Discussion.

The PRESIDENT, in moving a vote of thanks to the Authors, observed that the Institution was to be congratulated on having in their interesting Papers the completion of the account of the great works in Egypt carried out by English engineers, which had done so much to add to the prosperity of the country and to improve its prospects. The President.

Sir BENJAMIN BAKER, K.C.B., Past-President, remarked that, when asking the Authors to prepare the Papers for the Institution, he had thought it necessary to warn them that they must not be surprised if accounts of their very important and successful work did not give rise to a lengthy discussion; and must not regard a short discussion at Westminster as indicating any want of interest in the work on the part of engineers generally. A Paper published in the "Proceedings" was really addressed to engineers throughout the whole of the civilized world, the publications of the Institution being circulated to every Foreign Government department, and to all the leading engineering societies; and he was convinced that when the Paper by Sir Hanbury Brown was carefully studied, and the novelty involved in the details was seen, the work would be valued very highly. He believed that nowhere throughout the world, up to the present, had the capabilities of cement been demonstrated to the extent which had been shown in an unostentatious way by Sir Hanbury Brown, in the use he had made of it in the weirs below the Barrage. Sir Benjamin had always given great attention himself to the use of cement in every possible form; but he had been greatly struck with the boldness of Sir Hanbury Brown's proposition, when it was submitted to him for approval by the Egyptian Government, in regard to the application of cement as grouting, on so extensive a scale, to two weirs across the branches of such a large river as the Nile, where it was proposed to use it as a substitute for concrete *in situ*, which involved, as a rule, costly plant, and a certain number of skilled gangers and labourers not available in Egypt. Sir Hanbury Brown, in working out the problem, had recognized at once that it involved the use of a relatively large quantity of cement; and he had satisfied Sir Benjamin that, although it might be considered extravagant to put 37 per cent. of cement in concrete, still, under the conditions obtaining at the Barrage, and considering Sir Benjamin Baker.

Sir Benjamin Baker.

that, while skilled labour was wanting and there were difficulties in regard to plant, there was an unlimited supply of unskilled labour, and further, that the work must be done rapidly, and pumping of all kinds be avoided, this was the right solution of the problem. It was a novel solution, and one not likely to occur to an engineer working under ordinary conditions at home or in many other parts of the world. Engineers well knew that although a scheme often looked simple on paper, as soon as an attempt was made to carry it out, all sorts of little difficulties cropped up, which, in the absence of motherwit sufficient to overcome them, made the whole project a failure. Sir Hanbury Brown had faced these difficulties, and had modified his procedure so as to overcome them as they arose: with the result that he had carried the two weirs across the two branches of the Nile very rapidly, and had done what had never been done before, namely, made locks on the grouting principle, without any dams or pumping, thereby avoiding all the trouble of the thousand springs which had been encountered and dealt with at Asyût, as Mr. Stephens described in his Paper. The floor and walls of the lock had been constructed on a pervious, sandy, and silty bed of the river, without spending more than £50 in pumping. The weirs and locks were large; one of the weirs was 500 metres in length and the other 400 metres. Continental and American engineers would be extremely interested in a record of so much practical experience of work carried out under such disadvantageous conditions. The masonry formed by the cement grouting was practically solid. It could be used for reservoir-dams and for many other things, with the certainty that thoroughly strong, sound work would be obtained. Preliminary experiments made with blocks had shown them to be as sound as solid rock on being cut in two; and although it was thought that grout passed through water became rather weak, and of a spongy consistency, he had been unable to detect any indication of unsoundness in the blocks grouted under water. The experience gained here would no doubt be utilized elsewhere as soon as the Paper was published, and in a short time the method would be employed in hundreds of cases throughout the world, and Sir Hanbury Brown would get the credit which was his due. He was afraid Sir Hanbury would not have given engineers an account of his work, if he had not told him that it would be valuable in the "Proceedings" of the Institution. The work at Asyût was already known to many members of the Institution, from drawings and accounts published

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in the technical press. The difficulties in connection with the work had been overcome by Mr. Stephens and the former Director-General, Mr. Wilson, who took a great personal interest in the work when it was started, but who unfortunately died, and by the whole staff. Nothing but praise was due to the manner in which Sir John Aird's firm and their representative, Mr. Blue in the first place and Mr. McClure afterwards, had stuck to the job, and had completed it in 1 year less than contract time, although the difficulties had been so great that the whole of the contract drawings had had to be altered. On realizing the state of affairs, he had told Lord Cromer frankly that the contract ought to be cancelled, and that it was in the interest of Egypt to get the work finished in the shortest possible time, quite regardless of any technical interpretation of the liabilities of the contractors. He had told Lord Cromer that he was quite certain the results of the completion of the work at an earlier date, as regarded profit to the country from the utilization of water, would entirely outweigh any extra expense that might be incurred. He was glad to say that both Lord Cromer and Sir John Aird had confidence in him, and they had both said they would leave the matter in his hands. Accordingly, he had told the contractors to proceed with the work, to execute it thoroughly, and to his satisfaction in respect of quality and economy, and to do it in the shortest possible time, leaving the question of profit to himself. Both Lord Cromer and the contractors had agreed to those terms, with happy results; because, notwithstanding the increased difficulties, the work had been completed in a year under the contract time, and the Public Works Department admitted that that meant £600,000 profit, owing to the extra year's supply of water to the country. That entirely counterbalanced any saving which might have been effected by adhering to the original designs and keeping the contractors to the strict letter of their contract; and it afforded a good example of the results of the broad-minded, statesmanlike way in which Lord Cromer managed affairs in Egypt. Certainly without some one of that broad mind at the head of affairs there would never have been the Assuan dam, nor the subsidiary weirs below the Barrage; neither would the old Barrage, built by the French in 1850, have been strengthened and rendered fit to do its work. No one who had not been in Egypt 30 or 40 years ago could realize the terror with which that old Barrage had been regarded in that country. As soon as it was completed, about 1850 or 1852, and a head of water was put upon it, it had begun to move down-stream. Springs had

Sir Benjamin Baker sprung up below it, and as the whole cultivation of the Delta depended more or less on the integrity of the Barrage, the panic had been great throughout the whole of Egypt. Not a year had passed after that in which, when the water had to be regulated at the Barrage, the whole Delta was not in a state of more or less anxiety. His own acquaintance with the Barrage dated from 1875. In that year, wishing to know what sort of soil there was on the down-stream side, he had started an ordinary boring with a tube, thereby causing nearly a revolution in Egypt; because it was feared that putting down a 4-inch tube within 150 feet of the Barrage might cause a blow-up of the work and the loss of the crops in the Delta. Not until the British occupation had any one dared to attack it; the French engineers might have done so, but they had not been sufficiently powerful. When the British occupation came, the task had had to be taken in hand, and Colonel Western had done splendid work on the down-stream side, and in repairing the floor. Nearly £500,000 had been spent by him in strengthening the Barrage, which had allowed of a higher head of water. But that had not been entirely satisfactory, and the grouting-work described by Sir Hanbury Brown had been proceeded with. Even then it had been thought to be unadvisable to put the full head of water on the Barrage, and consequently the subsidiary weirs had been built below. The Asyût Barrage had taken 4 years to build, while the Delta Barrage had taken about 50 years: that showed the difference between the proceedings under Lord Cromer and a staff of English engineers, and the proceedings under Mehemet Ali, in 1850, with no organized staff, but as the result of consulting first one and then another, of different nationalities—in short, whoever happened to be in Egypt at the time.

Mr. Mansergh. Mr. JAMES MANSERGH, Past-President, found that the difference in level between high-flood level above the Asyût dam and summer level below it, as given on the section, was 28 feet, but he could not find in the Paper what was the maximum head that might actually occur. He did not suppose there was a difference of 28 feet at any time, because the sluices would be opened in advance, and the head water be lowered and the tail water raised. There were two rows of sheet-piling, one at the up-stream and one at the down-stream end of the 87-foot platform. These were driven 22 feet below the bed of the river; and what he desired to know was, what head might actually operate to force the water through the sand under the piles, and out at the lower side. With regard to the Delta Barrage, he had tried in vain to find, in the "Proceedings" of the Institution, a diagram of the original French dam. Neither Sir Hanbury Brown's Paper nor the previous Papers of Sir Benjamin Baker,[1] the late Sir William Anderson[2] and Sir William Willcocks[3] on Egyptian irrigation, contained such a drawing. It was a great pity that there was no record in the "Proceedings" of the initiation and progress of so important a work; and perhaps some member who had had experience in Egypt, and who knew the whole circumstances, would write a Paper giving a short illustrated history from the beginning, and recounting the changes that had taken place since. Indeed, Sir Hanbury Brown's excellent Paper would be improved by the addition of this information. He desired to congratulate both the Authors on their very interesting communications. Mr. Mansergh.

Lieut.-Col. J. H. WESTERN, R.E., pointed out that a full account[4] of the Barrage had already been written by Sir Hanbury Brown himself. Unfortunately, the officer who actually carried out the work, Mr. A. G. W. Reid, M. Inst. C.E., was dead. Col. Western.

Mr. BASIL P. ELLIS thought the most interesting part of the Asyût Barrage, from an engineering point of view, was the foundations. There was no doubt that they were exceptional, because a head of water of about 10 to 12 feet had to be held up on the up-stream side, and the whole bed of the Nile at Asyût was very soft silt. The foundations had therefore had to be made very heavy and very wide; in fact, while the superstructure was only about 50 feet in width, the foundations, including the aprons up-stream and down-stream, were about 218 feet wide. The aprons afforded the necessary protection to the foundation; and, as had been proved by the result, any risk of water passing under the weir had been entirely avoided. There had been no difficulties like those which had arisen in connection with the old Delta Barrage, and which were due to the fact that the foundations were not sufficiently secure, and probably not wide enough. The springs mentioned by Mr. Stephens had given much trouble, but with care the work had been accomplished successfully. The superstructure was faced with limestone instead of bricks, as had been originally intended, and the stone had had to be fetched Mr. Ellis.

[1] "The River Nile." Minutes of Proceedings Inst. C.E., vol. lx. p. 367.

[2] "Notes of a Journey through the N.E. portion of the Delta of the Nile in April, 1884." *Ibid*, vol. lxxvi. p. 346.

[3] "Irrigation in Lower Egypt." *Ibid*, vol. lxxxviii. p. 300.

[4] "The Delta Barrage of Lower Egypt." Cairo, 1902. Published by the Egyptian Government.

Mr. Ellis. from a considerable distance—about 100 miles along the Nile, and then a good way inland. Already the work had been of great benefit to Egypt, and it had been a decided financial success. The undertaking had been rendered still more difficult by the fact that it could not be proceeded with during more than 6 or 7 months in each year, and its completion within about 4 years from the start was therefore very satisfactory. It was quite impossible for any one to be in Egypt for any length of time without feeling that the condition of modern Egypt was largely due to Lord Cromer's great efforts during the last 20 years. The construction of the great dams at Assuan and Asyût was largely due to his influence. Sir John Aird and all connected with the work were very proud to have been associated with Lord Cromer and Sir William Garstin, as well as with Sir Benjamin Baker, Mr. Webb, the Director-General of Reservoirs, and Mr. Stephens, who had superintended the construction with great skill. It was a source of much gratification to the contractors that the work had been carried through so quickly and so satisfactorily. Sir Hanbury Brown's Paper described probably the most remarkable instance of cement grouting that had ever been carried out. He had watched the result of the grouting with interest, and believed that the method was of the greatest service to engineers. The lock made in the sunken weir below the old Barrage was a wonderful piece of work, well worthy of being visited by members of the Institution.

Mr. Fitzmaurice. Mr. MAURICE FITZMAURICE thought the success of the undertakings left little room for criticism; and as he had had the advantage of seeing all the works described during construction, he only desired some further information on one or two points. With regard to Sir Hanbury Brown's Paper, he thought it would be a great advantage to engineers if the cost of the work could be subdivided somewhat, the most important detail being the cost of cement delivered at the Delta Barrage. When cement had to be transported any great distance, the price became high; at Assuan, higher up the Nile, it was over £3 per ton. The cost of the weir-walls, as far as he could judge from the Paper, appeared to be about 25*s.* per cubic yard for cement alone, which was high. At the same time it had to be remembered that the core-wall and the footing-wall together were only 5·5 metres (18 feet) wide, while the total width of the protected river-bed was 60 metres (197 feet). It would also be useful if Sir Hanbury Brown would state what percentage of the whole cost should be apportioned to the two walls. The core-wall and the footing-wall were really only water-tight

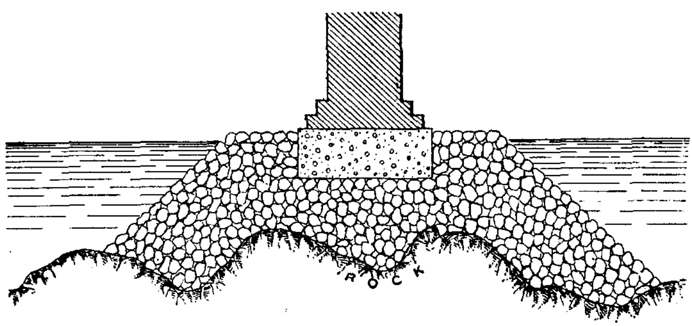
Mr. Fitzmaurice.

plates, much the same as a damp-proof course, and had no stability in themselves. The mode of construction seemed to be entirely *a question of the comparative cost of cement and of plant.* Where these costs had not the same relation as in Egypt, it was quite possible it might not pay to adopt the method described. Did Sir Hanbury think that satisfactory work could be obtained by making a wall with concrete blocks put down in two tiers, leaving 1 foot 6 inches or 2 feet of rubble around the blocks, so that the grouting could take effect all round them, and thus save a great deal of cement? There would probably be no difficulty in getting the blocks level, or in arranging for the grouting. Of course, it would not be possible to carry out such work with Sir Hanbury Brown's "pre-historic" plant; but in places like the Sudan, where cement would probably cost £5 per ton, block-laying with grouted rubble between the blocks might be done cheaply with a small amount of plant. He would like to know what time had been allowed to elapse after the completion of the grouting of the floor of the lock, before the water was pumped out. With reference to the Asyût Barrage, after spending a couple of hours on the works and seeing the various springs which had to be dealt with, he had felt glad that Mr. Stephens was doing the work, instead of himself; but after being there a couple of days and seeing the careful and methodical way in which the springs were vanquished one by one, he had begun to wish himself in Mr. Stephens's place. A more unfavourable foundation for a structure to hold up a head of water could not be imagined: it was practically a quicksand. The difficulty of the site was well shown by the fact that the width of protected bed of river was over 200 feet, to hold up a head of 8 feet of water. He did not think nearly as satisfactory a foundation would have been obtained with shallow brick wells under the piers, and with a shallow floor, as resulted with a thick floor and no wells; a much more satisfactory and even settlement occurred with the latter arrangement. It was also evident that the interlocking cast-iron piles must make a much more satisfactory water-tight construction than oblong wells, which could not be sunk truly vertical, and which it was not always easy to make absolutely water-tight at the joints. The fact that the driving of the piles had progressed at the rate of 50 to 60 feet per day showed that the method adopted was extremely suitable for rapid work. Had it been necessary to sink the double row of curtain-wells he did not think the work would have been finished at the present time. The lime-and-clay mortar used was certainly very good. Although

Mr. Fitzmaurice. the pressure on the piers was small, it would be useful to know what it actually amounted to on the down-stream side. The most suitable degree of burning for clay depended largely on the character of the clay. While Mr. Stephens had found that the best effect was obtained by burning to a light terra-cotta colour, he himself had found, in other parts of Egypt, that that was not at all suitable, simply because of the difference in the clay. In one case he had found it had to be burned to a fairly bright red, in order to get the same effect that Mr. Stephens obtained with a terra-cotta colour. When any large work had to be carried out, it certainly paid to put up a proper kiln for burning the clay for mortar. If bricks were burned in clamps a large proportion of them were always much over-burnt. The over-burnt bricks were of no use for making mortar, and in their production a good deal of coal was wasted, about 1½ cwt. of coal being needed per ton of clay burned.

Sir Guilford Moleswortb. Sir GUILFORD L. MOLESWORTH, K.C.I.E., Vice-President, mentioned the following instance of the use of grout which had occurred on one of the Indian State Railways, in sinking a well for the foundation of a pier. When the well had gone down about 30 feet, one side of the well-curb rested upon the rock, which was somewhat irregular. The material in which the well was sunk was a sharp, clean sand, through which the water flowed freely. It was

Fig. 1.



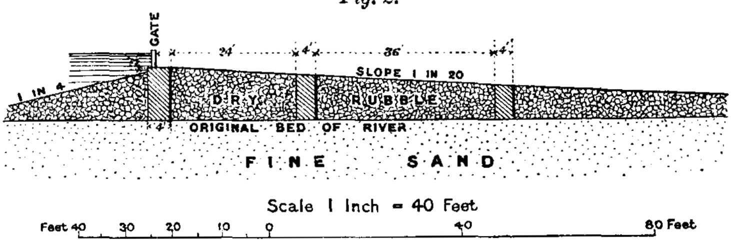
impossible to pump the well out, and to cut the rock so that the curb might have an even bearing upon it would have been a difficult, expensive, and tedious process. He therefore determined to throw into the well a large amount of grout, and to pump water into the well so as to maintain a head which would carry the grout down, and cause it to permeate the sand. The result was perfectly satisfactory. Probing afterwards outside the well showed that a large mass of concrete had been formed by the grout permeating the sand at the bottom and around the well. He would not have ventured to use that plan had the sand been of a clayey nature, because he did not think the grout would then have permeated the sand; but in clean, sharp sand the plan was perfectly successful. He had also used grout in putting in a river-pier for a bridge in Ceylon, on a somewhat irregular foundation of rock, about 8 feet below the level of the river (*Fig. 1*). His first step had been to form an island of broken rock, brought up to about 1 foot above the level of the water. Then, after pounding the whole of the surface of the island with a heavy ram to consolidate the loose rock, he had excavated in the island a pit into which grout was thrown. The grout had filled the interstices of the rock, forming concrete, and upon that he had built the pier. It had proved to be a cheap and efficient foundation. Sir Guilford Molesworth.

Mr. FRANCIS FOX had devoted a good deal of attention to the subject of grouting. About 39 years ago he had been engaged in testing a bridge, consisting of girders 250 feet in length, resting on abutments, with four intermediate piers, two for each girder; and, under a load of nine main-line locomotives, one of the brickwork piers cracked from top to bottom on all four sides. On pulling down the pier, which was 10 feet square, and was surmounted by a heavy column 3 feet in diameter, it was found that the stones had not been properly bedded; they had been left hollow in the middle. The failure of this pier threw doubt on the strength of the other three, and therefore holes were made through them, and with the aid of a funnel and sufficient static head, grout was poured in and the piers were grouted up. There had been no trouble since with those three piers, and the cracked pier had been rebuilt. In another instance of the successful employment of grout, the centres of an ordinary 25-foot brick arch had been struck before the work was set, and the arch had subsided; though, fortunately, after letting it down about 6 inches the men had thought it would be well to put the wedges in again and leave it. The bridge had been practically wrecked, the arch being broken in several places; and the masonry courses had been pushed out, so that unintentional plinths were produced on both abutments, at different levels. He tried to save the bridge by spending £20 on cement, and grouting it with a funnel; and to-day it was carrying the main line of one of the large railways, with locomotives running at 60 to 70 miles per hour. The difficulty attending the use of a funnel was that it was not possible to grout upwards Mr. Fox.

Mr. Fox. in a tunnel or arch; but the Greathead grouting-machine enabled grouting to be done in any direction. The last application of grout with which he had had to do was in connection with the walls of Chester. The towers on those walls, built many hundred years ago, were of great archæological and historical interest. The walls were cracking and sinking, because they were jerry-built. The interior of the walls was simply loose stone; in fact, if a stone was pulled out at the bottom of the wall the movement of the hearting could be heard. Consequently the Corporation had thought it well to repair the walls; and of course that could not be done by removing the ancient stones and fitting in new ones. Accordingly, a Greathead grouting machine had been obtained, holes had been bored in the walls and towers, and cement—or sometimes a mixture of hydraulic lime and cement—had been forced in; with the result that those broken-down walls had been turned into monoliths. All the old features of the walls had been retained, and the work had not cost a tithe of what had formerly been expended in rebuilding the walls. Grouting was a method which ought to be largely adopted by public bodies and railway companies; instead of pulling down structures, they could often save them by spending a shilling where otherwise they would have to spend a pound. With regard to the use of concrete, in his youth 2 to 3 tons per square foot was thought to be the maximum load permissible on concrete, and 5 tons to be as much as could be allowed on brickwork. Now, concrete was coming to the front, and, in testing, the pressure was not thought of until 40 tons per square foot was obtained; and sometimes it was possible to go up to 300 tons before the concrete was crushed. Consequently, a pressure of 12 to 15 tons per square foot was allowed on concrete; and he was carrying out some work wherein the pressure was 15 tons. He thought concrete would come more and more into use in the future, but great care must be taken in the selection and mixing of the materials.

Mr. Beresford Mr. J. S. BERESFORD had been puzzled by a point in regard to the grouting, namely, the pressure exerted by the column of grout at the Delta Barrage. It was equal to 17½ metres head of cement in an extreme case, entailing an upward pressure of 35 tons per square metre on the base of the floor. Under this pressure there would be danger of a weak floor blowing up, but nothing of the kind seemed to have happened: which made him think that the cavities underneath were not so large as had sometimes been said. Perhaps the pressure exerted by the grout was not quite so great as was calculated from the height of the column: it might be considerably diminished in the spreading of the grout through the rubble. The grouting process had been very successfully employed in the additions to the Beherah canal-head—a difficult work, which could hardly have been carried out in any other way. With regard to the subsidiary weirs of the Delta Barrage, he thought that was a case where wells might have been used for the core-walls. Figs. 3 and 4, Plate 1, showed that the closing of the grooves between the wells would not have been difficult. The clay in the trench would have gone to the bottom of the wells; and that clay, even if the piles driven between the wells had not been thought sufficient, would have thoroughly closed the joints: moreover, it would have been cheaper. At all events, wells might have been used at intervals, the spaces between being grouted up in the way described in Sir Hanbury Brown's Paper. The latter was of Mr. Beresford.

Fig. 2.



CROSS SECTION OF OKLA WEIR.

course the most satisfactory plan of doing the work, especially as regarded the locks; it gave rise to no anxiety, and no pumping was needed. It would seem, however, from the Paper[1] read before the Institution in 1886 by Mr. Kinipple, that the system of grouting was not then fully accredited. Mr. Kinipple appeared to have used it at the St. Helier harbour-extension, Jersey, and a full description of its use had been given in his lectures before the Royal Engineers Institute, Chatham, in 1889.[2] Regarding the diaphragm-wall, it was not absolutely necessary to have it continuously water-tight, nor so deep. For instance, the Okla weir (*Fig. 2*), near Delhi, was built on the surface of the river-bed, and he had been able to put his walking-stick under the foundations. It was 10 feet high, with falling gates 3 feet high on the crest, and

[1] "Concrete-Work under Water." Minutes of Proceedings Inst. C.E., vol. lxxxvii. p. 65.

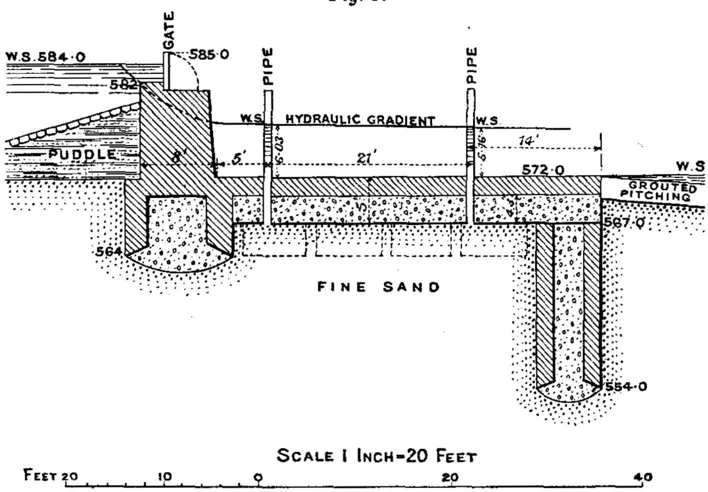
[2] Professional Papers of the Corps of Royal Engineers: Royal Engineers Institute Occasional Papers, vol. xv. p. 1.

Mr. Beresford. the down-stream slope was 1 in 20. It had stood perfectly well for over 30 years with little leakage. The whole leakage on a length of 2,400 feet was only 24 cubic feet per second in 1888, and was now doubtless smaller. The head in flood was about 6 feet, and at times 13 feet. The clay seemed to have been put into the subsidiary weirs of the Nile as dug from the field, but he thought it would have been better to puddle it and ram it in in balls. The Hindan dam near Delhi, which was built on round wells in two rows, one up-stream and one down-stream, with a beam of concrete between, became undermined by scour to a depth of 30 feet in 1880; the sand under the floor on the up-stream side being washed out through the openings between the wells. The work had been repaired by filling the deep scoured hole up-stream of the wells with clay, boring holes in the floor, filling up the greater part of the space under with sand, then pouring in hydraulic-lime mortar as far as it could be got, and finally tightening up the whole by ramming in sharp gravel through the holes with blunt crow-bars. That had had the desired effect, and the dam had stood well since. The same process had also been used by him in the Chenab weir where one of the piers had sunk 2 inches. Holes were bored in the floor at 5-foot intervals, and finely broken ballast rammed in; that had rendered the foundations thoroughly tight. The difficulty of the Asyût works seemed to have been due to the springs. It was not clearly stated in the Paper how far the embankments had been placed from the centre of the work; but the distance seemed to be about 65 metres on each side from the row of piles. The springs came through under a head due to the difference of level between R.L. 48 and R.L. 43. When the banks were made the water was at R.L. 48, and the foundations had to be lowered to R.L. 40. There was, therefore, the considerable head of 8 metres. It was very difficult to deal with springs of that kind. The further they were from the embankments, the less powerful were the springs of weirs across rivers with beds of sand. Colonel J. Clibborn, the late Principal of the Roorkee College, had made, in 1896, interesting experiments on the passage of water through large pipes filled with fine river sand, and he had obtained some useful results. Mr. Beresford had suggested that the best plan would be to experiment on the Narora weir across the Ganges, and to drill holes in the floor for the purpose; but, as in the case of the Delta Barrage, strong objection had been raised to boring holes near the work, and the suggestion had been vetoed. Later, on coming into authority, he had ordered two holes to be made in the floor, and had had pipes put in them. With the water

Mr. Beresford.

up-stream of the crest-wall standing 12 feet higher than the floor down-stream, the water had risen to a height of 6 feet in one hole and 5·16 feet in the other, above floor-level: which showed that the pressure on the bottom of the floor had been 11 feet of water against 5 feet of masonry (*Fig. 3*). As there was no backwater the floor had been in a very precarious condition. He had at once ordered a dwarf wall to be built along the foot, in order to put on the pressure of a backwater, but a few days later he heard that 300 feet of the floor had blown up. To his great satisfaction, he had found that the break was 900 feet from where he had made the holes; otherwise, it would have been assumed that drilling

Fig. 3.



CROSS SECTION OF NARORA WEIR.

the holes had caused the damage. He had sent an account of the incident to Sir William Garstin in a letter written about May, 1898, asking him to show the letter to Mr. W. J. Wilson; and he understood it was that experiment which had led to the increase of the thickness of the floor at Asyût from 2 metres to 3 metres. With regard to the action of water in sand, he had carried out a number of experiments himself, and he had found, even with grains $\frac{1}{100}$ to $\frac{1}{200}$ inch in diameter, that the sand would not blow so long as the thickness above any point was three times the head on the springs at that point. The main difficulty found in constructing weirs such as the Chenab weir was not the blowing up, but the undermining action beneath the floor. It was easy to lay the

Mr. Beresford. concrete and the masonry; but probably at the end of, say, 20 years the water had made cavities underneath. Formerly the only preventive of that action had been to do the work as carefully as possible; now grouting was used with great advantage: in fact, he did not know how the Asyût Barrage could have been executed by the method adopted without the grouting process, or how the springs all over the foundation could have been otherwise dealt with. But he thought work of the kind could be carried out on a more uniform plan: the foundations might have been laid on 6 inches of gravel, which would have drained off the springs and allowed the concrete and masonry to proceed; and afterwards, by means of pipes left at intervals, the whole work might have been grouted. That method had been partially adopted in the Punjab on a large work where the springs were troublesome. The filter at the down-stream end was one of the most important features of the Asyût design. It let the water through, but prevented the sand from following; and if the sand was prevented from going, the floor could not be undermined. The piles no doubt formed an impervious diaphragm, but they were not quite a substitute for wells: the latter were self-contained; and many works in India would have been ruined if the deep foundations had not been self-supporting. The piles did not seem to have materially reduced the springs, nor would he have expected them to do so. It was not clear how the concrete, 0·9 metre, say 3 feet, deep, stood the high pressure due to a head of 18 feet of cement grout, equivalent to 36 feet of water. Apparently it had not been applied until the masonry was completed; but that was not clearly stated in the Paper. The old Delta Barrage was fully described in Sir William Willcocks's "Egyptian Irrigation,"[1] where three reports by the late Mr. A. G. W. Reid were given, on the restoration work carried out under Colonel Western during the three years 1887–89. Colonel Western had been very modest in regard to his share of the work, but it was well known in Egypt that his had been the ruling spirit in the great operation of making the Barrage secure and capable of holding up 4 metres of water.

Mr. Davison. Mr. R. C. H. Davison related the following incident that had come under his observation some years ago in British Columbia in connection with grouting. A man wished to build a dam across a creek in the mountains. There was plenty of stone and he procured masons; but as the cement he had ordered did not arrive, he was faced with the alternative of either postponing the

[1] 2nd ed. London, 1899.

Mr. Davison.

work for that year or carrying on the masonry work dry, and putting in the mortar afterwards. He chose the latter, and the masons went on with their work. When it was finished it was pointed; and when the cement arrived the whole work was grouted. Afterwards he cut out several places to see how the work had succeeded, and he found that the grouting had made a thoroughly sound job. The height of the wall was about 15 feet.

Mr. Binnie.

Mr. W. J. E. BINNIE remarked that it might be interesting to place on record the experience gained at the Alexandria graving-docks about the time of the grouting of the old Delta Barrage. The graving-dock being constructed in limestone which was almost as porous as a sponge, it had been apparent that when the dock was pumped out it would be practically a concrete box floating in water; consequently it had been absolutely necessary to take every precaution to prevent the occurrence of horizontal joints in the invert. The thickness of the Portland-cement concrete at the invert was 12 feet. While carrying out the work it had frequently been found that when the wind came off the desert the Portland cement would set in 5 or 10 minutes, although it would take an hour to set in England. The concrete had been put in in barrowfuls. On completion of the invert it had been thought advisable to grout up the whole thing, and this had been carried out in the following manner. Holes 2 inches in diameter, spaced about 15 feet apart, were jumped in the invert, about 9 feet deep. A $1\frac{1}{2}$-inch wrought-iron pipe, fitted with a collar at the lower end and a ⊢-piece at the top, was then introduced into the hole, the joint between the pipe and the concrete being made with spun yarn kept in place by the collar. To the upper arm of the ⊢-piece was fixed a stop-cock and short length of pipe, and to the horizontal arm another stop-cock and a hose connection to an air-receiver and a diver's pump. The compressed air being shut off, grout mixed in the proportion of 2 volumes of water to 1 of Portland cement was poured down the pipe into the hole until no more was absorbed under the static head of the grout. The upper stop-cock was then closed, and the side cock connected with the air-receiver was opened. By means of the pump a pressure of 30 lbs. per square inch was put on the top of the grout, which was continued until the grout ceased to be absorbed. It had generally been found that 33 per cent. more grout could be forced in under this additional air-pressure. The column of grout had been about 20 feet high, and the total pressure had been practically equal to a head of 90 feet of water. Altogether 125 holes had been sunk in the dock-bottom, and out

Mr. Binnie. of these 55 had taken in no grout at all, and 70 had allowed the grout to spread in horizontal layers. This had been proved by the fact that when pressure was put on one hole grout arose in several of the other holes. Altogether 7½ tons of neat Portland cement had been put in, at a cost of £80. Before starting, the dock had been found to leak in about a dozen places, under a pressure of 26 feet of water. After the work had been done, and the pressure had been put on again, not a drop of water had come through the dock-invert anywhere.

Mr. Buckley. Mr. R. B. BUCKLEY, having had the privilege of visiting the subsidiary weirs near Cairo while they were under construction, and of watching the interesting process by which the blocks were constructed under water, had been fired with enthusiasm for the new system of building the core-walls of weirs, and had thirsted to put it into operation. But he had been perplexed by some doubts. First, he had had some hesitation in believing that the work was entirely solid; secondly, he had found it difficult to believe that it was really necessary to construct a weir of this kind with such solid work; and thirdly, he had been curious to know whether, having regard to its cost, it would be possible to take advantage of the process in India, where he wished to use it. The accompanying Table gave the cost of the Nile weirs and of three well-known Indian

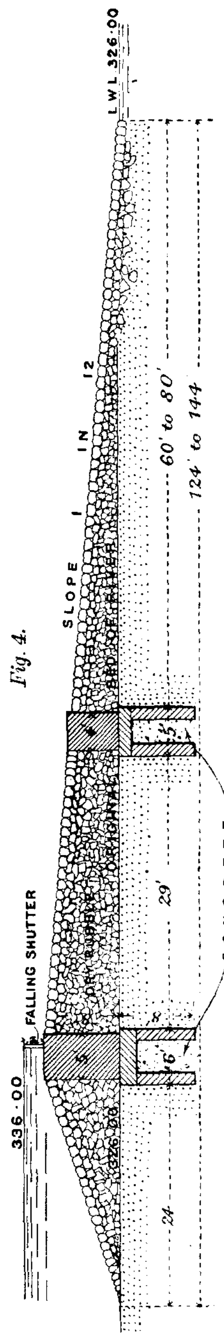
Weir.	Length.	Head.	Cost.	Foundation.
	Feet.	Feet. Ins.	£	
Nile (subsidiary weirs near Cairo)	3,000	10 0	434,000	Fine sand and silt
Chenab . . .	4,000	13 3	270,000	" " "
Sone	12,500	10 0	180,000	Sand and some pebbles.
Rupar . . .	2,400	13 to 14	115,000	Coarse sand and pebbles.

weirs. On working out those figures he had been rather taken aback. But probably there was no member of the Institution who was not well aware how fallacious such figures often were; and the figures of the Table as they stood were fallacious to a certain extent, because differences in the cost of labour and of materials rendered it impracticable to make comparisons based only on such data as were there given. For instance, the cost of the Sone weir (*Fig. 4*) was so remarkably low partly because the stone had only cost one-quarter of the cost of stone in Cairo. He had therefore proceeded to make a comparison on what he thought was a fairer basis. He had calculated what it would cost to construct one of

Mr. Buckley.

those weirs at the present time by the method actually used, and what it would cost to construct it by Sir Hanbury Brown's method, according to the sections of the subsidiary weirs. He had found that the Sone weir could be rebuilt for £250,000, rather more than it cost 30 years ago; but that if the work were done according to Sir Hanbury Brown's method, the mere cement alone put into the two walls, the core-wall and the footing-wall, would cost £300,000. Of course cement at the Sone weir was more expensive than it was in Cairo—costing about 20 per cent. more. That result had led him to fear that the system could not be largely adopted in India, owing to its expense. But, turning to the section of the weir, he had been puzzled to know why it should be so extremely strong. The Sone weir had to do practically the same work as the subsidiary weirs on the Nile; it held up the same head of 10 feet of water; and the maximum flood over the crest of the weir was about 15 feet, while that of the Nile weirs was about 16 or 17 feet. Why, then, should it be necessary in one weir to make a solid wall 10 feet thick, whereas in the other weir the wall was only 6 feet thick, and was not solid? It was filled with concrete, and not very good concrete either. The explanation was that, while the Sone weir fulfilled its purpose absolutely, it was not water-tight. A certain amount of water always found its way under that weir, while under Sir Hanbury Brown's weirs hardly any water passed. The subsidiary weirs on the Nile were the most water-tight weirs that had ever been built, and perhaps with good reason. But a weir for irrigation purposes in India need not be as tight as a bottle, and it was a question whether it was worth while spending an extra £300,000 to make it so. Having arrived thus far, he had

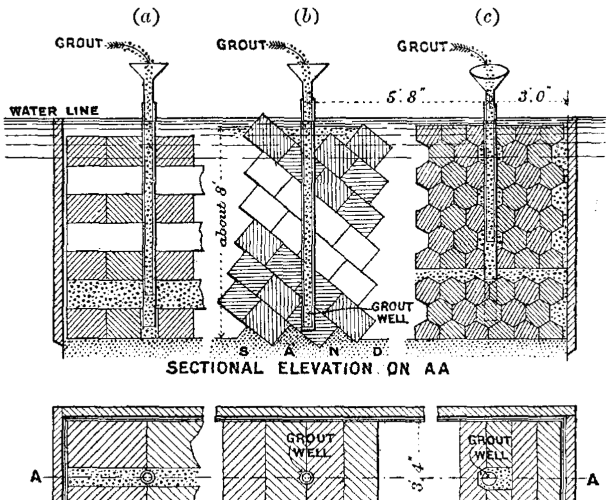
Fig. 4.



Cross Section of Sone Weir.

Mr. Buckley. set himself to devise some cheaper method of applying this admirably simple and very effective method, and he had made some experiments with a view to reduce the consumption of cement. In the subsidiary weirs on the Nile, 100 cubic yards of wall required 37 cubic yards of dry cement, which cost a large sum of money. *Figs.* 5 showed three examples of methods which he had tried in his experiments; the different samples were constructed under water, using the same kind of box, lined with canvas, as Sir Hanbury Brown had employed on the Nile. The first (*a*) consisted of concrete blocks, about 3 feet by 1 foot 6 inches by 1 foot, some of which were stretchers and some headers. Where the pipe came in between two

Figs. 5.



stretchers he filled in pebbles. On that plan a wall had been made 17 feet long by 3 feet 4 inches broad, and about 8 feet high, and had been grouted up with cement as described by Sir Hanbury Brown. When it was completed, the water had been drained out, the wooden side frames removed, and the block broken down. To all appearance that block when first uncovered had been perfect—like a piece of rock rendered all over with cement; and it had been necessary to use quarry-wedges and sledge-hammers to break it up. But on breaking down the wall for examination it had been found that while the vertical joints were perfect, nearly all the horizontal joints were bad. The reason was simple. Unless it was very thick and put in under a high pressure, the cement grout did not fill the horizontal joints solid. In rubble the grout put in might be thick or thin, and a perfect result was obtained; but where horizontal joints were used, unless the cement was absolutely of the right consistency it did not fill them, and the tops of many of those joints were frothy. He had considered that method a failure. He had then built another block (*Figs. 5, b*), 17 feet by 3 feet by 8 feet, with the same box, but with the blocks tilted, so that there were no horizontal joints. He had found this satisfactory in every respect; every joint was filled, and there was not a single hollow in the whole wall. But as he had experienced some difficulty in laying the blocks in that way, he had finally adopted the system of building the wall of hexagonal blocks, all headers (*Figs. 5, c*): then there were no horizontal joints; and when such a wall was grouted as the weirs had been grouted, absolutely solid work was the result. He had used 10·6 per cent. of dry cement in the first example, and somewhat less in some other samples. Thus, with less than one-third of the cement used in rubble, it was possible to make a sound core-wall of any length. In order to get a horizontal bond in the third method (*c*) all that it was necessary to do was to insert a layer of good-sized pebbles at the required point, and then a horizontal joint would be obtained which would hold the work together. As a matter of fact, in a core-wall for a weir it was not necessary to have any bond; the wall could not yield when it was once built and protected on both sides by stone. Another way in which a core-wall might be constructed would be with the same hexagonal blocks, but laid vertically instead of horizontally. Such a wall could be built with a crane travelling behind on the completed wall; into the box could be dropped vertical needles of cement, and then the work could be grouted up, and a very satisfactory wall would be obtained. He had tried various other things in his experiments, among them, grouting sand. Sir Guilford Molesworth's efforts in that direction seemed to have been successful, but his own had been failures. He had grouted sand under a head of 10 to 12 feet, and the only result had been that he obtained what an iron-master would call a "pig's head," an enormous bubble of cement inside the sand. He had also tried to save cement by putting a little sand in with it; but that had proved a total failure, as the sand and cement would not run evenly. On dismantling the work he had found that there were lumps of sand and then lumps of cement in the joints, and then spaces filled only with

Mr. Buckley.

Mr. Buckley. cement-froth. It was necessary to use pure cement in all cases. If that were done, and if there were no horizontal joints, perfectly sound work would be obtained, even if the consistency of the grout varied considerably.

Mr. Odling. Mr. C. W. ODLING asked whether there was any leakage through or under the Barrage. The Sone weir, which had been alluded to by Mr. Buckley, was not water-tight; there was some leakage through the weir itself, and considerable percolation through the sand on which the weir was founded. It would be interesting to know to what extent the Delta Barrage was water-tight. It was a great gratification to him, and he thought to all Indian engineers, to see Sir Hanbury Brown reading the Paper as a Member of the Institution, and a particular pleasure to Mr. Odling himself, as he had had some slight share in the selection of Sir Hanbury for service in Egypt.

Sir Hanbury Brown. Sir HANBURY BROWN, before replying, wished to say a word about the crisis of the second season's work on the Asyût Barrage. Such good progress had been made during the first and second seasons that it had been considered worth while trying to complete the floor right across during the second season. The late Mr. Wilson had discussed the question with him; and, at the risk of being jeered at as a cement-grout fanatic with the late Mr. Kinipple's shoes on, he had recommended putting in the closing piece of the floor in the way in which the floors of the locks of the Delta Barrage weirs had been put in, in order to avoid drawing spring-water from under the finished floor at both ends of the remaining length of floor-space, and so creating runs. Everything could have been got ready almost in the dry while the piles were being driven, as the piling was completed on the 14th July, and the breach did not take place till the 23rd July. If the grouting method had been adopted, the pumping might have been stopped on the 14th July, or a day or two after, and the floor between the piles could have been got in by grouting in a few days, and the work left alone till the next season. There need have been no hurry, as the grouting, if still incomplete, could have gone on after the 23rd July, the dams being maintained simply to produce still water, but not to withstand any head. He was of opinion that the grouting method would have succeeded where the system employed failed, and that at least a saving of expense and time would have resulted, and possibly a sounder bottom layer for the floor would have been gained. It would be seen by Fig. 9, Plate 2, that grouting had had to be resorted to in order to make the floor sound. It would

Sir Hanbury Brown.

have been simpler to put in the whole of that portion of the floor by grouting.

In reply to the discussion, he had been naturally much gratified by Sir Benjamin Baker's remarks, expressing the approval of one whose opinion had world-wide acceptance. Sir Benjamin had himself materially helped in the work by his advice given before the start: he had suggested a modified form of the design submitted for his opinion, and that modification had been accepted as a decided improvement. Sir William Garstin and he had congratulated themselves on having sought Sir Benjamin's advice. Subsequently Sir Benjamin had helped by making suggestions as to the method of forming the boxes. With regard to the position of the subsidiary weirs with respect to the old French Barrage, the weir on the Rosetta branch was 1,500 metres down-stream, and was quite a separate work. The weir on the other branch was 500 metres down-stream, and was also quite separate from the Barrage. In his Paper he had not attempted to deal with anything except what related to grouting as applied to the old Barrage and to the weirs. The description of the Barrage gates did not come within the scope of the Paper; but he had previously written a complete history[1] of the Delta Barrage from the beginning to the present time, which had been published by the Egyptian Government; and a copy of that work was in the Institution library. With regard to the cost of the cement used, delivered at the Barrage, each barrel of 360 lbs. had cost at the beginning of the work 10*s*., and towards the end 12*s*. The cost of the grouted masonry in the core-wall and the footing-wall was 240 piastres per cubic metre (33*s*. per cubic yard). The ratio of the cost of the grouted walls to the cost of the rest of the work in the weirs was roughly 2 : 3. Mr. Fitzmaurice had asked whether the system could be applied to concrete blocks surrounded by rubble. Sir Hanbury Brown certainly thought it could be; and the answer to that question had been given by Mr. Buckley, in his description of his experiments. The lock had been left undisturbed for 3 days after the grouting was done, to enable it to set before the water was pumped out; that period had been considered sufficient, and it had proved to be so. He thought Sir Guilford Molesworth's grout must have been of much thicker consistency than anything used in the Nile weir, otherwise it would have run to the outside of the heap of stone into which it was poured. Mr. Beresford was inclined to favour wells rather than the system employed on the Barrage weirs. The question of

[1] "The Delta Barrage of Lower Egypt." Cairo, 1902.

Sir Hanbury Brown. wells versus other systems was rather too big to discuss. With regard to the depth of the core-wall, it had been decided that the bottom of that wall should go at least as deep as the Barrage floor itself. The bottom of the Barrage floor was at R. L. 4·50 metres, and the core-wall was carried down to R. L. 4. He was not in favour of wells, because the rate of progress was so uncertain. He had been very glad to hear Mr. Beresford testify to Colonel Western's work, as Colonel Western himself had been so modest about it. With regard to Mr. Buckley's remarks, he considered the Sone weir quite a suitable work to select for comparison with the Barrage weirs; but in order to arrive at accurate figures of cost per lineal foot of weir for that purpose, the cost of the under-sluices of the one weir and of the locks of the other, and the contingencies of both, should be eliminated; and that could not be done even approximately. Moreover, coolie labour in Egypt cost double as much as in India, and expenditure on labour was a very large item in the cost. Again, as Mr. Buckley had also pointed out, the cost of the rubble, which was another large item, was four times as much on the Barrage weirs as it was on the Sone weir. He was prepared to accept Mr. Buckley's general conclusion that the Barrage weirs were costly as compared with Indian weirs; but it might be claimed that the extra cost was for rapidity of construction; and in comparing the rate of progress it was not fair to take equal lengths of weir, because a longer length allowed of more simultaneous work. The difficulty was, to complete the foundations of a weir right across a river-channel in one season, instead of in two or more. Neglecting the first experimental season, it might be said that each of the Nile weirs had been carried across its branch in one season of 8 months, and the undertaking to do so had been assumed with confidence. He certainly would not have undertaken to do the same if well-sinking had been adopted for getting in the foundations. At least two seasons for each branch would have been required with such a system. Mr. Fitzmaurice's remarks showed that he also did not believe in wells where rapidity was desirable. It would be interesting to consider the result of saving one season alone in the construction of the weirs. The summer Nile of 1900 had been one of the worst, if not the worst, on record. The second weir had been got in during that season, and had been so far advanced when the pinch came, that the two weirs had been brought into action, and in consequence, according to general opinion, 10 per cent. loss on the cotton crop had been avoided. The cotton crop amounted to nearly $5\frac{1}{2}$ million cwt., and 10 per cent. on that was over $\frac{1}{2}$ million cwt. The average price was

Sir Hanbury Brown.

over £2 10*s.* per cwt.; hence the value of the crops saved was more than £1,250,000, while the cost of the weirs, all told, was one-third of that amount. Besides that, the maize crop had benefited greatly, and a considerable and immediate economy in dredging the main canals of the Delta had been effected. It would be seen that the value of the first season's work done by the weirs was considerable, and if extra expenditure had been involved in building the weirs in time to obtain that result, that expenditure had been fully justified. With regard to the weir being water-tight, it had been considered necessary that the weirs should be as tight as possible, so that no water should be lost. In fact, they were as water-tight as they could be, and in summer not a drop of water passed them. Mr. Buckley's proposed system of hexagonal blocks seemed to be very good, but skilled labour would have to be employed to put the blocks in place, which would add something to their cost.

Mr. Stephens.

Mr. STEPHENS, in reply, stated that the cost given in the Paper for the barrage and regulator included all engineering and general charges, and that the cost of construction alone was £869,546. For such a structure as the Asyût Barrage, the trouble entailed in laying the foundations in the manner adopted, which necessitated the combating of so many troublesome springs, was well repaid by the economy of cost over any other method presenting itself. Had the floor-foundation been wholly grouted up, the additional cost (taking cement at 12*s.* 2*d.* per barrel) would have been over £105,000; and even if the pumping had been debited wholly against this part of the structure, the saving would have exceeded £65,000. With regard to Mr. Mansergh's question, the maximum head of water would never exceed 3·75 metres, and if that head were ever attained it would be in the summer time, with a possible height of 5 metres on the floor up-stream of the gates, and an exceptionally small depth of 1·25 metre on the floor down-stream. In flood time all the sluices were generally up, so that, ordinarily speaking, there was then no head of water; but during the flood of 1902, when the barrage was also used, there had been a head of about 1 metre, the gates then forming a submerged weir. The pressure on the base of one of the ordinary piers on the down-stream side of the gates was about 2·9 tons per square foot. It was quite possible that the amount of firing necessary to burn different clays to the same extent might result in different shades of colour. At Asyût the clay was of a slaty black colour, and this, when burnt only to the small extent desired, became a pale terra-cotta. He quite agreed with Mr. Fitzmaurice as to the advantages to be derived from

Mr. Stephens. burning the clay very carefully, and also agreed that, on large works, it would pay to erect a Hoffmann kiln for the purpose. With reference to Mr. Beresford's remarks, it had been found from experience that with the head of water met with at Asyût the best positions for the sudds were at a distance of 75 metres from the centre line, as stated in the Paper. Of course, so far as the springs were concerned, the farther the sudds were away the better; but as the water to be dealt with within the sudds had come chiefly from below, it had not been advisable to expose too great a width of river-bed, which would have entailed more pumping. The thickness of the floor at Asyût had been increased from 2 metres to 3 metres on account of the abandonment of the wells beneath the piers. The method suggested for leading off the springs to suitable outlets had been tried, and to a certain extent adopted, except that open channels instead of pipes had been chiefly made use of. Open channels a little deeper than the foundation were preferable to pipes, as where pipes were laid the water sometimes passed beneath instead of through them. This plan had served fairly well for a small portion of the lock-floor next the shore, where the floor was protected only by 6-inch timber piling meeting with V-shaped joints. The water had passed easily through these joints to the pumps at the back of the lock, preventing the development of serious springs; but it had been impossible to proceed on this plan continuously, as the springs away from the shore, being confined by the iron piles, had become very troublesome at the scar-ends. It had therefore never been possible to lay any long length of foundation continuously, as it had been found from experience that if long lengths were laid, the springs developing at the ends brought out sand from beneath the foundations. The movement of sand had been stopped by making a temporary sudd across the foundation-trench immediately in front of the scar-end as soon as it was considered advisable to stop any further floor-laying to a section. This sudd stopped the action of the springs by allowing the water to rise. The excavation for the junctions between such sections had in some cases been done by a Priestman grab. A lower layer of concrete deposited through shoots sealed up the site of these springs. Open channels in the concrete had often been brought out to the scar-ends, and such channels had caused no disturbance of the sand when the lengths of foundation dealt with were short; but as soon as these lengths had been joined to those already done, it had become necessary to make the sudd alluded to in front. It would be quite possible to lay without difficulty a small isolated piece of foundation, if intersected by open channels or pipes, with the surrounding water-level kept low Mr. Stephens. enough to drain the pipes or channels; but such a plan could not be successful for a long continuous length, such as the floor of this barrage, where the sides were protected by water-tight piling, and with the river perhaps flowing over the finished work within 100 yards of the foundation in hand, and at times over 20 feet above it. He ventured to think that the very small loss of sand from beneath the foundations, as proved by the small amount of grout used anywhere, showed that the method adopted had been successful. Even in the last section of floor dealt with (Fig. 9, Plate 2), which connected scar-ends where the worst springs were encountered, owing to their being left unprotected from the previous season, only 396 barrels of cement had been used in the grouting, at a cost of £240. The work was excellent throughout, and he thought that the junctions of the different sections at least equalled the other parts, the proportion of cement used at such places being slightly increased. The iron piles acted as a diaphragm, and for this purpose they had supplanted the proposed curtain-wells. The difficulty of making water-tight junctions between the wells presented probably the strongest objection to their use; but the slowness of their construction, as compared with the sinking of iron piles, also told strongly against them. The completion of the piling had generally followed close upon the completion of the excavation, owing to the pile-driving being generally commenced before the excavation was fully out. The exception to this had occurred across the deep channel of the river, where the removal of the sludge had caused some delay in the excavation. No grouting had been done until the masonry of the floor was up to its full height, or nearly so. In reply to Sir Hanbury Brown's remarks, in the summer of 1900, when it was decided to try to complete the floor right across the river, the suggestion to grout up the closing section was considered; but as by it nothing was to be saved as regarded time, it was not adopted. It was considered that with so broad a foundation as at Asyût the ordinary manner of building could not be surpassed for speed. He thought this conclusion was justified by the progress made with the masonry of the floor during the month of July, 1900, up to the time of the accident, which was much in excess of any grouted work done at the Delta weirs. The average per day for work in the floor had been 915 cubic yards, but the daily rate as soon as the excavation was far advanced had been much more than this. The piling had been finished on the evening of the 14th July, or only 8 days before the accident; and from this available time a deduction of 2 or 3 days must be made to allow for grouting up the pile-joints. The

Mr. Stephens. conclusion as to the advisability of continuing the work in the ordinary way had been arrived at irrespective of cost, it having been recognized that the expense of grouted work would be fully justified if, by adopting it, any increased speed in construction could be obtained. At the time of the accident the lower part of the floor had been advanced up to the limit of the site excavated. The masonry had therefore proceeded as quickly as was possible, but, owing to the springs and sludge to be dealt with, the excavation had not been fully completed when the accident occurred. Had the grouting method been followed, the progress could not have exceeded what had been done. He must therefore beg leave to differ from Sir Hanbury Brown's statements that had grouted work been adopted the foundations could have been completed in 1900. He must also differ from Sir Hanbury's opinion that had grouted work been adopted a better floor would have been obtained; though of course it must be admitted that a mortar composed of pure cement should surpass one made with an ordinary proportion of sand in it. The difference in the cost of the two mortars was very large however (with cement costing at Asyût 12*s.* 2*d.* per barrel). For grouted work 3·67 barrels per cubic metre were required, as against 0·95 barrel per cubic metre in the mortar used in the foundations at Asyût.

The President. The PRESIDENT thought it would be agreed that the Institution had reason to congratulate itself that works of so much benefit to Egypt had been conceived and carried out by British engineers who were members of the Institution. Military engineers were excluded from its membership, but the Institution had been glad to welcome Sir Hanbury Brown among its newest members, on his abandoning the military for the civil branch of the profession.

Correspondence.

Mr. Carey. Mr. A. E. CAREY considered that the grouting of the Delta Barrage was a notable example of difficult work carried out with the simplest appliances and at low cost. The plan adopted would not be possible in a tide-way where changes of water-level occurred. The loss of unset concrete on the sack-block system occurred principally within a few feet above and below low water. In order to avoid this loss he had devised [1] a "bag-box" arrange-

[1] British Patent, No. 4,339 of 1888.