Discussion.

The President. The PRESIDENT, in moving the vote of thanks to the Author, remarked that very often the skill and ingenuity required to carry out such a reconstruction as that described in the Paper was not evident from the finished work. He noticed that the pontoon at the head of the pier was destroyed in 1869 and had never been reconstructed, and that in its place the existing two slopes had been made. He did not quite know what those two slopes were, and perhaps the Author might further explain that matter. He would also like to know something about the timber of the old pier.

Sir Cyril
Kirkpatrick

Sir CYRIL KIRKPATRICK remarked that, as the Author was not the designer of the work but the contractors' engineer, he would deal mainly with certain matters affecting the contractors. He would appreciate the Author's views on the question whether, from the point of view of sinking the cylinders, to have the whole interior of the cylinder under compressed air—as had actually been done—was more satisfactory than the alternative method of employing a shaft leading to a working-chamber at the bottom of the cylinder. For the former method, as adopted, the kentledge had to be placed on the top of the cylinder, which was always rather dangerous; and he wondered whether, from a contractor's point of view, it would not have been more satisfactory and perhaps more economical to employ a shaft with a working-chamber at the bottom and to use the space between the inner and outer skins for the kentledge, which would avoid the necessity of putting all the weight on the top. The steelwork of the cylinder extended from the base upwards to the bottom of the taper piece, and above that point the cylinder was of cast iron. All that cast iron had been subjected to air-pressure, and he was inclined to think that that was rather dangerous, and that it would have been more satisfactory to make the whole cylinder of steel. Alternatively, the cast-iron outer skin could perhaps have been used down to the working-chamber, because it would not have been subjected to air-pressure. The answer might be that the proof of the puddling was in the eating, but he would like to have the Author's opinion on those two points. He thought it would have been more satisfactory if the junction between the cast iron and the steel had not been made at the angle of the taper portion. What had the joints been caulked with? He presumed that the ordinary mixture of iron filings and sal-ammoniac had been used, but he would be glad to have particulars of it. He did not understand the variation in the level of the bottoms of the cylinders shown in Fig. 5, Plate 6. Was the explanation that they followed a variation in the

strata? If so, it seemed rather strange that the variation was so wide and, moreover, almost uniform on the two sides. Another explanation might be that the strata were much stiffer at the sides. Apparently the waybeams came immediately over the rail-bearers, and presumably they were fixed directly to them. It appeared that the rail rested on the double waybeam, which rested on thin concrete carried on the cross girders and rail-bearers. He thought that was rather a weakness, from the point of view of deterioration likely to be caused by the penetration of moisture, and that a loose road, if it could have been laid with very little ballast, would have been preferable.

Sir Cyril
Kirkpatrick.

Mr. A. C. GARDNER observed that the reconstruction of New Holland pier had engaged the attention of the railway-company for some time before the war, and plans had been prepared and designs got out with that object in view. The war had caused the matter to be deferred; but, with the object of conserving the pier in use as long as possible, several thousand pounds had been spent on strengthening it with new timber; and the permanent way, which had consisted of two tracks throughout the length of the pier, had been taken up, and a single line had been laid down the centre of the pier in its place. Further, the locomotive weights permitted on the pier had been very much restricted. By those conservative measures it had been possible to use the pier for railway-traffic until after the war, and, in fact, almost up to the time of completion of the first contract to which the Author referred. During the work in connection with contract No. 1, as soon as it became necessary to demolish the old timber, the inherent weaknesses of the structure had become manifest; and, as the engineer responsible for the safety of the structure, he had advised that all railway-traffic upon it should be stopped. That had occurred in the early part of 1923, and from that date onwards the work of reconstruction had proceeded without undue interruption. The Author referred to the condition of the old structure. It had certainly not been renewed before its time; but, having regard to its age, to the difficulties that must have operated in those early days of railway engineering, and to the fact that it had been constructed in a tidal estuary where the speed of the current often exceeded 8 knots, he certainly regarded it as a tribute to the skill of its early builders. The Author made reference to the harbour and dock adjoining the pier. That dock and harbour were constructed by Sir John Fowler at the same time as the pier was built, and the Author referred incidentally to the fact that hydraulic machinery had been installed there for the handling of goods. He would like to correct a point in the Paper with regard to that, for, though it

Mr. Gardner.

Mr. Gardner. had no immediate reference to the pier, it was a matter of great historic interest. The working hydraulic pressure at New Holland

Figs. 17.

LORD ARMSTRONG'S ORIGINAL HYDRAULIC ACCUMULATOR.

was 600 lbs., not 500 lbs., per square inch. Up to the time when that machinery was installed, hydraulic pressures had been limited to a

maximum of 90 to 100 lbs. per square inch. Lord Armstrong, Mr. Gardner, who was responsible for the work at New Holland, had considerable difficulty in finding a foundation to carry a water-tower high enough to ensure a pressure of 100 lbs. per square inch, and as a result he sought an alternative. That alternative was the invention of the hydraulic accumulator—one of those ingenious devices which had made his name famous throughout the world. The first hydraulic accumulator was erected at New Holland, and the working-pressure was increased in one step from 100 to 600 lbs. per square inch. That hydraulic accumulator was still at New Holland; and although it was no longer in use, Mr. Gardner had made a point of preserving it because of its great historic value. A drawing made from dimensioned sketches of the accumulator itself was reproduced in *Figs. 17*. The Author's description of the reconstruction was so clear and concise that he had very little observation to make upon it, except perhaps in reference to a point with regard to the shuttering (p. 137). The Author stated there that, in order to obtain a good face, the shuttering should be removed as soon as possible, and that at New Holland it had been removed on the day following the pouring. That might be a little misleading unless it was qualified by the statement that it referred to the side shuttering only. The shuttering beneath the beams had been allowed to remain in place for very much longer. Although the Paper was entitled "The Reconstruction of the New Holland Pier," it would be more correct to describe it as "The 90-per-cent. Reconstruction of New Holland Pier," because the slopes at the pierhead had not been renewed. The Author drew attention to the fact that the original iron pontoon at the pierhead was destroyed by a storm in 1869. The slopes constructed in place of it had been only a makeshift, although they had persisted in use ever since. They had certainly done yeoman service. At the present time, with the largely increasing traffic across the Humber, which had recently necessitated the building of another ferry-steamer, and with the increase in motor-traffic which was deterred from using the ferry because of the difficulties, it would seem that Sir John Fowler's original pontoon arrangement was one which it would be well to revert to when the time came for the pierhead to be reconstructed.

Mr. J. S. WILSON observed that the Paper contained very interesting information and data with regard to the cylinders. The account given of the old timber work was of extreme importance. The fact that it had stood in that exposed position for as long as 80 years was good evidence in favour of the durability which timber always seemed to exhibit. Engineers were not unanimous about the proper method of covering steel in order to protect it from corrosion. A

Mr. Wilson. great deal of care had been taken in the instance under discussion to cover the steelwork with concrete, with the object of preserving it, and a large sum had been expended on the work. He had no doubt there were very good reasons for adopting the method, and he was sure the members would like to know them. The adoption of concrete for all purposes was very forcibly urged by advocates of reinforced-concrete construction, and it was sometimes suggested that as soon as concrete came in contact with steel some kind of magical change took place, not only in the concrete but also in the steel itself, and that the structure was immediately made stronger. But there were peculiarities of concrete that were disturbing. For instance, a few years ago, in some experiments made at the National Physical Laboratory,¹ samples of concrete had been exposed to the weather and very careful measurements had been made for 3 years. Those samples had extended 10 to 20 parts by length in 10,000. Dr. Oscar Faber, M.Inst.C.E., had produced² experimental evidence that concrete shrank to the extent of 5 parts in 10,000 in the course of 60 days, and 6 parts in 10,000 in 440 days. The relationship of the stress in the concrete to the stress in the steel in reinforced concrete was, of course, governed by the relationship of their moduli of elasticity. With concrete definitely attached to steel a stress of, say, 4 tons per square inch in that steel would produce a strain in the concrete of 3 parts in 10,000, which in tension would be more than sufficient to crack it. With round or square bars completely embedded in concrete, as in reinforced construction, the adhesion to the steel was assisted by the grip of the surrounding concrete, but the large girders and joists in this case presented wide flat surfaces, such as the 2-foot-wide flange-plates of the main girders, where there was no appreciable grip to assist the adhesion. In view of the facts that the repeated strains in the steel due to live load might be 3 parts in 10,000, that the concrete, when put on, might in weathering extend 10 to 20 parts in 10,000, and that later it might gradually contract 5 or 6 parts in 10,000, it would be difficult, without actual experimental proof extending over many years, to feel satisfied that a covering of concrete $1\frac{1}{2}$ inch thick on those flat surfaces could adhere satisfactorily to the steel. He had observed a number of cases where concrete had been put in contact with steel, and in many of them it had not remained but had come off after some time. The work which the Author had described was important; those responsible for it had very wide experience; and he hoped that in support of what had been done to preserve

¹ National Physical Laboratory Report, 1927, p. 144.

² Minutes of Proceedings Inst. C.E., vol. 225 (1928), p. 27.

the steel some evidence of the permanent character of the protection Mr. Wilson. might be forthcoming.

Mr. M. B. BUXTON observed that the cost of repainting the pier Mr. Buxton. would have been very high indeed, and the concrete casing adopted to avoid the use of paint was very interesting. He had had rather a similar case recently in a brewery, where waste beer had been allowed to flow round several of the steel stanchions and had eaten them away very seriously. His firm had put some concrete casings round the stanchions and had got over that difficulty very cheaply. Concrete was often used as a fireproof covering for steel. Inside a large structure the cover was 2 or 3 inches, and on the outside walls 4 inches: in every case that had to be taken as part of the dead load. Within the last few months some very interesting tests had been carried out in America by Professors C. T. Morris and J. R. Shank at the Ohio State University on steel beams encased in concrete.¹ They had tested an ordinary bare beam and a similar beam encased in concrete, and had found a very marked increase of strength—in some cases 50 to 100 per cent. Those experiments confirmed the results of earlier tests made by Professor Peter Gillespie at Toronto.² In Great Britain the concrete was taken as an additional dead load, and no regard was paid to its strengthening effect on the steel. He considered that that matter deserved the attention of engineers, because a much lighter beam could be used if encased in concrete, and if allowance were made for the additional strength. The cross girders shown in Fig. 11 were well encased in concrete, and it would seem that they had been greatly strengthened thereby. It might have been possible to reduce the section on that account and save money. Had the Author made any tests on those beams to see if the casing gave an increase in strength? He thought the Author had something of the sort in mind, in view of his remarks on p. 138.

Sir GEORGE HUMPHREYS observed that, in view of Mr. Wilson's Sir George Humphreys remarks, he would like to mention that at the beginning of 1927 he had occasion to look into the question of the covering of large beams with concrete. He went to Glasgow and inspected a good many bridges which he understood had been in existence for 20 to 25 years on the Caledonian Railway. He thought they had been erected under the direction of Mr. D. A. Matheson, M. Inst. C.E., when he was the engineer. He had been very favourably impressed by the way in which concrete had stood the test of time. The bridges were

¹ Ohio State University, Engineering Experiment Station, Bulletin No. 37 (1928). ["Engineering Abstracts," No. 37, p. 70.]

² University of Toronto, School of Engineering Research, Bulletin No. 5 (1925), p. 27.

Sir George
Humphreys.

mostly over-bridges, and the only deterioration he had been able to find was in the lower flange of the girder, where it was struck by the blast of the locomotive; otherwise the concrete seemed to be very sound, with very few cracks. He had gone there with his own predilections against that way of preserving steel, but he had been agreeably surprised at what he saw. He would advise engineers interested in the matter to go to Glasgow and look at those bridges, of which there were many in that city.

Mr. Berridge.

Mr. H. BERRIDGE remarked that he had burnt his fingers badly with concrete and steel a few years ago, and he thought that if he confessed it might save somebody else from a similar experience. The work in question was of considerable size and in the tropics. The materials used had been a volcanic rock, sea sand, and English cement mixed with condensed water. For some time the concrete and the steel embedded in it had been quite satisfactory, but after about 12 months the whole structure had failed. He had found that what everybody had thought was sand was not sand at all in the ordinary sense of the word; that was to say, instead of being silica, it was some form of lime from sea-shells; and instead of being composed of grains of irregular shape, it consisted, as might be expected, of tiny plates. Although in many cases the concrete had been 4 or 5 inches thick over the steel, the salt air had got in and the steel had corroded. He advised anybody who intended to put concrete round steel near the sea to examine the sand very carefully and to get a chemical report on it.

Mr. Keigwin.

Mr. A. D. KEIGWIN remarked that in Hong Kong a wharf had been built some years ago of structural steel piles with channel members on each side carrying the decking. The air was extremely salt, and corrosion took place very rapidly. The deck-beams had all been covered in concrete and had been also wired round in order to hold the concrete to the steelwork, the cover over the flanges being about $1\frac{1}{2}$ inch. After some years it was noticed that the concrete had begun to crack on the lower surface of the beams throughout the structure, and on removal it was found that sea air had got in through the porous concrete and had started very severe corrosion. It had been found necessary to cut off the concrete over the whole of the bottom of the beams and halfway up the webs, and the exposed surfaces had had to be annually painted and tarred, which practice was still being followed. The upper portion of the work did not show any signs of deterioration. The timber beams carrying the wooden decking had been removed quite recently and examined, and there did not seem to be any deterioration there. The experience at Hong Kong was that the humid air was laden with salt, the concrete was somewhat porous, cracks

occurred owing to continual vibration, and the concrete absorbed the salt, which got into the steelwork and started rust. He had found this trouble also in reinforced concrete, and in most cases above mean water-level in the tropics. Mr Keigwin.

The AUTHOR, in reply, remarked that Sir Cyril Kirkpatrick had referred to two methods of sinking cylinders. The advantage of the method described in the Paper was that, no matter how high the mud rose in the interior of the cylinder when it was pitched, the working-space for the excavators was not reduced. Another advantage was that the cylinder was adaptable for grabbing at any period of sinking with the air-lock removed, and the removal was not a lengthy operation. His firm had been sinking cylinders elsewhere in the same district at the same time as at New Holland, but in stiffer top material. In that case an internal shaft to the cylinder with an annular filling of concrete had been adopted. The costs of the two systems were found to be practically the same. The cost of the provision and the handling of the kentledge was offset by the extra cost of shuttering and placing the concrete in the annular space, erecting and withdrawing the access-shaft, and of handling the heavier locks. There had been accidents in sinking cylinders, attributed to exposing cast-iron to air-pressure; but it was his opinion that they had been caused by additional pressures on the cast iron, which had complicated the stress. At New Holland the stress in the cast iron had been kept within reasonable limits, and there had been no side pressures forcing the cylinder out of position. The joints between the cylinder-rings had been made with spun yarn and red lead. The levels of the cylinders shown in Fig. 5 were the actual levels to which they had been sunk, and the explanation was the undulation of the chalk. The question of the waybeams and the use of concrete covering was a matter of design which he was not in a position to discuss; but the use of concrete could be fully justified by the results in the Caledonian Railway bridges to which Sir George Humphreys had drawn attention. A number of bridges in Glasgow were covered with fine concrete, and he understood it had been quite successful as a protective covering. Mr. Wilson had referred to the 2-foot flange-plates of the main girders. A colleague had had an opportunity recently of examining the girders of Glasgow Cross station which had been protected with concrete for about the period mentioned by Sir George Humphreys. The breadth of some of the bottom flanges approached 2 feet. The surface of the concrete was not broken, which might be taken as an indication that no corrosion was taking place below; otherwise the rust would have burst the concrete. The failure mentioned by Mr. Berridge was

The Author. obviously due to a bad aggregate. The failure mentioned by Mr. Keigwin was more difficult to explain; but it had been found at New Holland that extreme care was necessary to ensure sound concrete round the bottom flanges. The surface of the concrete had been sounded afterwards with a hammer, and even with the care taken, a few hollow places had been found. Those had been punctured and grouted. In breaking up some work at Sunderland recently he had come across some $1\frac{1}{4}$ -inch square bars which had been surrounded by concrete for 30 years, and they were clean and without rust. The pierhead and the slopes as to which the President had asked for further information had been described by Mr. Gardner. The slopes ran parallel to the jetty frontage and fell uniformly a depth equal to about the tidal range in a distance of 200 feet. Obviously, by that means passengers and goods could land at the point on the slopes convenient for the water-level. The timber of the old pier was memel and was not creosoted. At some period it had been tarred. He had made no tests on the lines suggested by Mr. Buxton, but his opinion was that the designers had been conservative in their assumptions.

Correspondence.

**Mr. Cunningham
ham.**

Mr. HARRY CUNNINGHAM remarked that he had been interested to observe in the pier the use of a steel superstructure encased in concrete. The Author had described in detail the methods employed in shuttering for and depositing the concrete, and he had very properly called attention to the desirability of designing the work in such a way as to render possible the re-use of the shutters to the maximum degree. That point was kept in mind by expert designers of reinforced concrete, and repetition work on a large scale had warranted the use of steel shutters, which had the advantage of not requiring the services of craftsmen, such as joiners, and could be handled after a little practice by good labourers. It might be asked why the superstructure of the New Holland pier had not been designed in reinforced concrete. From the contractors' point of view it was well that it had been designed as steel girderwork. Too often structures to-day were designed in reinforced concrete without due consideration of the erection problems. The ease and consequent economy of erection of the spans of that pier were sufficient answer, especially as the foundations were no doubt lighter than would have satisfied the railway-company had the superstructure been entirely of reinforced concrete. It would appear from consideration of the design of the superstructure that the time was ripe for steelmakers and those interested in steelwork designs