. worked their slipways on the Clyde

Mr. Bruce Bell. for many years in this manner, and in some cases built new vessels on the side of the slipway, and launched them by removing them on to the cradle.

Sir Frederick Bramwell.

Sir FREDERICK BRAMWELL said he did not know that he had much to say on the subject of the Paper, but it touched incidentally upon other modes of raising vessels for repair, in which he had some experience. He might say after Abernethy, "Read my book," as he believed that the history of the matter, both with regard to slips and to other modes of repair, had been fully dealt with by himself in a Paper read before the Institution of Mechanical Engineers in 1867.¹ It might be interesting to mention a mode of docking ships for repair mentioned in Belidor's "Architecture Hydraulique," in which he suggested that, in lieu of the expense of pumping out a dry dock below the level of the water, there should be, in places where there was a sufficient supply of inland water, a lock made, into which the ship would be floated, and then, the inland water coming in and raising it, it was to be taken into a higher lock, and, the gates being closed, the water was to be allowed to run down; that was a mode of raising the ship out of the water instead of pumping the water away from the ship. There was a good engraving of it in the excellent edition of the book which was in the Library of the Institution. With regard to the telescopic arrangement of the cradle of the slip, the employment of hydraulic power, and the other matters mentioned in the Paper, they were, according to his recollection, quite accurate. Slips and dry docks were useful in cases where there was a suitable foundation; but there were places in which it was desirable to repair a ship where it was impossible to get a good foundation, and in such places it was necessary to resort to a floating dock. He did not think it was possible to make a floating dock at the same small amount of cost for which a slip could be made where there was a good foundation; but it was perfectly possible, by means of a floating dock, to raise very readily the largest ship, to get it up in a short time, to repair it, and to lower it again with regularity and success. A dock that he designed twenty years ago, had been at work for many years at St. Thomas's, in the West Indies, and although curtailed of its original dimensions, it was still competent to raise 3,000 tons dead weight with facility. The sides of the dock were not closed in the manner of an ordinary

¹ Institution of Mechanical Engineers. Proceedings, 1867. "On floating docks and other arrangements for affording access to ships for external repairs," p. 80.

dock, but were open-girder work, and the lateral stability of the dock was obtained by means of floats which worked within the girder-work, and which might be said to rise and fall within that work, the fact being, that the floats remained on the surface of the water, and the dock rose and fell past the floats. The sides being open, there was as much ventilation for the workmen employed, as there was when the ship was upon a slipway. Mention had been made of hydraulic keel-blocks, all coupled together, and subjected to one pressure. He knew that they had been used in London in the floor of an ordinary dry-dock; but he believed they were abandoned because they were found to strain the ship. The notion was to give the ship an elastic bed, and thus to prevent strain; but it would be seen on consideration that blocks of that construction must cause strain because they were all coupled up and were under one pressure, so that if they were all of one size they all had an equal tendency to rise out of the presses in which they were placed. Therefore, whether the part of the ship over them weighed much or weighed little, the upward tendency of the block being the same, the ship had to keep down the block, say at the ends of the vessel where the weight was little, not by the weight of the ship itself, which it could not do, but by acting as a girder, and transmitting to the keel-block so situated a portion of the weight which resided in the central part of the ship. He believed it had been found better to get rid of that water-bed for the ship to lie upon, and let it bear upon rigid points of support at intervals along its length, and he thought that the water-bed difficulty was one of the reasons why the original sectional floating-dock in America, which he saw last autumn, after an interval of thirty years' working, just as it worked thirty years ago, had never met with so much favour as the more rigid slipway, or the more rigid complete floating dock, where a firm floor could be given for the ship to bear upon, although, no doubt, at first sight, the floating support appeared to be one which might accommodate the patient in great comfort.

Mr. A. GILES did not think the advantages were as great as Mr. Giles had been suggested in the Paper. It was called a primitive form of repairing vessels, and the Author went back as far as the days of Carthage. He thought that a slipway, notwithstanding all the ingenuity of the hydraulic process for lifting ships, was a primitive form, and he demurred to the statement that it was applicable to vessels of the largest class. He concurred with Sir F. Bramwell as to the necessity of having a rigid foundation for the keel of a ship. The Authors insisted that where the foundation

Sir Frederick Bramwell.

Mr. Giles. had to be made partly on piles and partly on the ground, there was a liability to settlement or fracture at the points of junction. He quite agreed with that statement: what then must be said as to the foundation that the Authors proposed to lay below the water-line by dredging out a trench, by casting stones into the bottom, and by laying the floating platform thereon? Was it to be supposed that that could be rigid and perfectly true for the purpose of hauling a vessel up? He thought there must be a practical difficulty in laying a slip below the water without a cofferdam, a difficulty that had not been sufficiently explained. He admitted that at such a place as Penarth, where the range at spring-tides was 39 feet, and at neap-tides 29 feet, it would be easy enough to make a good foundation on the shore, but how many ports were there in which there was such a range of tide, and where it was not wanted to dock or repair vessels drawing more than 12 feet depth. There were many ports with less than 12 feet rise of tide, and that being so, there must be a foundation not laid under water upon a heap of stones, but properly laid by means of a cofferdam, which was something very near what was called a dry dock. The Authors also spoke of another plan applicable in situations where there was a sufficient range of tide to enclose the upper part of the slip within watertight walls, provided at the bottom with gates. That statement simply meant a dry-dock; and showed that the system of slips was not quite satisfactory for the largest vessels. The time of getting a ship on the cradle had been taken at one hour, and the hauling up at two hours, but in another place the time had been given as about four and a half hours. If a slipway was laid upon the shore in an exposed situation, as it must be in some places, and would perhaps be at Penarth, it would depend upon the weather whether the ship could be accurately fitted on the cradle before the process of hauling commenced. It was said that since the slipway had been at work in 1879, no less than one hundred and thirty ships had been hauled up and repaired. Taking the time thus given as three and a half years, that would be at the rate of one ship in about ten days. In going into the question of finance, the Authors stated that the slipway would cost £25,000, and that it would be much cheaper than a dry dock. Mr. Giles could only say that many years ago he made a dry dock, which would do all that the slip in question could do, for less than £20,000. Before the slipway was regarded as a financial success, the figures should be examined. Five per cent. upon the cost, £25,000, would be £1,250, and the expenses and repairs might be taken at £1 a day, say, in all £1,600. On

that basis as the cost of docking thirty-five ships, the expense was nearly £50 a ship, a large price for docking a ship of the size mentioned, and he ventured to think that a good many shipowners would object to pay £50 for such an operation. He should like to ask whether, when the Authors spoke of the financial success of the undertaking, they did not include repairs with the charges for hauling up. Another large dry-dock establishment, not far distant, had for many years been worked without profit, until the proprietors took to repairing, and since then they had done very well. Mr. Giles quite agreed that a vessel hauled up had better ventilation, and everything could be better seen than in a dry dock; but in reference to the time required in the dock, it should be borne in mind that the repairs now required for steamships were mostly connected with painting. Iron steamships—and nearly all steamships were now of iron—required docking for painting almost every voyage, certainly every three or six months, and for that purpose they need not be in dock more than two or three days. The average time in dock of a number of vessels in which he was interested was about three days, so that to make a system successful it would be necessary to get vessels in and out once in every three days. The Authors had compared their method with a plan adopted in Philadelphia, at a cost of £163,000. He could not conceive any dry-dock for the purpose of accommodating vessels of the class above mentioned costing so much money. He thought that the objections to which he had referred increased with the size of the vessels. It had always struck him that there was a point at the launch of a ship where it encountered an enormous strain, namely, when she was going off the ways, and the stern was floated while the bow of the vessel hung on the ways. The strain occurring to a ship of great length must be very considerable, and no doubt had necessitated a great increase in the strength of the keelsons and bottom plates. He thought that Mr. Brunel felt that objection when he hesitated to launch the "Great Eastern" end on, and had launched her broadside. He therefore thought that a long vessel, being hauled up the slip, would to a great extent suffer a strain from her stern being afloat while her bow was held fast in the cradle. Of course with vessels of ordinary size the strain would not be so much felt, but with vessels 400 or 500 feet long, he thought the objection a serious one.

Mr. G. W. RENDEL said he had considered the subject of slip-ways for gunboats and other small ships of war, and he certainly thought he saw advantages in the proposals of the Authors as regarded some of the mechanical arrangements, especially those

Mr. Giles.

Mr. Rendel.

Mr. Rendel. to enable the removal of the links to be dispensed with. He had not considered the use of slipways for very large vessels, but he thought there must be great difficulty in finding any site adapted for the very long incline to be made under water, especially where there was no rise and fall of tide. For large ironclads he should say that it would be quite out of the question to compare a slip of that description with a stone dry-dock, or some of the other well-known systems of floating dock. For such purposes as storing gunboats, slipways were evidently well adapted, especially if arranged so that, after drawing up one vessel, they could deposit it and proceed to draw up another. Such small vessels, which were not wanted except at long intervals, could be kept in a better state of repair, with their bottoms always clean, on shore than afloat.

Mr. Owen. Mr. G. WELLS OWEN observed that reference had been made to the fact that Mr. Brunel had launched the "Great Eastern" sideways instead of lengthways. Mr. Owen wished to add that in 1860 he was engaged in constructing the gridiron on which the "Great Eastern" was laid up after her first voyage. It was laid on the shores of Milford Haven, and consisted of balks of timber laid transversely, and fastened down by short piles of timber, or in places where the timber could not be driven, of iron, into the rocky shore at low water. The ship was brought up broadside on, and laid on the gridiron in that way. He had no doubt that Mr. Brunel, in so designing the gridiron, acted on the same principle as in launching the ship.

Sir Charles
Hartley.

Sir CHARLES HARTLEY said that towards the conclusion of the Paper the Authors had stated that they did not advocate the indiscriminate adoption of slipways in every case where it was desired to set up a ship-building or a ship-repairing establishment, but considered that in many situations, with regard to first cost and facility in execution, the slipway possessed advantages which should specially recommend it to capitalists. That modest claim almost disarmed criticism, for it was undeniable that in many places the establishment of slipways for the repair of vessels of moderate size was a good and cheap substitute for dry or floating docks. When, however, it was asserted that "Since then the improvements introduced have been entirely in the details of the apparatus, which, from being at first merely required to deal with the light wooden ships in use at the commencement of the present century, is now constructed for speedily withdrawing from the water the largest existing iron vessels," one naturally inquired where such slipways were to be found, and under what

circumstances they had been built; for although slipways for small vessels were preferable as a rule to other modes of dealing with vessels requiring repair, it by no means followed that the same remark applied to vessels of very large tonnage. It was well known that at the present day there was a perfect mania for building large ships, and that merchant vessels from 3,000 to 5,000 tons were numerous everywhere. Perhaps the Authors could state where slipways were found capable of accommodating vessels of that displacement. The only illustration given by them of a modern slipway was shown in Figs. 1 and 2 for vessels up to 300 feet in length and 2,500 tons gross tonnage, and to that example he would confine his remarks. It was obvious that in rivers, in tideless seas, and where the range of tide was very inconsiderable, such as the Mediterranean, the length of a slipway under water must be very great to accommodate the long ocean-going steamers of the present day. With a slope of 1 in 19 (which, it was said, was a suitable one for a large slipway) the submerged slipway in a tideless sea or a river at very low water must have a length, if curved ways were not used, of at least nineteen times the draught of the ship to be raised, merely to reach her stem; and, in spite of the telescopic arrangement that had been so well described, the slip would require to be further extended to at least one-half of the length of the vessel. Thus, supposing a ship to draw 16 feet and to have a length of 300 feet, the length of the slipway under water would have to be 450 feet—a most serious consideration where the provision of a rigid platform under water at every part was a *sine quâ non*. Again, such a slipway to be successful would require to be established in still water, and that without the use of jetties, which were highly objectionable in situations where strong currents prevailed. He might be permitted to refer to Mr. Labat's system at Bordeaux—alluded to in the Paper—a system of hauling up vessels broadside, and to a similar method adopted with great success at Budapest by Mr. M. Jackson, Chief Engineer of the Danube Steam Navigation Company. In some localities, and especially on the shores of silt-bearing rivers, the plan of hauling up vessels of moderate dimensions broadside on and over greased slipways, as contradistinguished from ways which had rails on them, was the best that could be adopted; and he had no doubt that Mr. Jackson would cheerfully give the benefit of his great experience on that subject. The cost of a modern slipway, capable of lifting a vessel of 2,500 tons, was said to be £25,000, exclusive of land. It would be highly satisfactory

Sir Charles
Hartley.

Sir Charles Hartley. to know what proportion of that estimate was for foundations, the most important and the most difficult part of the structure, and also the nature of the foundations. At Belfast, where a slipway was constructed in 1847 for vessels of 1,000 tons, the foundations had cost £12,000 out of a total expenditure of £17,000, the entire length being only 560 feet. It was a difficult matter to compare the cost of slipways with that of dry docks, sectional docks, and hydraulic lifting docks, unless the peculiarities of each case were well known and carefully considered. Many dry docks capable of receiving vessels of much more than 2,000 tons displacement had been constructed in this country and abroad for less than £20,000 each, although instances might be given of dry docks which had cost from four to eight times that amount. For example, the four graving docks recently constructed at Spezzia had cost £312,000, or nearly £80,000 each, and the Somerset dry dock at Malta had cost £150,000. Such cases, however, were very exceptional; and the same might be said of some of the floating docks recently constructed—notably the iron floating dock weighing 4,500 tons, constructed at a cost of £132,000 by Schneider and Co. at Creusot for Saigon in Cochin China.¹ Those costly works being expressly built to accommodate the largest men-of-war afloat, could not, of course, be usefully compared with slipways and docks built exclusively for the purposes of merchant and passenger steamers. After considering some of the advantages and disadvantages of slipways compared with other arrangements for the repair of ships, he thought it might be fairly said that, except in special cases, the provision of a dry dock was more advisable than that of a slipway in a locality where some of the vessels requiring repair exceeded a length of 300 feet or 2,000 tons displacement. That opinion was strengthened by a letter that he had received from a large firm of shipowners in the north of England, an extract from which he might be permitted to read:—"We decidedly demur to haul a ship of 350-feet length up a patent slip if a floating or a dry dock could be had. We should consider such a vessel liable to strain by being put upon a slip, although we believe that it is occasionally done, for by enquiry which we have just made we find that a steamer of 300 feet in length has been put upon the 'Wallsend Slipway' at Newcastle without any bad results whatever—but they have not had a longer one on. We may mention, however, that this slipway is of recent construction and probably one of the best in the kingdom." He fully agreed with

¹ Minutes of Proceedings Inst. C.E., vol. lviii., p. 380.

the Authors that in setting up a shipbuilding establishment, the choice of a plan should be left entirely to the engineer, after he had made a careful study of the locality, as in all such cases the chief merit would deservedly belong to those who, after a long and patient study of different systems on the ground, chose the method best adapted to the special circumstances of the site where economical first-class ship accommodation was urgently needed.

Sir Charles
Hartley.

Mr. J. B. REDMAN said the value and interest of the Paper would have been considerably enhanced if the Authors had given the tonnage, also the names and dimensions of the largest vessels that had been dealt with by the ingenious systems which they had described. After carefully reading the Paper, he had been unable to arrive at a conclusion as to what was speculative, and as to what had actually been done. He presumed that the example given of a slipway for vessels of 300 feet length, and 2,500 tons, was intended to illustrate the system advocated by the Authors. No doubt if vessels of 4,000 or 5,000 tons (which were becoming so common) could be raised upon slipways and repaired in the same manner as in dry docks, there was manifestly the advantage of light and ventilation; but, on the other hand, the old system of graving-docks gave a level keel, and greater facilities for shoring, as compared with slipways. The objection to a slipway for raising vessels of great weight was met by the advocates of the system by saying, "That is true; but the modern iron vessel is, in the first instance, launched on crossways of a very similar character." No doubt that was so, but the vessel, until she was launched, was in the hands of the naval constructor, and the launching of the vessel was perhaps one of the most crucial epochs of its existence, and launching from the shipwright's ways appeared to him to be a very different operation from that of re-hauling the vessel on to *terra firma*, up a slipway, for the sake of repairs. The Authors had referred to the obvious disadvantage of piling, intermixed with ground of a yielding nature; but he thought they had been rather ungrateful towards a system which had formerly been used in all naval constructions, such as docks, lock-pits, slipways, and other structures where the mass of work rested upon piles. Although the foundations for such works, in the majority of instances where the materials were at hand, were now formed by masses of concrete made with Portland cement, which were got in at a much greater depth owing to the improved mechanical advantages of the present day, still there were situations, especially in the Colonies, where, even at present, piling must be resorted to. To put piling on one side altogether, appeared to him rather to ignore a method that had done good service in constructions of that kind. The Authors

Mr. Redman.

Mr. Redman stated, "After the first starting of a slipway, slight settlements are sure to take place, but are easily compensated by wedging up the rail-bearers when required." He thought that paragraph was very suggestive as to the increased difficulty there would be either in hauling up or in launching a vessel of 5,000 or 6,000 tons, like the "City of Rome." No doubt piling for such purposes was objectionable. There had been an example, on a large scale, in the very great difficulties that occurred in the launching of the "Great Eastern." Notwithstanding all the calculations made with the greatest accuracy, and the care taken with the piling and the preparation of the bed for the broadside launching of that vessel, he believed it was generally acknowledged that it was the slight inequalities arising from the greater bearing power of the piles as compared with the intervening spaces, the very slight irregularity produced thereby, and the increased friction and resistance to the moving mass, that caused Mr. Brunel so much trouble, and possibly hastened the termination of his career. The Authors had further stated, "In a slipway on the Authors' plan at Penarth, the length of ways is 867 feet, and the expense of placing and hauling up a vessel weighing 2,300 tons may be taken as the wages of sixteen men for one hour, and three men for two hours." He should be glad to know whether that was a hypothetical case, or whether such a vessel had actually been handled. The Paper also stated—"Since the slipway was set at work in 1879 no less than one hundred and thirty ships have been hauled up and repaired, without the slightest accident, beyond the breakage of a few rollers at first starting." It would be interesting to know the tonnage of the largest vessel so handled. The Authors had further stated, "There is, unfortunately, little room for doubt that in many instances graving and other repairing docks have been a source of considerable loss." Undoubtedly they were a source of loss when they were dry docks or graving docks only by courtesy, and leaked exceedingly. There were docks on the Thames, constructed mainly by the owners of the yards, that leaked like a sieve, and the consequence was that they were not a very profitable enterprise; but he could give many examples of docks that had been the mainstay of families for three generations, who had lived in opulence upon them. It was a serious charge against graving-docks to say that they had generally been a source of loss. It was also very suggestive, that although the bill for the first great Metropolitan dock—the London Dock—contained a clause for constructing dry docks, the "long shore" interest expunged it, and so with all its successors until the Victoria Docks first obtained the necessary powers. No doubt if vessels of 5,000 tons could be hauled up and launched

in the way proposed, shipowners would be glad to avail themselves Mr. Redman. of them at the reduced cost; but when there was a dry dock into which ships could enter without risk, whether the charge was double or treble, they would probably prefer the dry dock. Everybody knew that even taking a vessel of that tonnage into a floating-dock, especially in a gale of wind, was a rather nervous process, but what would it be to haul a vessel of that description up an incline of 1 in 20?

Mr. W. B. LEWIS observed that it ought not to be taken for Mr. Lewis. granted that every one admitted that the "Great Eastern" was stopped in launching by any settlement in the ways.

Mr. REDMAN supposed the stoppage arose from irregularities in Mr. Redman. the resisting medium forming the ways, which created a variation in the friction to the moving mass.

Mr. T. SUMMERS said it was stated in the Paper that his firm had Mr. Summers. made hauling machinery, which "will no doubt answer well for moderate weights, but it is open to objection when applied to vessels of large dimensions, both on account of the difficulty in making gearing to withstand such enormous strains, and in obtaining wire rope sufficiently large, pliable, and durable." The first slipway on which their system of wire-rope haulage had been used, was on their longest slip, which was set to work January 1879, and had been constantly in use ever since. The ground-ways were on an incline of 1 in 24, and were 622 feet in length, the cradle being 221 feet long, and 82 tons in weight. The engines which worked the hauling gear had two cylinders, each 10 inches in diameter and 12 inches length of stroke, fitted with link motion for reversing them. A worm on the engine crank-shaft, geared into a worm-wheel having fifty-six teeth, and that drove a shaft carrying a pinion with fifteen teeth and 4-inch pitch, which geared into a spur-wheel with ninety-five teeth, to which was bolted the large barrel, which thus made one revolution whilst the engine made three hundred and fifty-five. A smaller barrel, keyed on to the first-motion shaft, was found very useful for hauling up the empty cradle, or for small vessels, and, as it ran six and a third times as fast as the large barrel, it saved much time. The importance of such a means of hauling up the empty cradle quickly had been alluded to in the Paper, but of course, with hydraulic gear such an apparatus would be an additional complication and expense, whereas on the system referred to, that supplementary barrel was only a small portion of the winch. The large barrel was 5 feet in diameter, and 7 feet 3 inches long, and wound on itself a steel-wire rope 9 inches in circumference, and manufactured

Mr. Summers. by Messrs. Bullivant, who guaranteed its ultimate strength to be not less than 180 tons, although they believed it would not break under a strain of less than 200 tons. They had hauled up vessels on this slip, some weighing 1,000 tons, which added to that of the cradle was equal to 1,080 tons, giving 45 tons theoretical pull on the hawser. Their experiments showed that the friction was about 50 per cent., which gave $67\frac{1}{2}$ tons pull on the hawser, or a factor of about one in three. The wire rope after four years' usage was as good as when first set to work. The next slipway on their system was that at Ayr, designed by Mr. J. Strain, M. Inst. C.E., to haul up vessels weighing 1,200 tons, with a cradle weighing 150 tons, and worked by a 12-inch wire rope, also supplied by Messrs. Bullivant, and guaranteed to have a breaking strength of 360 tons. The third slipway where wire rope was used for haulage was their own smaller one. This had been worked for many years with ordinary chain, and, as that was found to be a slow process in consequence of the frequent "fleets," and as the links of the chain when passing over the barrel always bent, and frequently broke, they determined to alter the steam winch to suit wire rope. That had been successfully done, and much heavier vessels than before were now handled by the introduction of a large sheave fixed to the end of the cradle, giving two parts of rope instead of one, with the standing part fastened to an anchor-bolt in the foundation under the steam winch. The rate of haulage with the single part of rope was from 12 to 20 feet per minute, according to the weight of the ship, and vessels had been frequently hauled up in forty minutes after they were blocked. The saving in time and expense of this system, as compared with the hydraulic method, was considerable, and on the first cost probably one-half or one-third. By the introduction of the sheave at the end of the cradle, and so hauling by two parts of the wire rope instead of one, the hauling power was doubled, and, if necessary, a second pulley could be introduced, and the hauling power thus multiplied three-fold, without putting any more strain on the wire rope or the gearing of the steam winch. For instance, it was contemplated to fit the system to a slip suitable for vessels weighing 3,000 tons, to which must be added the cradle weighing 250 tons, or a total of 3,250 tons. Adding one-half for the friction of the cradle, would give a gross of 4,875 tons, on an inclination of 1 in 24, producing a strain on the wire ropes of 203 tons. Messrs. Bullivant guaranteed a strength of 360 tons with a rope 12 inches in circumference, so that two parts of such rope would have 720 tons of ultimate strength. Then 720 tons, divided by the strain

of 203 tons, would give a factor of safety of three and a half. Mr. Summers. As before remarked, that could be increased by adding another sheave, so that vessels weighing 4,000 tons could be easily hauled up. If a small or light vessel had to be hauled up one part only of rope would be used, and the ship would come up rapidly. But, by the hydraulic system, a small and light vessel took almost as long to haul up as a large and heavy one, because of the delay by the reciprocating action of the hydraulic ram whereby one-half in time was lost, and also by the time taken up in "fleeting." Thus if the cradle had to be moved 600 feet, and the hydraulic ram moved 10 feet, there would be 60 fleets, which, at three minutes each, would occupy three hours for "fleeting" only. He thought the system of steel-wire haulage for slipways possessed several important advantages over any other yet introduced, as it was much less expensive to lay down, less costly to work, more rapid in its action, and could be employed for any sized vessel.

Sir JOHN COODE was pleased to have his view confirmed that a re-
pairing slip was a good thing for vessels up to about 2,000 tons, but
he quite agreed that for vessels beyond that tonnage, a dry dock was
in every sense preferable. The mode that had been described of
laying the lower end of the platform was, in his opinion, so far as
he could understand it, not a satisfactory proceeding. He knew the
difficulty attending such an operation; but he thought that to sink
the platform by merely weighting it with stones, and letting it
down upon a dredged bed, which had been equalised by a layer of
rough rubble stone, was not a satisfactory engineering operation.
Where the rise of tide was considerable, and the means of laying
the full length of the slip in the dry existed, a repairing slip might
be used with advantage for vessels of a moderate size. In his own
experience, he had to lay the foundation of a slip in an excavation,
which had been laid under a cofferdam and dried, and there the
foundation from top to bottom was rock. The rails being laid
upon a solid rock, with a thin bed of neat Portland cement inter-
vening, the operation was most successful. But where the range
of tide was small the only thing that, in his opinion, would enable
an engineer to lay a satisfactory foundation, and that would
warrant a shipowner in placing a ship on it, would be to construct
a dam and lay the foundation entirely in the dry. That, of course,
meant a dam of considerable length; and in an operation of that
kind, the difference in expense between a repairing slip and a dry
dock almost, if not entirely, vanished. A slipway was excellent for
a young growing port, and for vessels of a limited size, but for

Sir John
Coode.

Sir John Coode. vessels of 4,000, 5,000, or 6,000 tons, a dry dock was the only safe and proper thing that an engineer could recommend. Looking at the matter all round, it might be said that a repairing slip was good, but that a dry dock was better. He should be glad to know if the wire rope was an endless one.

Mr. Summers. Mr. T. SUMMERS replied that one end of the rope was fastened to the cradle, and the other to the drum. A light vessel, say up to 1,500 tons weight, could be hauled up without stopping, but when a much heavier vessel was hauled up part of her length, the rope would be passed round a sheave at the end of the cradle, making the second part. There was no sheave at the bottom of the slipway. The diameter of the drum, for the 12-inch wire rope, was 9 feet. Their own rope was 9 inches; the pitch of the crown-wheel, working the drum, was 4 inches; the diameter was 10 feet, being twice the diameter of the drum.

Mr. Lightfoot. Mr. T. B. LIGHTFOOT, in reply upon the discussion, said that Mr. Bruce Bell's remarks consisted chiefly of extracts from a paper read by him before the Institution of Engineers in Scotland in December 1858, and related more to questions of priority of design than to any criticism on the Paper. No doubt Mr. Miller was the inventor of the hydraulic hauling-apparatus described as having been introduced by Mr. Morton, though it generally went by the name of Morton's gear. He was not aware that the method of relieving with hydraulic cylinders was used so long ago as the year 1850; but in that also Mr. Bell was doubtless correct. With regard to the time in fleeting on the old system, where the rods had to be disconnected and removed, he could only say that the times given had been taken from actual work at a slipway erected by Messrs. Morton in 1874, and he believed they correctly represented the average, though of course, in some cases, the vessel was more quickly placed than in others, while, if the weight was small, the hauling up took less time than if the full power of the machinery was being exerted. He had read Sir Frederick Bramwell's paper on the floating dock built for the Island of St. Thomas, and other methods of docking vessels for repairs, with much interest, and would have named it in their communication had it not been that slipways were only mentioned in it incidentally, in common with careening and other systems. The same speaker, as well as others, urged the necessity for having an absolutely rigid support or floor for the vessel in place of one of a slightly yielding nature. He regretted that no reasons had been given for that preference, for unless it could be demonstrated that

the majority of vessels of the present day had perfectly straight keels, it seemed to him that a rigid support must be positively injurious. Far from the keels being straight, they were in many instances bent considerably, sometimes to the extent of 4 or 5 inches, that bending being the result of a settlement of the wooden or iron structure, and if, when being docked, the curved keel were compelled to settle down on a level and rigid support, it would be suddenly forced back into a straight line, an action which could not fail to set up most destructive strains. On the other hand, on a properly constructed slipway, the cradle and foundations yielded slightly, and accommodated themselves somewhat to the shape of the vessel. It was for that reason they considered Mr. Bruce Bell was wrong when he advocated a firm and unyielding masonry or concrete foundation, and differed from those speakers who contended that a rigid support was the best. The enclosing of the upper portion of a slip within watertight walls was of course a system only to be adopted in special cases; but it must be remembered, that not only was the amount of enclosing wall much less than that for a dry dock, but the pressures to be resisted both by the walls and by the gates, were also much less; and therefore the cost was comparatively small. The arrangement was adopted not because slipways proper were found to be unsatisfactory for vessels of large size, but to economize length in situations where there was a tide. Mr. Giles had instanced a dry dock constructed at a cost of 20,000*l.*, which would accomplish all that the slipway mentioned in the paper would do. He did not know if Mr. Giles understood that the slipway would accommodate two vessels of 280 feet at one time; but if the dock referred to would do that, there must have been some extraordinary and abnormal circumstances to account for the lowness of cost; and of course under those circumstances, a slipway, if more expensive, would not have been recommended. In relation to the cost of the Philadelphia dock, he could not do better than refer to "The Naval Dry Docks of the United States,"¹ by C. B. Stuart, in which might be found detailed accounts not only of that, but of many similar establishments. Those docks were certainly designed in a most extravagant manner. They consisted of a floating dock, a basin, and slips, and in America were considered at the time as extraordinary triumphs of engineering skill. With regard to the straining of vessels when being placed on the cradle, some such action must take place; but it was obvious from experience that

¹ 2nd edition. 4to. New York, 1852.

Mr. Lightfoot. it was not attended with the slightest damage or injury to the vessel. He might mention the slipways on the Tyne belonging to the Wallsend Slipway Company, the general arrangement of which was shown in the diagrams. There were two ways, placed side by side, and each a little over 1,000 feet long. Since being put to work about nine years ago, nearly nine hundred vessels had been taken up on them without the slightest accident of any kind, the heaviest ship being her Majesty's troopship "Tyne." As additional and important testimony as to the safety and advantage of a slipway, he might perhaps be allowed to quote a few words from a letter he had received from one of the most successful ship-builders of the day, Mr. Charles Mitchell, of Newcastle-on-Tyne, who said: "Speaking generally, I consider a slipway better than a dry dock for all vessels up to 2,400 tons gross register, which represents a screw-steamer about 310 feet long by 36 feet beam, and there is nothing to prevent much larger vessels being slipped, but up to this time it has not been the custom to have stronger slips than corresponds with the above size."

In reference to Mr. Redman's observations, the tonnage and dimensions given in the Paper were those dealt with in actual operation, the tonnage being the gross weight of the vessel itself. In several cases the weight of vessels taken on the Author's slipways had considerably exceeded that for which they were designed. He did not think it was correct to say that the launching of a vessel was one of the crucial epochs of its existence. It appeared to him that the process of launching was as much a matter of course as the putting in of the rivets; accidents in launching were unknown now-a-days, except in a very few instances through gross carelessness. He did not consider that the hauling up of a vessel like the "City of Rome" would present any great difficulty. The question of constructing slipways for the largest vessels was purely a commercial one, and if it could be shown that such an establishment would be likely to pay, he would have no hesitation in carrying it out. The difficulty would be in getting a sufficient number of large vessels to keep the slip fully occupied, as it obviously would be undesirable to use machinery designed for 6,000-ton vessels, for those of only 2,000 tons, excepting in rare cases. This appeared to be the obstacle to the construction of very large slipways. The particulars of wages in hauling up a vessel of 2,500 tons at Penarth were not hypothetical, but taken from a real case, the gross weight of vessel being nearly 2,400 tons. He did not think Mr. Summers's remarks had modified the state-

ments made in the Paper respecting Day and Summers's gear. So Mr. Lightfoot, far, it had only been used in two small slips; and at Ayr, where it was now under construction, the weight of vessel to be dealt with was only 1,200 tons. But even here a 12-inch wire-rope, coiling on a drum of no less than 9 feet diameter, had to be adopted. The arrangement of working with blocks had often been applied, generally with chain, and of course only for small weights. He thought Mr. Summers was wrong in his calculations as to the gearing for 3,000-ton vessels; for instead of a pull of 203 tons being enough, he knew from experience that nearer 400 tons would be required, and therefore the factor of safety would only be about $1\frac{3}{4}$. But the gearing for working such large drums would be so heavy and expensive, that any saving in cost over hydraulic power would certainly disappear long before vessels weighing 3,000 tons were reached, while even for a weight of 1,500 tons he questioned whether the risk of breakage of gearing, failures of wire-rope, and renewal of the same, would be compensated by a reduction of a few hundred pounds in first cost. The hydraulic ram, worked on the Authors' system, only took twenty seconds to fleet instead of three minutes, and therefore the deductions on this head were incorrect; and the same advantages as to speed in hauling up light vessels were gained in hydraulic apparatus as with wire-rope by having the triple-powered arrangement shown in the diagrams.

Mr. JOHN THOMPSON said his remarks would be mainly directed Mr. Thompson. to answering the objections which had been urged against the system of laying foundations under water for slipways without the use of cofferdams; and by a few illustrations he hoped to show that this could be carried out with perfect efficiency and at moderate cost. The various operations would be understood by reference to Fig. 1. When the portion of the site below low-water had been dredged out to the desired depth, the foundation was made by filling in broken stone of convenient size to near the level of the intended platform, upon which a layer of macadam was placed, bringing the foundation up to the required height. As a guide for accurate execution of this work, a line of piles A, was driven on each side of the foundation, clear of the sides of the timber platform, and to these piles guide-timbers B, were affixed at the required inclination of the slipway, and at the depth of the ends of the straight-edge above it. The foundation was now ready to be dressed off true by divers, who, as they frequently had to work in the dark, were provided with iron-faced straight-edges C, made about the weight of a similar volume of water, so as to be easily moved.

Mr. Thompson. These were long enough to reach across the entire foundation, and to slide underneath the guide-timbers. With these straight-edges the divers were able to dress the macadam face so truly, that in one case of a foundation 360 feet long, it was found, after the platform was finished, that there was only one error of $\frac{3}{10}$ inch. The foundation having been thus completed, guide-piles D (Fig. 2), were driven in pairs, about 50 or 60 feet from each end of the intended platform, near the position in which it was to rest, and the platform, which was completely finished on shore, was launched

FIG. 1.

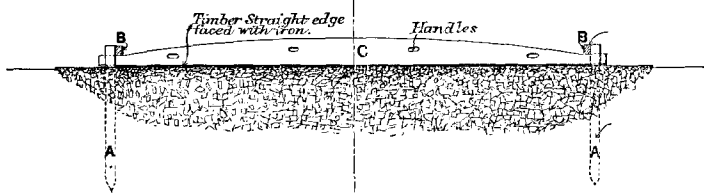
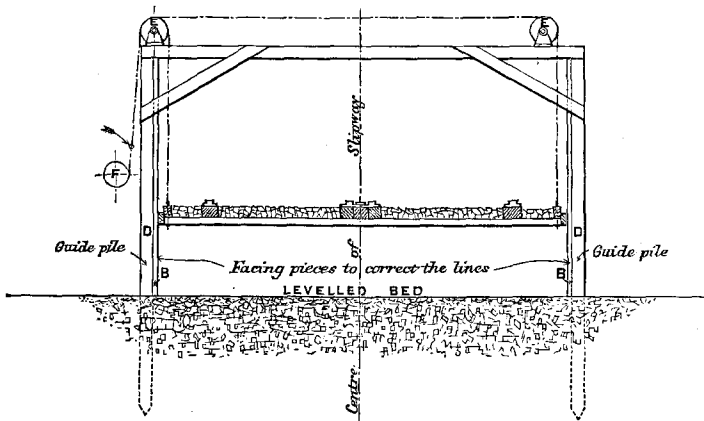


FIG. 2.



like a ship and floated down between the guide-piles. Both the guide-piles D, and the guide-timbers B, were aligned from the shore without difficulty; but in order to obtain complete accuracy, corrected facing-pieces were affixed to the guide-piles, and corresponding facings to the platform itself, so as to bring it in absolute contact with its guides. Chains were then attached to each side of the platform, carried over sheaves E at the tops of the piles, and being brought over to one side of the slipway, were connected together, and then attached to a winch, F, placed on a

barge floating alongside. The scarp joints at the water-line junction Mr. Thompson. were now carefully put into position, and watched to see that they were not displaced during the operation of sinking. Large stones or ballast were now spread evenly over the platform, until there was sufficient weight to sink it, when it was carefully lowered by the winch. In this way any tendency of one side of the platform to sink before the other was prevented, and the platform could be placed in the position intended with certainty and accuracy. In working under water by this system, the expense of divers' work, preparing a foundation for a platform 360 feet long, was about £800; this, however, did not include the cost of slag, nor of the men employed in the barges to convey the slag.

With regard to the statement as to the strain put upon a ship by lifting it with ten or twelve presses off the cradle, he could not conceive how a ship could be much strained by such a process. There would be, no doubt, some strain, but nothing compared to what it was subject to both in launching and in meeting the waves of the ocean. Mr. Giles had spoken of slipways of very large size; but in the Paper, although they were referred to, they were not recommended. In several cases they had recommended their clients not to make slipways for ships of more than 320 feet long and 2,500 tons burden. He might mention the reason for not making such large slipways. As a practical question no doubt they could be made, and would act satisfactorily; but the point was whether there was a sufficient number of ships of, say, 500 feet requiring repairs to render such large slipways profitable. It must be remembered that, although a dock capable of taking a ship of 500 feet could at another tide take two or more ships, so long as their aggregate length did not exceed 500 feet, yet the cradle of a slipway built to take these large vessels could not receive more than one vessel at a tide, however small it might be. In this country, the majority of ships were from 200 to 300 feet long, and the size he had recommended was limited to this, merely to ensure constant employment, without which neither a slipway nor a graving-dock would be profitable in our larger ports. With reference to the slipway at Penarth, the information given in the Paper was obtained about twelve months ago. According to his calculation there was one ship on it every five or six days, and he knew that some ships were on for very extensive repairs. Mr. Giles had put the cost at £50 for each ship; but the charge was not made in that way; it was so much for docking, and so much per ton per tide for rent of the slipway. If a ship went on for extensive

Mr. Thompson. repairs, the cost would be say £10 or £12 for docking, and say $1\frac{1}{2}d.$ per ton per day for rent, so that profit was made by rental as well as by docking. As to the straining of a ship by putting it on or launching it off the cradle, taking the inclination of the ways at about 1 in 20, and remembering that the fore end of the cradle was not more than 18 or 20 inches deep, and the after end 6 feet, he did not think that as a rule there would be more strain upon the ship by placing it on the cradle than by putting it into dock where the blocks were level. In a graving-dock the after end touched the blocks first and strained the ship, but so slightly that it had never been recognised; and why there should be anything said of injurious strain when a ship was placed on a cradle he could not understand. The ship was put on, the cradle was hauled up, and no side-blocks were inserted until the after part of the ship touched the blocks. It did not heel over to the one side or the other, and there could not be a straining when that was the case. Notwithstanding the clear explanation of Mr. Summers, Mr. Thompson still saw great difficulty in providing in the gearing sufficient strength to carry the strain upon the rope. It would require a very large drum, and that necessitated so large a spur-wheel and so large a pitch that he thought its use would be attended with great risk.

Correspondence.

Mr. Godfrey. Mr. G. B. GODFREY only last year had completed, for Earle's Shipbuilding and Engineering Company, Limited, at Hull, the largest slipway that had yet been constructed. He referred to its bearing power for taking dead weight, and the hauling power of the engines. The length of the slipway was about the same as that described by the Authors, namely, 860 feet, and having an inclination of 1 in 25. For the foundations he could not agree with the Authors, that mere "surface dressing" was sufficient, excepting where the ground was rock or other hard material. He thought on all softer ground, piling for the whole length was a superior mode of construction, and less subject to settlement, and consequently less costly in maintenance than ordinary excavation and "filling in with suitable material." With piling, and also the method of construction described by the Authors, the whole structure was so bound together, that any settlement or lateral movement was not possible; but, without piling, there must always be a tendency to unequal settlement of the ways, which, he thought, would not be so easily wedged up as the