Discussion.

The President, in moving the vote of thanks, observed that the Paper must be very interesting to those who had been concerned in the construction and maintenance of marine works of the character described by the Authors. Formerly works of that kind had been almost entirely of either cylinder or timber-pile construction, but the advent of the reinforced-concrete pile had provided another means of construction giving greater permanence than timber piling and probably greater economy than cylinder construction. The difficulty hitherto had been to secure adequate lateral strength to withstand the impact of shipping. That point had been dealt with very ingeniously by the Authors' system of raking piles connected to the deck and by the provision of detached timber piling in front of the jetty, protected again by floating booms. He thought the Authors were justified in assuming that the blows from large ships were not likely to be heavier than those from smaller ships. It had been his experience that most damage was done by small ships, such as fishing-craft and ferry-boats. He supposed less respect was paid to permanent works by those who were accustomed to use them frequently, and, though they navigated their vessels with skill, they did not always navigate them with great care. The President

Dr. Faber remarked that a matter that had not been brought out as clearly in the Paper as it might have been concerned the design of the jetty. The series of vertical reinforced-concrete piles on the front of the jetty was obviously more liable to be damaged by a vessel out of control than was any other portion of the jetty, and one of those piles might be supporting one of the big cranes, so that a serious accident would be involved if the support of that crane was lost. The big cross beams had, therefore, been so designed as to be strong enough to act as cantilevers about the central group of piles, and carry the front of the decking and the crane without assistance from the front piles. Dr. Faber.

Mr. F. E. Wentworth-Sheilds considered that the Authors quite rightly claimed that, without any waste of material, they had managed by means of raking piles to produce what he considered to be an unusually stiff structure. That was very important, not solely from the point of view of the jetty's ability to resist the blows of ships. Early reinforced-concrete jetties were really copied from the old timber jetties, in which stiffness did not matter very much. Mr. Wentworth-Sheilds

Mr. Went-worth-Sheilds. A timber jetty could sway quite considerably without anything serious happening; in fact, the resilience of the jetty gradually brought the ship to rest, and it was rarely that under ordinary handling a timber jetty was broken by the impact of a ship. On the other hand, it was exceedingly important that a reinforced-concrete jetty should not sway. A striking instance of the importance of that had occurred at Southampton, where about 25 years ago one of the earliest reinforced-concrete jetties in this country was built. At the same time, and only a little way away from that jetty, a length of reinforced-concrete wharfing was constructed. The jetty was a three-pile structure built in what he might describe as the timber-jetty style. It was braced diagonally above low water, but there was no bracing below low water, although the dredging alongside was carried to 15 feet below low water. The wharf was a frame for a retaining-wall, built in much the same way with piles and a decking, but backed with earth, so that, while the jetty was free to move laterally to a certain extent, the wharf was almost rigid, because the bank of earth behind it prevented lateral movement, if a ship came against it. In course of time both those structures deteriorated, and there was a tendency, in the reinforced concrete which was above the mean water-level, for the steel to rust and eventually burst off the concrete cover. About 5 years after those structures were built, the deterioration of the jetty became very noticeable, whereas the deterioration of the wharf was hardly visible. That was obviously due to the fact that, whereas the jetty could sway under the influence of cranes working on it and ships bumping against it, the wharf, which also had very many loaded barges bumping against it, was unable to sway, owing to the earth at the back. The Authors had assumed that the raking piles at Bevan's jetty could bear a pull of 59½ tons. That, for a penetration of 12 feet, meant a skin-friction of 1 ton per square foot, and it certainly seemed unusually high, to say the least of it. He thought it was quite probably a correct assumption for such a stiff jetty, but had the structure not been so stiff he would have been very disinclined to assume that those piles would resist such a tension. It would be of interest to know what formula the Authors had used in their calculation of the bearing-strength of those piles. Mr. Alfred Hiley, Assoc. M. Inst. C.E., had recently described[1] before The Institution an interesting formula which took into consideration not only the weight of the hammer, the height of its fall, and the set, but also such factors as the length, weight, material, and condition

[1] Minutes of Proceedings Inst. C.E., vol. 221 (1926), p. 97.

Mr. Wentworth-Sheilds.

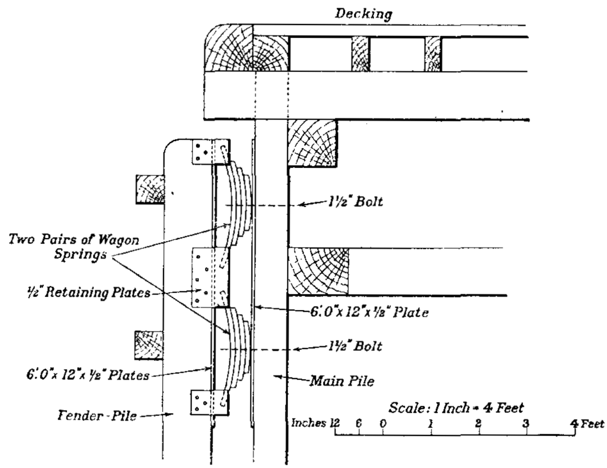
of the pile, and the condition of the helmet. Undoubtedly all those factors made a great deal of difference in the results obtained from a certain hammer-blow, and it seemed, therefore, that the old-fashioned formulas of the type of the *Engineering-News* formula were quite out of date, and that a much better formula was required for such piles as those described, which were very heavy in relation to the weight of the hammer. He ventured to disagree with the Authors' statement that "precast concrete, which was allowed to mature before it was immersed in brackish water, will be much less susceptible to damage than concrete which is covered by the tide a few hours after pouring." It seemed to him that concrete which was covered by the tide a few hours after pouring was the very thing required for the type of structure in question. For that type of structure the impermeability of the concrete was far more important than its strength. A certain degree of strength was necessary, but those who had to maintain such structures would, he was sure, agree that, in order to prevent the kind of deterioration he had just referred to, impermeability was more important. Some very interesting experiments on the permeability of concrete had recently been described[1] by Dr. W. H. Glanville, Assoc. M. Inst. C.E., which brought out clearly that by far the best way to make concrete impermeable was to cure it under water. Therefore, if it were possible (although, of course, it was not) to induce the tide to flow over the whole of the concrete in such a jetty a few hours after it was placed, the benefit would be very great. At Southampton it had been found that concrete moulded in situ between tides always stood excellently, and there had never been the slightest trouble with it. He did not suggest that any improvement could be made in the design described in the Paper; he merely disagreed with the particular statement he had quoted. He noticed that the Authors had specified that the concrete was to be of a certain mixture, the proportions of all the materials, even the water, being laid down, and a certain slump was called for. They further specified that cubes from the concrete were to withstand 3,000 lbs. per square inch pressure at 7 days. That was certainly rather bold and unusual. The contractor had been told exactly what materials he was to use and how to mix them, a particular brand of cement had been specified, and then he had been told that the resulting concrete must show a certain strength! What would have happened if the required strength had not been attained? In a recent work in France the

[1] "The Permeability of Portland Cement Concrete," Dept. of Scientific and Industrial Research: Building Research Technical Paper No. 3, London, 1926.

Mr. Wentworth-Sheilds. engineers had specified the compressive strength of the concrete, the consistency, and the water/cement ratio, taking, no doubt, the experiments of Professor Duff A. Abrams into account. The contractor had been allowed to use any proportions he liked. He thought that was really a more consistent specification than the Authors'.

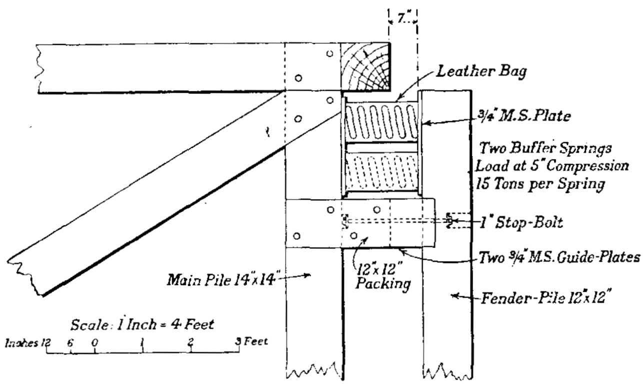
Mr. Du-Plat-Taylor. Mr. F. M. G. Du-Plat-Taylor remarked that an important point in the simple and excellent design of the jetty described in the Paper was that no reinforcement was exposed or bonded below high water. He thought the ideal jetty would be one in which every part below high water was precast, although he agreed with Mr. Wentworth-Sheilds about the importance of maturing concrete under water. That, of course, could be provided for either by

Fig. 10.



watering or by maturing the precast elements under water elsewhere. The difficulty with structures in which joints had to be made between high and low water was that it was not easy to ensure that the exposed surfaces of the steel and concrete were properly cleaned before the next piece was put on. For instance, it was quite conceivable that, in order to make the jetty in question entirely of precast members below high water, the lower brace which united the raking piles and the vertical piles could have been precast and fitted over the vertical piles, the raking piles being subsequently driven through holes in it. That would have required considerable accuracy in driving the piles. The connection between the piles and the bracing, of course, would have to be formed by wedging and grouting. He mentioned that only to show the kind of construction he suggested as the most desirable. On p. 292 the Authors stated that the western half of the area behind the wharf was made up to a level of 4 feet below Ordnance datum, whereas in Figs. 1 it was shown as 3 feet below Ordnance datum. He would be glad to know the Authors' formula for concrete piles driven into chalk. The arrangement of the fender-piles was interesting. It looked, however, as if the rope fender, which was confined in a slot and was never turned round so that the fibres got a chance of being moved, would very soon be as hard as a board. Ordinary rope fenders on board ship, of course, were turned round and round, and the fibres were compressed first one way and then the other, so that they retained a certain resilience. He had had some recent experience with spring fenders for a small timber pier, for which two arrangements had been prepared. In the first, four ordinary Mr. Du-Plat-Taylor.

Fig. 11.



railway wagon-springs were to be fitted (*Fig. 10*). That arrangement allowed a maximum working-load of 21 tons for the four springs, equal to the blow expected from a vessel of 1,000 tons. However, the design shown in *Fig. 11* had been finally adopted. Ordinary railway buffer-springs were used, enclosed in leather bags half filled with grease. Those springs cost only about £1 apiece and could be easily renewed. That arrangement was suitable only for vessels of 1,000 tons, but by fitting more springs it might be adapted to heavier vessels. The hoisting-speed of the cranes (300 feet per minute) appeared to be very high. Had any difficulty been experienced in working them? He had found that dock-cranes hoisting at 260 feet per minute were difficult to operate without accidents. What was the cost of working the cranes per ton of coal or other material handled?

x 2

Mr. Wilson. Mr. M. F.-G. WILSON concurred with what Mr. Wentworth-Sheilds had said in praise of the form of jetty described in the Paper. The raking piles gave very great stiffness to the structure and were very simple to drive and fix. They had, moreover, the great advantage of superseding the diagonal bracing usually inserted in piled structures. He expected jetties of the kind described would be very much used in future. Raking piles had been used in the Dominions, more especially in Canada, and in the United States for some time past, but they had been very little used in this country until now. The rapid-hardening cement had evidently been very successful, seeing that the piles had been handled within 7 days of their manufacture. He could not understand how they had been driven 45 feet through solid chalk; the chalk could not have been really hard. Perhaps there was a pocket of soft material; otherwise that seemed a great depth for them to be driven. The independent fender-piles were also a very good arrangement, far better where possible than piles attached to the concrete direct, as was more usual in this country. Had the fenders lasted well, or did they suffer much damage by blows from ships? He would have thought that, as the jetty was 600 feet long, there should be no difficulty in berthing vessels without the use of dolphins. It would be interesting to learn what formula the Authors had used for driving the piles. A blow of 20 foot-tons seemed very heavy. He had worked out the permissible loading by the Wellington formula, which gave it as 200 tons. One could not, of course, really calculate what blow a vessel would give a wharf or jetty, as there were so many indeterminate factors, but as a matter of comparison the Authors' calculations were very interesting, especially as they showed that the jetty as constructed with raking piles was ten times as strong laterally as the ordinary braced jetty with the same number of vertical piles. Mr. Wentworth-Sheilds had spoken of the maturing of concrete. The piles would be matured, he thought, before they were driven, and his experience was that concrete put in under water in a tideway was more liable to be imperfect than was concrete allowed to set properly and mature in the dry. He generally considered that a concrete block was more reliable and more resistant to sea action than was concrete put in in mass in the tideway, and he thought that was really what the Authors had in mind in stating that those piles would be safer when they were cut above high water than when cutting was done below high water. [Mr. TAYLOR remarked that the Authors referred in the Paper, not to concrete poured under water but to concrete poured in the dry but soon covered.] The Authors referred to the reduction in the strength of the concrete with the increase in water-content of the mixture. That was a point that had received considerable attention lately. They stated that the loss of strength resulting from an increase of water was greater than the loss due to omission of the same proportion of cement; but he thought that applied only to the early stages of maturing. Given plenty of time, the wet mixture would make as strong a concrete as the drier mixture. Mr. Wilson.

Mr. ASA BINNS remarked that many points of detail had already been discussed, but it seemed that the most important question was the general design of the jetty. As the President had remarked, there were all sorts of alternative forms of construction, and the Paper described an ingenious design for a reinforced-concrete jetty unsupported from the shore and exposed to very difficult conditions. He suggested, however, that it had not been essential, from an engineering point of view, to construct that jetty in reinforced concrete. It had been built for cement-manufacturers, who naturally would prefer it to be of concrete, but he thought the question ought to be considered from a point of view quite unbiased by any such consideration. If he were constructing a dolphin jetty of the character described, of similar depth and width, and for loads such as the Authors had adopted, he would prefer to use timber, even to-day. The Port of London Authority at all its lock-entrances had jetties projecting into the river to assist shipping in making the locks. All those jetties were of timber. They were much more severely used than was a jetty of the kind described by the Authors, and that was why the Port Authority still favoured timber construction. Those jetties had a much greater depth of water than the one described, and the problem of stability was quite as difficult as it was in the jetty described by the Authors. A previous speaker had observed that engineers in this country had not adopted raking-pile construction to any large extent. The isolated dolphin jetties in the King George V dock,[1] of which there were seven, were each 500 feet long and 20 feet wide, with a depth of water of 35 feet, and they were completed about 8 years ago. Raking piles were used there in just the same way as at Bevan's jetty, but the jetties had been built in the dry before the water was run into the dock, and it had been possible to brace them in a much more efficient manner than that adopted in the ingenious construction described in the Paper. A jetty situated on the Tilbury side of the river, immediately opposite the jetty described in the Paper, had been constructed in reinforced concrete nearly 10 years ago, of cylinders Mr. Binns.

[1] Minutes of Proceedings Inst. C.E., vol. ccxvi (1923), Plate 8, Fig. 6.

Mr. Binns. with very strong triangular bracing. Between the upper and lower decks was a storage-warehouse. If a reinforced-concrete jetty was essential, that type was quite as good a design as the one which the Authors had described. If a ship moving fairly fast collided with a timber jetty, as had happened to the Port Authority's entrance-jetties at times, the cost of repairs to both ship and jetty was not nearly so serious as it would be in the case of a reinforced-concrete jetty. The Authors referred to the convenience they had found in the use of the Port Authority's floating derrick for transporting the jetty-cranes to the site. They also complained of the cost, as everyone did. He wished to say, therefore, that the Port Authority suffered a very heavy loss annually on those floating cranes, but notwithstanding that they had recently purchased a 150-ton floating crane because they desired to give such facilities. He had recently had erected eighty quay-cranes, weighing approximately 50 tons each, for various docks. They had all been erected on one site, and a floating derrick had transferred them up- or downstream to the various groups of docks where they were required.

Mr. Hurse. Mr. A. E. HURSE remarked that a few observations on the geology of the site would explain Mr. Wilson's difficulty about the 45 feet penetration of the piles into the chalk. When dredging was being carried out it was found that for half the length of the wharf-site the dredging was done entirely in chalk, but farther west something softer was encountered, which he had called marl. On reading a Paper[1] by Mr. J. P. Porter, Assoc. M. Inst. C.E., he had reconsidered the matter, because Mr. Porter referred to transported chalk and rotten chalk, and the question arose whether that might not be the solution of the extraordinary ease with which the piles had been driven at Bevan's jetty, which had greatly surprised him. He had been used to driving piles in other material and had had considerable experience in Belfast at the shipbuilding yard of Messrs. Harland and Wolff. Lately he had done some excavation in chalk for a large works, carried down to about 28 feet below the surface, or 15 feet below Ordnance datum. The level of the water was + 5 feet O.D. In carrying out the excavation it had been necessary to install a 6-inch pump. When a 3-inch pump was used, water lay on the surface of the chalk, and it had been possible to excavate the chalk with a shovel, without using a pick. Before the 6-inch pump was installed he had been able to drive a 4-inch by 4-inch stake 4 feet into the chalk with an ordinary maul. He therefore thought that chalk, as soon as the water left it, was very much

[1] Minutes of Proceedings Inst. C.E., vol. 224 (1927), p. 242.

Mr. Hurse. like French sandstone when exposed to the air. He had asked Mr. Simon Priest, a geologist, whether it was likely that there would be transported chalk on the site of Bevan's works, and Mr. Priest had replied that there was no reason to doubt that transportation of chalk had occurred, considering that the jetty in question had been built right across the estuary of what had formerly been a much more important stream than it was at the present time, namely, the Ebbsfleet. Mr. Priest had referred him to a memoir of the Geological Survey,[1] where there was a reference to a sort of delta which was now roughly the Northfleet football-ground. A well, sunk at the old Tower cement-works there, had passed through 56 feet of alluvium. The Authors of that memoir distinctly hinted—they did not say definitely—that that delta had been deposited by the Ebbsfleet and not by the Thames, as originally the Thames had been much farther north. If that was so, he thought it would be easy to account for it, because at Northfleet bluffs of chalk stood out of the river. As the old Ebbsfleet swung round it deposited a large mass of material round the foot of the bluff, which might account for the penetration of 45 feet. *Fig. 8* showed that the driving of the piles had varied considerably with their position, the penetration per blow being greatest at the west end of the site.

Mr. Williamson. Mr. James Williamson remarked that it was not often that an important jetty structure consisted of such simple elements as did the one described in the Paper. In recent work at two places, carried out according to the designs of the firm with which he was associated, a good deal of experience had been obtained in pile-driving under conditions where chalk was encountered. One was Barking power-station, where chalk underlay the ballast, and the other was at Ipswich, where chalk was reached at a very small depth below the foreshore. At Barking the chalk, so far as it had been examined, was not very hard anywhere. It had been examined in the cable-tunnel, and steel piles had been driven down in cylinders through the ballast into the chalk. At Ipswich the conditions were even more extraordinary than those encountered by the Authors. The work at Ipswich had been done in two sections, one part having been completed a few years ago and the other part being in progress at the present time. In view of the results obtained in the first part, the work in the second stage was being done not on the results of borings, but on the results of driving test-piles. The piles were for a jetty not quite so deep from deck

[1] "The Geology of the Country around Dartford." Memoirs of the Geological Survey of England and Wales. London, 1924.

Mr. Williamson. to river-bed as was Bevan's jetty. The result given by the test-piles had shown that it would be necessary to use piles 75 feet long and 18 inches by 18 inches in section. In one part of the harbour no satisfactory set was obtained after piles had been driven more than 100 feet through chalk, the maximum depth of driving being 148 feet with a pile spliced till it was 171 feet long. Several thousand piles in connection with various works had been made with "Ferrocrete" cement, and regular tests of the cement as well as of concrete blocks had been carried out. The particular difference between the test-results of "Ferrocrete" and ordinary cement was the great strength exhibited by 3-to-1 sand briquettes of "Ferrocrete" cement. The following Table gave average results of a few tests recently carried

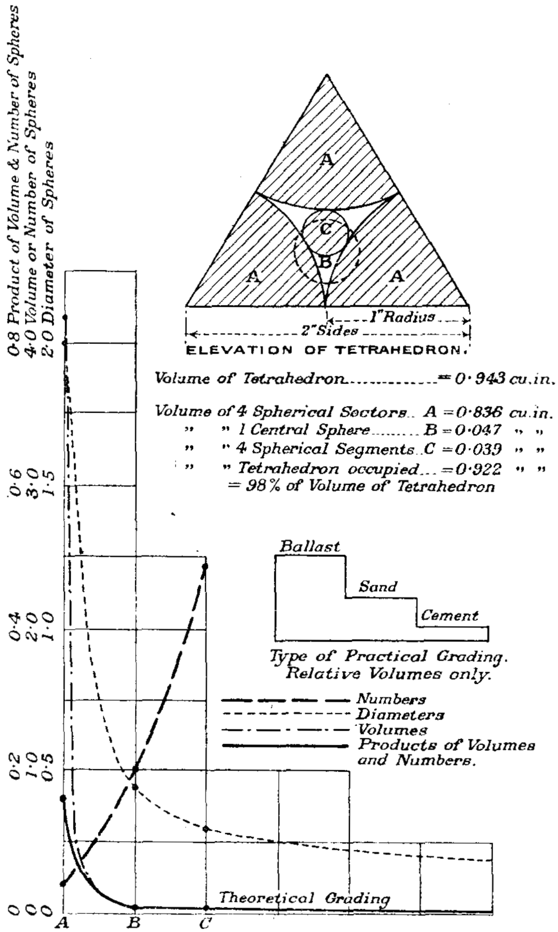
Age.	Neat Cement.	3 : 1 Mortar.
Days.	Lbs. per Sq. In.	Lbs. per Sq. In.
3	790	426
7	950	533
28	..	618

out at a laboratory of repute on cement taken from the job. There was regularity between the various individual tests. At 7 days the 3-to-1 briquettes were almost as strong as the British Standard for ordinary neat cement. A considerably larger proportion of water was required to make the briquettes than was required for ordinary Portland cement. The average results of independent tests for fineness showed that with ordinary cement on a sieve with 180 by 180 meshes per square inch there was 7 or 8 per cent. of residue, whereas with rapid-hardening cement the percentage was regularly less than 1 per cent.; he had known it to be as low as 0·3 per cent., and it was usually about 0·7 per cent. The design of the moorings was discussed by the Authors from the point of view of a ship's knocking against the jetty. In most case it was also necessary to consider the pull that might be set up by the tides or currents of the river in conjunction with the wind. Figs. 1, Plate 5, showed that the jetty lay north-west and south-east, so that a ship lying at it would be exposed broadside on to a south-west wind. It would be of interest to know whether the Authors had considered to what extent that must be provided for, and to what extent allowance had been made in the fixing of the bollards for wind-pressure tending to blow a ship away from the jetty in conjunction, with say, a rapid ebb current in the river. The connection between the fender-piles and the jetty from that point Mr. Williamson. of view might possibly be improved. It consisted of straps round an 18-inch by 18-inch pile near its junction with the main deck, so that whatever pull there was—which he thought in certain circumstances might be quite heavy—would have to be taken by shear on the cross section of the pile. The cross section of the 75-foot by 18-inch by 18-inch piles at Ipswich was almost identical with that of the piles described in the Paper. The main rods in the piles at Ipswich were provided in one length of 75 feet, and it was interesting to know there was no need to splice the reinforcement of piles of at least that length. When the piles at Northfleet had been subjected to hard driving with only a short length in the chalk and the whole of the rest of the length of the pile standing clear, had there been any whipping of the pile under the heavy blows of the hammer? He thought in certain cases it had been found that driving under those conditions tended to cause cracking somewhere near the middle of the length, owing to the heavy blows and the high stress in the pile caused by its lateral bending as a long column. In any case he thought the cross beams would require to be as deep as they were in order to enable an efficient connection to be made with the piles, capable of transmitting the high tensile stress when they were taking a pull of about 60 tons.

Mr. H. J. Fereday, referring to the protection of the rigid Mr. Fereday. structure by flexible fender-piles, remarked that if a 12,000-ton vessel was moving towards the jetty at a speed of 1 foot per second, it was very questionable what would happen eventually to the pier. It seemed to be too high a speed for such a vessel. Probably at first care would be taken that ships never reached that speed, but as the flexibility of the fenders came to be recognized, that speed would probably be attained. He knew that designers of such structures were always in a quandary in selecting the conditions controlling their designs: whether they should be normal with a reasonable factor of safety, or abnormal. He thought the normal design should be taken, with a good factor of safety. It might be that in time abnormal conditions would arise and some damage would be done, but that damage must be repaired. That practice was frequently followed. For instance, buildings were sometimes destroyed in this country by earthquake shocks, but that contingency was not provided for, although steel-framed structures would probably meet the case. Again, trains in some countries had been blown off single-track bridges, but no one thought of building new bridges with wind-screens. It was, therefore, a question of common-sense assumptions together with technical

Mr. Fereday. ability to provide for them; and as far as he could see the structure described met the case in providing for speeds not exceeding 1 foot per second. He had tried to work out the division of pressure between the rope fender on the rigid structure and the three vertical

Fig. 12.



fender-piles, but he could not satisfy himself, because the pressure on the buffer at the top varied with the height of the water. The mention of $\frac{3}{4}$ inch to $\frac{1}{4}$ inch broken ballast (p. 297) suggested grading, a subject which was being considered now more than it used to be. In considering the mathematics of the subject, he assumed a large

Mr. Fereday.

rectangular box with a layer of sand at the bottom, and in that rectangular box he assumed imaginary 2-inch cubes, each containing a 2-inch ball, so that every ball touched six other balls. In that condition those balls were in unstable equilibrium, but if the box was well shaken they settled down so that every ball touched twelve other balls and the balls would be in stable equilibrium. The six lines joining the centres of any four adjacent balls formed the six edges of a tetrahedron, which was one of the five solids with which space could be filled. That tetrahedron contained parts of four balls 2 inches in diameter. Inside the tetrahedron could be placed one smaller ball between the 2-inch balls and four smaller half-balls outside the centre ball and each touching three 2-inch balls. More balls could be added, their size being graded until they were infinitesimally small and infinite in number. The upper curve in *Fig. 12* showed the diameters of the balls, another line represented their number, a third line was the volume of the balls. The thick line represented the product of the number and volume. A peculiarity was that one of the tetrahedrons would take one-fifth of the volume of a 2-inch ball—one ball 0·43 inch in diameter, the next size being 0·16 inch, and so on. The balls mentioned occupied 98 per cent. of the space in such a tetrahedron and left only a small portion for the sand and cement. If no smaller balls were introduced, the spaces could be filled with 3 per cent. of water, and the entire surface of every ball would be thoroughly wetted. It was obvious, therefore, that an equal volume of cement grout would render the whole mass homogeneous. The usual type of grading was as shown in *Fig. 12* (as an inset). Actual practice was so different from the theory he had outlined that it seemed that further investigation might prove of benefit in the mixing of concrete.

Sir Cyril Kirkpatrick.

Sir CYRIL KIRKPATRICK observed that, broadly speaking, he thought the design of the jetty was admirable. It was a little strange that a deck-loading of only 2 cwt. per square foot had been provided for in addition to the point loads. He had no doubt the Authors had had specific instructions as to the loading, but that value, which was usual for an ordinary warehouse floor, was extraordinarily low for such a jetty. A more usual value would be 30 cwt. per square yard, which was not abnormally high. With regard to the question of the resistance of the raking piles to tensile loading, figures for some pile-drawing tests that he had carried out some years ago on the Tyne were of interest. In one case 14-inch by 14-inch timber staging-piles had been driven in connection with the King Edward bridge ; the force required to extract them from 12 to 15 feet of sand and gravel ranged between 35 and 55 tons. At

Sir Cyril Kirkpatrick. another span where there was a depth of 30 to 35 feet of silt and sand, a pull of 55 tons was required to draw 12-inch by 12-inch and 13-inch by 13-inch piles. He did not know how that material would compare with chalk fill, but he thought those figures would be rather reassuring than otherwise. The fenders were very stiff in a direction at right angles to the jetty, but they did not appear to be very stiff to resist the blow of a heavy vessel rubbing along the face of the jetty, because they had a fairly long unsupported span. In Continental practice a single pile was driven in front of the jetty and left quite free, and on the whole that seemed to answer very well. He could only assume, in that connection, that the Authors had solved a rather difficult problem. However, heavier longitudinal blows might be experienced in the future when users got accustomed to the wharf.

Mr. Savile. Mr. L. H. SAVILE remarked that the design described in the Paper marked a forward step in the use of concrete and steel, and it indicated that engineers were improving upon former practice, in which a timber structure was merely copied in reinforced concrete. A timber structure could not be made as stiff as the structure described in the Paper, and the object had been to make the island jetty described as rigid as possible. In the past stiffness had been secured only by the use of either cylinders or monoliths. In consequence he congratulated the Authors on the advance they had made, which he hoped might lead to further and possibly better designs on the same lines. On p. 293 the Authors referred to a 20 foot-ton blow on the piles with a 5-foot drop of a 4-ton monkey. The raking piles, however, had been driven at a slope of 3 to 1, and in that case he did not suppose the full value of the blow had been obtained. At the west end of the jetty the piles had been driven to an extraordinary depth—about 40 feet—in the chalk. As those piles could be made in 7 days, he thought it would have been worth while, when it was realized that very many piles would have to be driven to that great depth, to put additional material on to the toe, so as to double the cross-sectional area of the pile at the bottom, which would have reduced the depth to which the piles had to be driven. He saw nothing impracticable in making a reinforced-concrete pile in that way. When piles were driven with a batter of 3 to 1, he thought there would be a tendency for them to pull away in the earlier stages of driving. Had any trouble been experienced in keeping the piles up against the leaders? Such heavy piles would have been very difficult to hold if they had tended to work the wrong way. There was no reliable information on what the impacts of ships would be, and it had occurred to him that, if the Authors

Mr. Savile.

introduced a hydraulic buffer with a recording-gauge attached to it, in place of the rope packing between the fender-piles and the concrete, in the course of time it might be possible to get valuable information about the impacts of ships. He did not care for the rope packing; it was sure to become very hard, and when it compacted it would leave a gap, so that the pile would bump against it. He would have preferred to fill that space with timber, and instead of using a chain on each side he would rather have bolted the fender-piles back solidly to the wharf. He thought there was no doubt that expensive longitudinal bracing between the groups of fender-piles was unnecessary; but it would have been wise to put a series of struts along at about low-water level and another at about high-water level, which by transferring forces to neighbouring piles would help very largely to resist a heavy glancing blow tending to break off the piles and possibly fracture the concrete arms at the top between which they were free to slide. The depth of cover over the reinforcement in the main part of the structure was given as 2 inches; he had not noticed that the depth of cover on other parts of the wharf was mentioned. That was a very important question. A few years ago he prepared a report[1] on reinforced-concrete structures built for the Admiralty in various parts of the world, and particularly those where damage and deterioration had taken place. That report gave details of nearly forty structures, and showed that deterioration was taking place in practically all cases above low-water level, in very many above mean-tide level, and in many above high-water level. Most of the damage was in the deck-beams, the decking, and the upper parts of raking struts. He was rather of opinion that that was caused by damp air containing salt, which was blown against the structure and forced into it by the wind, thus bringing the salt into contact with the steel and so setting up rusting of the steel, which caused the concrete to break off. The permeability of concrete was now being considered by the Institution Sea-Action Committee, and, with the co-operation of Dr. R. E. Stradling, Assoc. M. Inst. C.E., of the Building Research Board, experiments were about to be made on rendering concrete impermeable. Dr. Stradling did not agree that the rusting of reinforcement was due to damp air blown in; he understood that he took the following view. Portland cement as at present manufactured contained after setting a quantity of free hydrated lime finely disseminated throughout the cement. In all concrete there were very fine surface cracks. When sea-water entered those small

[1] Inst. C.E. Sea-Action Committee. Fifth (Interim) Report (1925), p. 40.

Mr. Savile. cracks it came in contact with the free lime, and the sulphates in the sea-water combined with it to form gypsum. The formation of gypsum caused expansion, and the expansion caused the small cracks to enlarge slightly. This process was repeated with every ebb and flow of the tide until the water was able to penetrate to the steel and cause oxidization. The reason why that did not occur below water, where, as far as his experience went, little or no deterioration took place, was that, once the sea-water had entered the pores, the concrete was not subject to periodical change, and the resulting chemical action was limited to that consequent on the access of a comparatively small quantity of sulphates in solution. Deterioration therefore ceased at a very early stage and no serious damage was done. He thought that was a possible explanation why the failures that occurred in reinforced-concrete structures were not found below water, a fact that had previously puzzled him, and, he expected, others also. When aluminous cement was used, no free lime was present and the causes of decay he had mentioned would not appear to be operative. It would be interesting to know whether there was any evidence that, when aluminous cement had been used for making reinforced-concrete sea-structures, the deterioration above sea-level was obviated. There was another possible means by which the salt might get to the steel, and which would apply with both Portland cement and aluminous cement, namely, the absorption of water charged with any soluble salt that might crystallize out. That might happen even where no free lime was deposited, and the expansion of the crystals would also cause the structure to deteriorate. His object in calling attention to that possible cause of deterioration was that he did not consider that, in important members of a reinforced-concrete work, like the A frame of the structure under discussion, 2 inches of cover was sufficient; the minimum specified now for Admiralty structures was 2½ inches, and for large members he would suggest 3 inches; further, a coating of hot tar should be given to the portion of the structure above half-tide level, so as to prevent the sea-water from coming in contact with the surface of the concrete.

Mr. Gedye. Mr. N. G. Gedye observed that there was no doubt that the advantage obtained by the use of raking piles was very great, and obviated most of the difficulty of putting in bracing in situ in a tideway. From the many examples of reinforced-concrete work in such a situation that he had seen in course of execution, he knew that there was a tendency to rush tidal work so as to get as much as possible done during a tide. In the United States of America raking piles were being used in jetty-construction to an increasing extent. He had recently had occasion to examine the plans of a number of modern American structures, in many of which the piles were driven at an angle of 30 degrees to the vertical, apparently with no difficulty. That was a rather steeper angle than had been adopted at Bevan's jetty. If there was any possibility that the berth in front of a jetty similar in design to that of the Authors would be deepened in the future, it would become necessary to set back the front raking piles in order to prevent them from projecting beyond the fender-piles when such deepening had been carried out. The Authors had shown that the jetty was very adequately stiffened transversely, but with large vessels berthing at the jetty in a tideway such as the Thames at Northfleet, where the tide ran at $3\frac{1}{2}$ to 4 knots at times, there was a chance that a very severe longitudinal stress might be imposed on the structure when such a vessel was making fast or warping in. There were no raking piles and no diagonal bracing of any kind in a longitudinal direction. Had any need for such bracing, or any disadvantage consequent upon the absence of that longitudinal stiffness, been revealed in service? It would, perhaps, have been easy to introduce a few piles raked both ways in the longitudinal plane about the middle of the structure, and that would have added considerably to the stiffness. The method of attaching the floating fenders by wire-rope pendants threaded through the timber of the fender was very good. Had any damage occurred to the wire ropes from their wearing against the fenders, or had the floating fenders been torn from or damaged by the wire ropes? Even if such damage did take place, however, repairs would be simple and cheap. Both shipowners and jetty-owners in certain circumstances strongly objected to fixed horizontal fenders, even when, as Sir Cyril Kirkpatrick had suggested, they were set back from the face and intended to act solely as struts. The owners of a jetty for which he had recently been responsible had objected strongly to horizontal members in the neighbourhood of the face, on the ground that small craft were liable to get caught underneath the fenders on the rising tide, as well as on account of the longitudinal rubbing fenders and strake projections on large vessels. A floating fender, 40 to 50 feet long or more, got over the difficulty Sir Cyril Kirkpatrick had mentioned of the side stress imposed on the fender-piles which had no longitudinal support, because the long floating fender was the member which received the blow of a ship, and any longitudinal component of that blow was transmitted by that member over four or more sets of fender-piles, and therefore the chance that one set of piles would be seriously bent or damaged by a longitudinal Mr. Gedye.

Mr. Gedye. blow was remote. There could be no doubt that a structure such as the one described could be built much more quickly than any form of cylinder construction.

Mr. Jackaman. Mr. C. J. JACKAMAN, referring to the facilities which the design had afforded for the execution of the work, remarked that owing to the absence of the usual transverse diagonal bracing between the piles, which would have had to be done as tide work, much delay had been avoided, because, as soon as each bent of six piles had been driven, the fixing of the timber moulds for the large transverse beams connecting those piles had been put in hand, followed by the fixing of the reinforcing steel and concreting. Simultaneously with that work, the fixing of the shuttering and reinforcement for the secondary beams and decking had been in progress, and concreting had followed. The adoption of the rapid-hardening "Ferrocrete" cement had been an important factor with regard to time, because when the concrete in a few bays of the decking had set, a considerable addition to the working-area had been obtained much sooner than had hitherto been found permissible, and, owing to the isolated position of the structure, both working- and storage-space had been valuable. The construction of the low-level bracing-slab had been left until the tides permitted. Had such unexpected depths of penetration in the pile-driving not been met with, the full advantage which the design afforded for rapid execution would have been realized. As an instance of the possible progress he might mention that as much as two and one-half complete bays—50 feet of jetty—had been completed in 1 week. With regard to the last paragraph on p. 297, dealing with the quantity of water used in mixing the concrete, and in particular the last sentence of that paragraph, he would appreciate any further remarks which the Authors would make on that important point. No doubt Dr. Faber had by experiment arrived at the most suitable quantity of water to be used, which, while giving a resulting concrete of the maximum density, made it fluid enough to be workable. The Authors referred to the absence of any provision for a transverse movement of the special piling-frames his firm had built for the work. As the structure was of uniform cross section it did not appear that any such movement was called for; but Figs. 6, Plate 5, showed that the ends of the braced beams supporting both the pile-driving machinery and the large derrick crane simply rested on the cross-head timber over the top of the temporary staging-piles, and therefore those beams could, as was intended, be moved transversely so as to secure correct alignment. In common with many of the previous speakers, he hoped the Authors would supplement their Paper by giving the formula they had used for the safe load on the piles, as well as the factor of safety they had adopted. It would also be of considerable interest if the skin-friction of the three trial-piles drawn from the foreshore were given. Mr. Savile had suggested that the feet of the piles might have been enlarged to prevent excessive penetration. In some other work he had carried out that had been tried with timber piles for a staging, by bolting on pieces on all four sides. Very little difference had been found in the driving of the piles, but owing to the large hole made in the foreshore the skin-friction of that portion of the pile which would otherwise have been embedded in the foreshore, above the pieces bolted on, was lost, and the practice had to be abandoned. It was a very soft foreshore in the Isle of Wight, and it had been found that an ordinary 14-inch pile used for temporary staging could be loaded to a skin-friction of 5 cwt. per square foot. Mr. Jackaman.

Mr. M. G. J. McHaffie observed that a comparison of the three designs shown in Figs. 5, Plate 5, was very informative. The honours appeared to rest with the type adopted at Bevan's wharf, as regarded both cost and speed of construction, but on those points nothing was said in the Paper. It would be of interest if the Authors could give some sort of comparison in those respects. The Authors stated that the original design provided for dredging to a slope inside the front piles, but that the contractor had preferred to cut steps. He feared it had been a case of Hobson's choice for the contractor. It was not practicable to dredge a slope as such. The usual practice was to dredge out in steps, the horizontal dimension of which in relation to the vertical was a measure of the slope it was desired to form. Although that might appear to be unimportant, it had a certain importance in that it might cause engineers to fear difficulties which did not arise, because, in the driving of piles raking in the same direction as the slope of the ground, expecially in hard material like chalk, whilst considerable difficulty might be expected in retaining the foot of the pile, there was really very little difficulty, the foot of the pile in practice resting on a horizontal bed. The jetty was designed to carry locomotives, but from the cross section it was not apparent how the tracks were to be carried, as the longitudinal beams were 6 feet apart between centres. In the calculation of the resistance to sinking of the piles on the compression side and to lifting on the tension side of the A frame under the effect of horizontal forces, the assumed value of 6 tons per square foot for the ultimate resistance of chalk appeared to be rather low, although the Authors stated that from information gathered from test-piles their assumptions were justified. Assuming that to be Mr. McHaffie.

Mr. McHaffie. the case, they stated that the resistance to drawing in the case of the outside piles was $59\frac{1}{2}$ tons. Applying that to the piles at the east end, which were driven 12 feet into the chalk and therefore had 72 square feet embedded, the skin-friction would be about $16\frac{1}{2}$ cwt. per square foot, which seemed rather high. He agreed that very little information existed regarding the resistance of piles to drawing, and it would undoubtedly be of great assistance if engineers could give further particulars. He had recently been concerned with the drawing of reinforced-concrete piles in a tidal foreshore, which had been driven, about 5 months before, into 6 feet of recently-deposited and therefore fairly loosely-compacted gravel and 7 feet of very fine closely-compacted sand. The piles were T-shaped in plan, with a rectangular stem. The area of the pile in contact with the gravel was 81 square feet, and the area of the stem in contact with the fine sand was 50 square feet, making a total of 131 square feet in contact with the soil. The piles had been drawn by a large floating crane, to the hook of which was fitted an ordinary weight-registering dial. The piles weighed 10 tons each, and the pull required to start movement was 40 tons, which, deducting the weight of the pile, gave 30 tons as the effort required to overcome the skin-friction, or about $4\frac{1}{2}$ cwt. per square foot. He had also attempted to draw some timber piles driven through about 20 to 25 feet of ground, the nature of which was not known, but which was probably clay or sandy clay. Two lighters had been used, each capable of a lifting-effort of 80 tons, and they could not move the piles. It had been feared that there must be some under-water bracing that had got covered by muddy silt, although divers could find no trace of it. Eventually the piles had been dredged out. He thought the Authors had considered all that could be put forward with regard to the method of estimating the impact of ships, and they were entitled to take cognizance of the greater care used in the handling of large vessels as compared with small ones; but there were one or two further points in that connection. Practically every vessel had some individual peculiarity when being manœuvred; some answered to the helm sluggishly and others quickly. A single-screw 5,000-ton steamer which he had in mind had the peculiarity that when she was put astern under her own steam her stern veered to port and her bow to starboard. Knowledge of the peculiarities of a ship was therefore especially necessary when bringing her alongside a wharf. Large ocean liners were berthed entirely by a fleet of tugs, and therefore had no opportunity of displaying any peculiarity. A 12,000-ton cargo-boat, on the other hand, used her own steam to come alongside, and had perhaps two tugs in attendance. When such a vessel used a jetty at infrequent intervals, there was a pilot on the bridge who knew the river, but possibly did not know the ship's peculiarities. On the other hand, a small vessel was handled by her own master, who usually had a pilot's ticket when he used the same port and berth frequently, and he knew not only the river but the ship as well, and was able to counteract any of the little peculiarities his ship possessed. Therefore, because a ship was big and attended by tugs, it did not necessarily follow that she would give a slight blow. Mr. McHaffie.

Mr. F. H. Hebblethwaite observed that the pile-driver used on the work was stated to be a 4-ton monkey with a 5-foot drop. From the slides shown on the screen he had learned that what appeared to be a drop hammer suspended by a rope had been used. That had surprised him, because it was so very slow compared with a steam pile-driver. The efficiency of the ordinary steam pile-driver could be very much increased in a way he had discovered by accident. The old Lecour driver consisted of a hollow cylindrical monkey in which a piston worked. The piston-rod came out at the bottom, and rested on the head of the pile. A three-way valve on the top of the monkey controlled its action. That type had the serious defect that the movement of the monkey to which the pile and the valve were attached frequently broke either the valve or the pipe. He had experienced that difficulty at Santa Fé in 1885, and had overcome it by fixing to the piston a pipe which passed through a gland in the top of the monkey. The valve was attached to that pipe, and the monkey could then go up and down without dragging the steam-pipe with it. That was the machine which the British Steel Piling Company was now making, quite independently of what he himself had done in 1885. That type of pile-driver had been used in 1900 in the Hong Kong Naval Yard extension. The work had been done at night, and there had been complaints about the noise made by the pile-driving. The noise was due, not to the fall of the monkey, but to the exhaust. He had therefore attached a hose-pipe to the exhaust and taken it down to the bed of the sea. That had not only stopped the noise, but had also had a surprising secondary result; the piles had penetrated nearly twice as far with each blow, and the work had therefore been done much more rapidly. The driver had become a condensing engine, and the back-pressure had been removed. Mr. Hebblethwaite.

Mr. Taylor, in reply, expressed the Authors' thanks to the President and other speakers for their commendation of the design put forward in the Paper. The point raised by Mr. Wentworth-Sheilds, that the stiffness of a reinforced-concrete structure was of great value in reducing corrosion, was extremely interesting. Mr. Taylor.

Mr. Taylor. He had not taken quite that view of the value of stiffness before, but the particular case cited afforded ample evidence in that connection. Mr. Wentworth-Sheilds had also suggested that the assumed value for the maximum permissible pull on the front raking pile in the event of a blow from a ship might be justifiable, owing to the stiffness of the structure. It was a very difficult question to decide, but he thought it probably was justifiable, because when a pile was pulled in the ordinary way, it had to be loosened by jerking it from side to side. If the jetty received a blow in the front, such a loosening action would not be appreciable. He thought, moreover, that driving the other piles nearby assisted in tightening the front rakers. Also, in dealing with a pull on those piles the Authors had entirely ignored the pull on the front vertical pile, which would, of course, come into play before the structure could be appreciably moved. In the calculations submitted for the stiffness it had been assumed that the vertical piles bent and that the raking piles did not. In practice he did not think that was strictly correct, but the assumptions were reasonably safe. It was true that concrete put under water soon after it was made was better than concrete made and cured in the dry. But the real objection to placing concrete between high and low water on a job of the kind in question in a tidal estuary was mud. The tide did not allow much time, especially near low-water level, and it was extremely difficult in practice to make sure that the whole of the work was entirely clean before the concrete was put in. There was no fear that the concrete would not set properly if it could be got in in a clean condition. The requirements of the Authors' specification for the concrete had been referred to by Mr. Wentworth-Sheilds. The cement had been fully guaranteed; but, however good the cement or the ballast might be, great importance must be attached to the mixing. He thought it was justifiable to ask the contractor to produce test-cubes of reasonable strength. Hundreds of cubes had been made, and he doubted if more than half-a-dozen had failed to come up to the standard, so that the Authors had not made an unreasonable demand. At the present time he did not think it was practicable to specify the exact quantity of water to be used, unless one was prepared to go to inordinate expense, because one never knew how much water the ballast contained. He regarded the slump test as a useful check, but he wished something better were available. He rather favoured the use of precast members. The jetty referred to in the Paper as having been constructed 20 years ago had precast members and had proved very successful. Even in that case, however, there were of necessity many joints. A perfectly satisfactory jetty could be made with precast members for the decking, etc. But for tidal work, on such members as the bracing-slab of Bevan's jetty, precast work was not so suitable. The piles had been roughened near the position to be occupied by the slab and the slab had then been cast around them. That had the advantage that the slight shrinkage of the concrete served to grip the piles. If that slab had been precast with holes to accommodate the piles, the only shrinkage which could have taken place would have been that in the thin layer of grout; that would have been ineffective in getting any grip on the pile, and the pile would also have tended to become loose in the slab. The Swanscombe jetty, to which the Authors had referred, had had coil-spring fenders, which had proved very satisfactory, for 20 years. He did not think, however, that any arrangement of coil springs that he could devise would be suitable for dealing with 12,000-ton ships, and that was why rope fenders were used in the jetty at Northfleet. Those fenders did get hard—that was inevitable—and they had to be turned frequently and changed occasionally, but he thought they performed quite a useful function. He agreed that a hoisting-speed of 300 feet per minute was too high for cranes in ordinary work, but that speed in practice usually referred only to the hook returning light. Doubt had been expressed by Mr. Wilson whether the 45-foot penetration of the piles really was in solid chalk, and he shared that doubt. It was not possible in the bed of a tidal river to explore the bottom adequately unless a caisson was put down under air-pressure, and the work at Northfleet had not warranted the expense of that. The Authors had, therefore, had to rely on borehole exploration, which was admittedly unsatisfactory. Nearly all the mud had been dredged away and there was chalk a very short distance below the bottom of the dredged bed. How hard that chalk was, only the driving of the piles could show. The results had shown a wide variation in hardness and had proved that it was impossible to predict—even with chalk which was supposed to be a very uniform material—what the penetration would be. No one had imagined that the piles would be driven more than 40 feet into solid chalk—in fact, the contractor had expected difficulty in driving them 12 feet—but the eventuality had been anticipated and all had gone well. The damage to the fendering had been very slight indeed: one of the floating booms had been broken and one of the rubbing-pieces on the fenders damaged. The ships that came alongside were mostly large, and they were handled with extraordinary care. The dolphins at the ends of the jetty were very useful for mooring ships. Mr. Wilson had rightly remarked that a ship could easily moor against a jetty 600 feet in length, but the jetty in question was frequently used by two steamers and sometimes by three, and it was useful to get the

Mr. Taylor.

Mr. Taylor. bows and the sterns well beyond the ends of the jetty. The dolphins were very much cheaper than an additional length of jetty, and they increased the effective length of the structure for mooring purposes. The actual cost of the jetty was about £90 per linear foot, and therefore to have added 150 feet to it would have cost about £13,000, whereas the two dolphins had cost only about £4,000. The dolphins also served as some protection against damage to the ends of the jetty. The jetties in King George V dock, cited by Mr. Binns, were in some respects similar to the Northfleet jetty; but Mr. Binns had had the advantage of constructing them in the dry, which would have been impossible in the case described in the Paper. Mr. Binns had also expressed the opinion that the jetty might just as well have been of timber and was of concrete only because it served a cement-works. That was not the case. The Authors had been responsible for a good deal of timber work in suitable cases, but they did not think the present case was suitable. The jetty was situated in the open river, very near to the fairway, and jetties in such tidal rivers were exposed to great risk of damage. The problem had been to build a jetty which was not only satisfactory but also attractive to big steamers. They were dealing with a new class of trade, and it would have been no use putting up a jetty if the steamers would not lie there. The cost of handling cement over the jetty direct into the steamers was very much less than that of loading it into lighters, taking it to London, reloading it by stevedores in the docks, and so on. Those commercial questions must affect the design. The Authors, therefore, considered that a very stiff structure was essential, and he thought there could be no doubt that that had proved to be the case. Mr. Binns seemed to think that a virtue of a timber jetty was that, if a steamer ran through the middle of it, it would not take long to repair. He admitted that timber work could be repaired very cheaply and easily; but that was not quite the point: a jetty which could be cut in two was undesirable, because the loss of the trade on the jetty was a far more serious matter than the mere cost of repairs. For many years he had tried to see all the various cases of damage that had occurred to jetties on the Thames. A prominent feature of those accidents was that in almost every case the area damaged by a blow to a concrete jetty was very much less than would be involved in a timber jetty struck by a similar blow. He did not think there could be any comparison between the strengths of the two types, and that was largely due to the great strength of the reinforced-concrete deck, which at Bevan's jetty was a horizontal beam 40 feet wide and 600 feet long. It was strong enough to bring a very large number of piles into action to resist the force of

Mr. Taylor. a blow, in addition to which the inherent strength of the deck prevented a ship from cutting so far into it as it would into a timber deck. It would be impossible to reproduce the strength of a deck of that character in any practicable form of timbering. The use of timber for the controlling-jetties at the approaches to dock-entrances had been referred to by Mr. Binns; but those jetties were built primarily as moorings and fenders and were therefore built with a view to being knocked about. They were comparable to the timber dolphins used in the work described in the Paper. If they were knocked about it did not matter very much, so long as the main structure was not damaged. With reference to Mr. Savile's remarks about the driving of the rakers, the Authors had relied largely on the information given by Mr. Wentworth-Sheilds in connection with the dolphins for the Southampton floating dock. The records of the piles at Bevan's jetty did not seem to indicate that the driving was any less efficient on the rakers than on the verticals.

Dr. Faber. Dr. Faber, in reply, observed that there was no doubt that the corrosion of the steel inside a reinforced-concrete jetty was of great concern to engineers. Some of the early jetties had been designed without reference to that question, but experience had now been gained, and modern reinforced-concrete jetties could be designed to have a much longer life than timber jetties. The reinforced-concrete jetty at Swanscombe, which had already been referred to, had been built in 1907, and although at that date information about corrosion was relatively scanty, yet that jetty had shown no sign of corrosion in 21 years except on the under side of the deck beams, where the cover had been less than was considered best practice to-day, and where in some places the concrete had had to be renewed. There seemed to be no reason why that jetty should not have a very long life. An interesting point had been raised by Mr. Wentworth-Sheilds, namely, whether the Authors were justified in claiming that it was an advantage of the type of design described that reinforcement below high water was not exposed in order to make joints within the height that was covered and uncovered by the tide. He agreed with Mr. Wentworth-Sheilds that in order to make a watertight concrete—which was important as regarded corrosion—it was best, where it was possible, to cover the concrete with water as soon as practicable. He thought the reason for that was undoubtedly that when cement or concrete hardened under water it expanded, whereas when it hardened in air it contracted. If concrete contracted round stiff reinforcement it was put into a state of tension, and there was a tendency for hair cracks to develop, which were weaknesses as far as corrosion was concerned; whereas, if the concrete could be hardened under water, the

Dr. Faber. interaction of the expanding concrete and the steel reinforcement put the concrete into compression and the steel into tension. The concrete in compression did not tend to open or give air or sea-water access to the reinforcement. But another important point was the difficulty of making really good concrete near low-water level in a tideway where the water was running at 3 or 4 knots. Such work was not very satisfactory, and it was better if it could be avoided. Even with the bottom brace of Bevan's jetty there had certainly been difficulties. The timber shuttering, which was about 40 feet long and 7 feet wide, tended to float and had to be clamped tightly to the piles. Between the depositing of concrete and its being covered with water about 2 hours might elapse with spring tides and less with neap tides. It had been necessary to nail boards on the top of it to prevent the water from scouring the cement away. Where the concrete had not been covered, the surface had been badly eroded and had had to be remade. Possibly the best compromise was what had been done in the present instance, namely, to make the piles on land and keep them as wet as possible during the first week; then, when they were hard enough to be handled, to submerge them, so that hardening was completed in the river, and to avoid cutting into the reinforcement or making joints in the structure below high water. Comment had been made on the fact that the Authors had specified the composition and at the same time the strength of the concrete. Mr. Jackaman had not made any complaint on that account. He did not think it was an unreasonable course if a reasonable strength was specified. It was possible to so maltreat excellent materials that no proper strength was obtained, and he thought an engineer was justified in seeing that that was not done. He did not think the time had yet come when it was advisable merely to specify the strength of the concrete and to allow the contractor to make it of anything he liked. It had been suggested that that was done abroad. But strength was only one of many qualities which the concrete ought to have: supposing for purposes of argument that a 12-to-1 concrete were made which had a satisfactory strength, it would still be lacking in adequate resistance to corrosion and many other essential properties. He agreed with what Mr. Taylor had said regarding pile-driving through the chalk. Boreholes were unsatisfactory because, though they indicated what the material was, they gave no information about its condition. He had failed to follow Mr. Binns when he said that he would have made the jetty described in the Paper of timber. Mr. Binns had shown two slides of reinforced-concrete jetties which the Port of London Authority had constructed comparatively recently, both of which, he believed, were giving excellent service in every way. He did not think Mr. Binns could give an example of a timber jetty, recently constructed, and designed primarily as a platform to carry heavy cranes. If a ship were to force its way through a timber jetty of that kind—which Mr. Binns had shown it could so easily do—it would be disastrous if a large crane was standing just where the ship went through. The remarks of Mr. Fereday on the voids in concrete treated mathematically by a consideration of spheres of different sizes had interested him, because he had also tried to work out something on those lines. Mr. Fereday compared a modern specification with the ideal curve connecting the number of spheres with their size. That diagram showed a wider disparity than actually existed, because the ballast and sand were themselves in practice very considerably graded, and further, the ideal curve could never be realized in practice, because the small particles, instead of finding their way entirely into the spaces left between the large particles, to a certain extent got between the large particles and so separated them. A mathematical theory which did not take that into account was not entirely satisfactory. It had been questioned whether the Authors were justified in taking so high a value for the friction against the withdrawing of piles on the tension side when only 12 feet of penetration had been obtained. They had given their arguments for what they were worth. A good many piles had been driven into the chalk and withdrawn by means of a barge. The submergence of the barge in the process of drawing had been measured and the pull had thus been estimated. That pull had seemed to justify the figure adopted. It had been checked by ascertaining the blow required to drive the piles and subtracting from the bearing-value the estimated portion of the load carried by the end bearing, the balance being of course the side friction available. Sir Cyril Kirkpatrick had given figures on the same subject which seemed in very close agreement with those the Authors had obtained. When the design for the jetty was first prepared it included a horizontal timber fender, three piles deep, just above low water, and another just above high water, which were to be connected to the fender-piles so that the sliding blow of a ship would be transmitted over a large number of fenders; but Mr. Taylor persuaded him not to employ it, because he did not expect that much damage would be avoided in that way and a big capital sum would be locked up in something which could always be added later if necessary. Up to date no appreciable damage had resulted, and the floating boom, which was one timber instead of the six he had originally proposed, certainly seemed to answer all requirements. There was also the point that, if a sliding blow hit one particular fender, the damage would be localized, instead of Dr. Faber.

Dr. Faber. possibly involving several fender-piles. It had been suggested by Mr. Savile that the blow of a ship might be measured by a hydraulic gauge at the top of the piles, in place of the rope fenders. He thought that was a very interesting suggestion and hoped it could be carried out. It might, however, be better to have a pneumatic gauge, which would have a certain elasticity. A hydraulic gauge might record a much heavier blow than would actually be obtained in practice, because it would not be so elastic as a rope fender. The depth of cover of concrete would be found in Fig. 3, Plate 5, where it was given as 2 inches. Aluminous cement undoubtedly resisted the action of sea-water very satisfactorily, but its price at present was prohibitive. The longitudinal stiffness of the jetty had been mentioned by Mr. Gedye. It so happened that about 80 feet of the jetty had been completed and put into use before the rest was constructed. On that portion a certain longitudinal vibration had been noticeable, as would be expected, but when the jetty was completed and when the original number of piles contemplated had been driven and connected, no longitudinal movement was noticeable. The trestles were not in one plane, and the four raking piles were really two trestles side by side, which were stiffened by the horizontal slab and so had considerable longitudinal rigidity. The longitudinal stiffness of the crane-beams with the big cross girders was, of course, very considerable. Before the jetty as a whole could be deflected longitudinally it would be necessary to bend about 120 stiff connections between those longitudinal beams and their respective cross members. The wire ropes and their connection to the floating boom had so far given practically no trouble, and he thought the arrangement was economical and satisfactory. It was rather difficult to give relative costs in a useful manner, because the costs of the jetties shown in Figs. 5, Plate 5, were not comparable. Bevan's jetty cost about £90 per linear foot, whereas the Swanscombe cylinder jetty had cost about £20 per linear foot, but the latter had been built in 1907, and it took only a vessel of about one-third the size of that using Bevan's jetty. The question of cutting steps in the dredging had been mentioned by Mr. McHaffie. In the first design a uniform slope was shown for the dredging, and the experts of the dredging company had said that it must be stepped. That had been agreed, and it was shown as stepped on the drawings. When the work was in progress the dredging-master at one stage explained that he was following the drawing as closely as he could, but he rather wished the step had been shown as a slope! He gathered that it must be possible to do it either way. He agreed with Mr. Hebblethwaite that the worst noise of a steam-hammer came from the exhaust. That had been found in the pile-

Dr. Faber. driving at the site of the new offices of the London Electric Railways at St. James's Park station. There the trouble had been cured by silencing the exhausts of the pile-drivers. The steam pile-driver was not very suitable where it was desired not only to drive the pile into the ground but also to fix it firmly when it was driven. The large number of blows of the steam pile-driver, as compared with a few heavy blows of the drop hammer, undoubtedly caused much more vibration in the surrounding soil. Some of the timber piles driven at Northfleet by a steam-hammer had actually come up again and floated away. When they had been driven by a drop hammer to the same depth they remained fixed in the chalk, so that for that particular purpose a drop hammer was much more useful.

Correspondence.

Mr. Case. Mr. A. Havelock Case observed that the piles apparently had been unduly punished, having regard to the load that they would have to carry; and a minimum penetration of 12 feet into the solid chalk seemed to be somewhat unnecessary, unless it was to provide for that factor of the design required to resist the drawing of the piles by an overturning-moment. Interesting information was given (p. 293) regarding the resistance of piles to extraction, but it was well known that the resistance of piles to drawing varied within wide limits, even with piles of the same structure.

He suggested that the effect of a blow from a ship coming alongside, serious enough to overturn or even materially damage the structure, would not necessarily draw the raking piles, but would probably displace the deck by bending the piles to the point of fracture, and cause them to break away from the under side of the deck-beams, the stiff deck being strong enough to withstand the blow, but the piles failing to do so. The three horizontal comparative forces P indicated on Figs. 5 were suggestive, and were closely involved with the interesting question of impact of ships dealt with on p. 293. The Authors gave the kinetic energy of a 12,000-ton ship moving at a speed of 1 foot per second as 187 foot-tons. He gathered that that was arrived at by applying the general principle of gravity units thus: $(12{,}000 \times 1^2)/(32 \times 2) = 187$; but he suggested that gravity, or the force of impact due to falling bodies, was not the only one applicable to a ship moving under the influence of some horizontal force, such as its own steam or the wind, any more than it would be to a locomotive charging into a buffer-stop or a projectile coming in contact with an armour-plate. It was optimistic to