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.

ment, not unlike that shown in Fig. 5, Plate 1. One form of the Mr. Carey design was a box with a canvas bottom, slung from projecting beams secured to the finished superstructure in rear of the length to be built. The object of the canvas bottom was to allow plastic concrete deposited in the bag-box to accommodate itself to the irregularities of the sack-block mound prepared to receive it, the box sides protecting the unset concrete from the wash of the sea. This design had been worked out for use at La Guaira Harbour, Venezuela, where the range of tide was insignificant. The foundations of the breakwater there had been built in sack-blocks of 160 tons weight. Between water-level and the level at which a hopper-barge could float was a depth of about 10 feet, and this portion of the work had presented considerable difficulty. Ultimately the difficulty had been surmounted by tipping 60-ton sack-blocks from a rocking depositor running on the surface of the already finished work.[1] The use of cement grout in the manner described by Sir Hanbury Brown, where work had to be carried out in a tide-way or strong current, was an expedient to be adopted under conditions of special emergency. The jointing of the block-work on the Hermitage Breakwater at St. Helier, Jersey, with cement grout, executed by the late Mr. Kinipple, had resulted in a fine piece of work. When this method was used, however, it was impossible not to have some misgiving as to the extent of the penetration of grout into the joints, owing to imperfect vent. It appeared to be demonstrated that, as employed on the Delta Barrage, grout did not travel along the horizontal joints. Also, in a strong current the loss of cement must be considerable. It was obvious that, with a full pipe, cement grout used in the manner described would displace water of half its specific gravity, and consequently that fears of the cement being drowned were groundless. In skipping plastic concrete through water in a confined foundation in a tide-way a much larger quantity of cement was necessary than sufficed for sack-blocks, in order to make good the inevitable wastage. In many instances, however, it would be a more economical method of construction than the use of sack-blocks, as it required less plant.

Mr. H. A. CARSON, when visiting the works in their early Mr. Carson. stages, had been greatly interested in the process of moving earth in small baskets or bags carried on the heads or shoulders of Arabs, and he would like to have some further information as to the portion of the total excavation in earth moved in this way,

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[1] Minutes of Proceedings Inst. C.E., vol. cxv. p. 338.

Mr. Carson. the horizontal distance through which it was moved, and the cost per cubic yard. There were certain obvious advantages in the use of cast-iron sheet-piling; for example, the displacement for a given transverse strength was much less than with timber, and the iron piling would presumably drive much more readily. He thought, however, that a statement comparing the relative advantages and disadvantages as to cost, etc., would interest many readers of the "Proceedings." Was it, for example, thought that cast iron would be more durable than timber? Cement grout has been used by engineers in different parts of the world in many ways. It had apparently been used very effectively and judiciously at Asyût and at the Delta Barrage. The injection of cement grout into a mixture of gravel and stones, as practised at the latter work, was an efficient method of economizing. Considerable quantities of grout had been used during the construction, under his direction, of a large tunnel of concrete recently built under Boston Harbour. In this case some economy had resulted from diluting the cement in the wet mixture with one to three times its volume of sand of as fine grain as the cement itself. He had sometimes found that coarse grains of sand tended to a stratification in settlement that was unfavourable to uniform strength and impermeability.

Mr. Colson. Mr. C. H. Colson mentioned that the use of cement grout for filling fissures in rock and for closing leaks in dams had been found to be of great advantage during the construction of a dock at Malta in the years 1882–1890, under the superintendence of Mr. C. Colson, M. Inst. C.E. The excavation had been in rock much broken up by fissures, through which had passed considerable quantities of water, entailing continuous pumping on a large scale. It had therefore been of great importance that every effort should be made to close the fissures as far as possible, and to prevent the ingress of water. With this object it had been decided to try to fill the fissures with cement grout, and the work had been carried out in the following manner. Wherever an open fissure could be found above the waterline it was cleared out until an open run was reached; into this was built a 4-inch pipe, which was carried up 6 to 8 feet as a stand-pipe, and all other openings to the fissure that could be found were closed with cement concrete or wooden wedges. The water in the excavation, which was then only a few feet deep, was allowed to rise to the level of the sea, and neat cement grout, mixed as thickly as possible, was poured down the pipe until it would take no more. It was found, however, that some of the pipes became full much more quickly than the known Mr. Colson. size of the fissures appeared to indicate should have been the case, and it was considered that some means ought to be adopted to put the cement grout under pressure. Making the stand-pipe longer would have been inconvenient, and a double-barrel force-pump, specially constructed with ball-valves that could be easily cleaned, and mounted on a tank which could be filled with grout, was therefore obtained. The pump was connected to the pipes cemented into the fissures by a 2½-inch leather hose, and the grout was pumped into the fissures with any degree of pressure that was necessary, up to the strength of the gear. This arrangement proved very successful, and a large quantity of cement was forced into all open fissures round the excavation. After allowing the cement to set for about a week, the pumping was resumed, when it was found that the volume of water had been considerably reduced. As the excavation proceeded, fissures varying between $\frac{1}{8}$ inch and 6 to 8 inches in width were continually met with, which were quite full of cement, and from which considerable leakage would have occurred but for the treatment which had been adopted. The cement had in some cases penetrated to a distance of about 100 feet horizontally from the place where it was put in, and to 50 feet in depth. The dams referred to had been constructed of single piles on a sloping rock bottom covered with a deposit of stony mud ranging from 2 feet to 6 feet in thickness. At times, owing either to portions of the rock slipping from below the feet of the piles, or to the mud being not sufficiently solid to fill the small interstices which in some cases occurred between the piles and the rock, leaks had developed, which had been successfully stopped by allowing the water inside and outside the dam to level up, driving 2-inch wrought-iron pipes fitted with a loose point through the mud to the cavity formed by the leak, and forcing cement grout down the pipe until it had filled all cavities and appeared at the surface of the mud next the piles. As the dams were in 30 to 45 feet of water, and had to withstand considerable pressure at the bottom, the grout had been left to set for a week or 10 days before the dam was pumped out; but the treatment adopted had been successful in stopping the leak on each occasion. Similar methods had also been used in the construction of wharf-walls at the same port, during the years 1901–3, under the supervision of Mr. F. W. Kite, M. Inst. C.E., and afterwards of Mr. C. H. Colson. These walls had been constructed inside dams, on a rock bottom in which at times large fissures, in full communication with the sea and

Mr. Colson. yielding large quantities of water, had been met with. As the rock bottom when first bared had been very sloping, and had had to be squared down to make a footing for the wharf-wall, it had been necessary that it should be kept dry; but as the amount of leakage from the fissures had caused very considerable expense in pumping, the fissures, when of large size, had been stopped by clearing all deposit, clay, etc., out of them as far as possible, drawing all water coming from them into one outlet, stopping all other visible inlets to the fissure, and building in a 2-inch wrought-iron pipe. The water inside the dam was then allowed to rise to sea-level, the outlet which had been left in the fissure was stopped by cement concrete deposited by a diver, and after that had set as much cement grout as possible was forced into the fissure through the 2-inch pipe, by the help of the force pump previously referred to. After the grout had set, the dam was again pumped out, when the leakage from the fissure which had been under treatment was usually found to have been practically stopped. Another interesting application of cement grout had been made by Mr. C. Colson, for the purpose of preserving a large dam, which had to stand for some years, from the ravages of the *Teredo.* The dam was constructed of Memel timber in single piles, and after it had been standing for about a year it was found to have been attacked rather badly by the *Teredo.* As the sheathing of the piles with copper or other protective covering, even if possible, would have been very expensive, it was decided to coat the piles with a skin of cement. With this object, fillets $\frac{3}{4}$ inch thick were nailed vertically on the face of the dam at intervals of 6 feet, the space between them was then studded with large-headed nails, and match-boarding was nailed outside all, from fillet to fillet. The space left between the match-boarding and the piles, into which the nails projected, was then filled with cement grout poured down a tube. This treatment covered the whole dam with a continuous sheet of cement that was quite successful in resisting the *Teredo.* Sir Hanbury Brown stated that after the grout had been undisturbed for the remainder of the day and the succeeding night, the block was hard enough to stand without support. As the block was 21 feet high, the grout appeared to have set firmly enough to stand the strains in a very short time, and it would be interesting if Sir Hanbury could state what test-conditions the cement had complied with, and what had been its chemical composition. In the construction of the lock, in which presumably grouting could not be absolutely continuous, had any difficulty been found in obtaining a proper joint between grout deposited from one set of pipes and that run in from the next? Mr. Colson had found that when grout was run its upper surface was almost invariably covered with a soft layer which had lost all its setting qualities, and which would entirely prevent any proper union with material deposited after it had formed. Had this layer been found in the core-blocks, and in what state had the top of the rubble in the lock been when the lock was pumped out? Further, had there been any current in the river while the grouting was being carried out, or had the work been done in still water? Mr. Colson.

Mr. WM. JAFFREY desired to point out that while the names of various gentlemen, including the Author, were associated with the successful work described in Sir Hanbury Brown's Paper, Mr. Kinipple's name was mentioned only to say that he had recommended stock-ramming with clay, which had been unsuccessful; and not a word of acknowledgment was made of the debt of obligation which the Irrigation Department of Egypt, and the gentlemen named in the Paper, were under to Mr. Kinipple for making known fully, by description and illustration, the work he had done elsewhere, of which profitable use had been made by them. Mr. Kinipple was dead, and therefore could not speak for himself. Mr. Jaffrey had been closely associated with him for many years, and was conversant with what he had done in connection with the grouting of work under water, from the time (1858) when he began to employ it. He might describe many applications of the method made by Mr. Kinipple, but would refer only to its use at one work, and to the published descriptions of that work; because what was done there had evidently served as an example which had been followed in the works described by Sir Hanbury Brown. The work in question was the extension of the Hermitage Breakwater at St. Helier, Jersey, carried out in 1887–9. Mr. Kinipple had resolved that this breakwater should be solid from the granite bed to the coping-level, and that where the granite was overlaid with clay and sand the latter should be removed, and the breakwater be founded on the solid rock throughout. This had been done; and the work was described and fully illustrated in two lectures[1] delivered by Mr. Kinipple at the Royal Engineers Institute, Chatham. In 1892 Mr. Kinipple also recommended, in the articles published in *Engineering*,[2] Mr. Jaffrey.

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[1] "Subaqueous Foundations." Royal Engineers Institute Occasional Papers, vol. xv. p. 1; also *Engineering*, vol. l. p. 439.

[2] Vol. liii. p. 609.

Mr. Jaffrey. stock-ramming and grouting for making good defective foundations, and described certain applications of it which he had made, showing how it might be applied in other cases. In these articles reference was made to his earlier lectures, reprinted in the same journal. At the Hermitage Breakwater the method of construction adopted was the following:—The width of the foundation was fully 50 feet, and it was formed in lengths or sections of about 12 feet 6 inches at a time. Each of these sections was enclosed on three sides by a barrier or wall of bags of concrete, and the fourth side was formed by the completed end of the breakwater. Over this area of 50 feet by 12 feet 6 inches, loose rubble and shingle were deposited and struck off by divers to a level surface. The depth of the loose material varied between about 1 foot and 6 feet 6 inches, depending on the irregularities of the rock bottom. This loose mass was cemented together by neat cement grout passed down through pipes from above water-level. One pipe was used, and it was carried down through the loose material to the rock bottom. After a convenient area had been charged with cement, the pipe was transferred to another area, and so on, until the whole section of the bottom or foundation of the breakwater had been dealt with. The work done was excellent both in respect of providing a thoroughly level base and as regarded solidity. On the top of the base so obtained, concrete block-work was built, of which the exterior joints below low water of neap tides were caulked with canvas, and the blocks were cemented together into a solid mass by neat cement grout. The foundation-work above described consisted in cementing together loose material under water in the construction of new work; but old work formed of blocks, bags of concrete, or rubble, was also converted into a monolithic mass by means of cement grout passed down through pipes; and both of these classes of work were fully described in the articles referred to. In the repairs to the Barrage, what had been done was to cement together solidly, with Portland-cement grout, a mass of loose rubble forming the foundations of the work, and also to fill up certain cavities with cement grout. The method of doing this was identical with that pursued at Jersey (with which the Irrigation Department was familiar), namely, passing the grout down through one vertical passage until a certain area had been dealt with, and then through another vertical passage, and so on, until the whole area had been treated. In the case of the Barrage the vertical passages were bore-holes through the masonry piers; in the case of the breakwater they

Mr. Jaffrey.

were iron tubes: that was the only difference. The cementing together of the loose material of the base of the Barrage was thus merely following out, and in the same manner, what Mr. Kinipple had done at the Hermitage Breakwater, Jersey. Not merely so, but neat cement grout had been used for the Barrage, as strongly advocated by Mr. Kinipple,[1] and Sir Hanbury Brown recorded the experience which Mr. Kinipple had previously recorded in the publications above referred to, namely, that the weight of a column of liquid cement grout was about double that of a column of water. At the Barrage it had been found that the distance travelled by cement grout from the bore-hole was 7 metres. At the Hermitage Breakwater, in grouting up the open-jointed block- and bag-work of the lower part of the foundation of the older portion of the work, it had been found that the cement travelled horizontally a distance of about 40 feet from the bottom of the vertical grouting-tube, as stated by Mr. Kinipple.[2] In describing the subsidiary weirs below the Delta Barrage, Sir Hanbury Brown stated that for the construction of the core and subsidiary walls a method of skipping cement into boxes to form a succession of blocks had been considered, but this arrangement had been abandoned in favour of a system of grouted block-work, in connection with which experiments had been carried out by the Irrigation Department. Sir Hanbury might have stated that in *Engineering* Mr. Kinipple had described the experimental blocks, both large and small, which he made in 1883 and 1884 by grouting under water, and of which he had presented a small specimen to the Museum of the Royal Engineers at Chatham. Sir Hanbury Brown had had the advantage of that experience and had only had to repeat it. Further, the construction of the grouted walls of the weirs with three-sided timber frames was merely repeating, but with timber sides instead of bags of concrete, the system of construction adopted by Mr. Kinipple for the base of the Hermitage Breakwater. The work as a whole had been well and skilfully done, and every credit was due to those who had carried it out; but in doing so they had had the full advantage of being acquainted with, and of being able to adopt, the methods of Mr. Kinipple, carried out successfully at other works, and no acknowledgment had been made of this fact. Mr. Jaffrey regarded this as unjust to the memory of an engineer who had done good service in his day in connection

[1] *Engineering*, vol. l. p. 774.
[2] *Ibid.*, vol. liii. p. 647.

Mr. Jaffrey. with marine works and in regard to securing solid work under water, especially by the use of Portland-cement grout; and he desired to put on record the evident obligations the engineers who had had charge of the Barrage were under to Mr. Kinipple.

Mr. Robertson. Mr. F. E. ROBERTSON remarked, on the subject of founding in sand, that he remembered reading in an American technical journal an account of the construction of a length of sewer through quicksand by blowing dry cement by means of compressed air through ordinary tube-well pipes, and thus causing the sand to consolidate to some extent. The remarks in Mr. Stephens's Paper as to the use of underburnt clay for hydraulic mortar should not be taken as of general application without a test in each case. Most of the mortar in India was made with fat lime and ground-up bricks (known as "surkhi"), and experience was in favour of well-burnt brick. If salt were present in the soil, as was so often the case in India, mortar made with underburnt surkhi would disintegrate. The value of this class of mortar depended largely upon the intimate mixture of the lime and surkhi. Drop walls of detached wells or blocks were not to be trusted in sand unless the spaces between them were carefully filled by piles or concrete. He knew of at least one case of failure of an arched flood-viaduct on inverts, with a brick floor up-stream and down-stream to the toe of the bank, terminating in drop walls about 10 feet deep, built of detached blocks. The down-stream wall had not had a sufficient apron of loose protection, and when a flood scoured a hole below the bridge, the sand flowing out through the interstices between the blocks had let the bridge gently down until the arches were shattered. Ferro-concrete piles, now coming so much into use, seemed suitable for drop walls, as they could be moulded into any shape, and holes could be left in them so that they could be rapidly sunk by means of a water-jet.

Mr. Siccama. Mr. H. T. H. SICCAMA considered that the application of Mr. Kinipple's system of subaqueous construction on a large scale marked a new departure in hydraulic engineering. It would be interesting to know, however, whether on the works in Egypt the same thing had been observed as Mr. Buckley mentioned, namely, that the cement filling settled chiefly in the vertical joints between the rubble, and less in horizontal planes. If this should prove to be the usual result, it would greatly detract from the trustworthiness of the method. In Mr. Kinipple's experiments the Portland-cement grouting had filled all interstices perfectly, and had formed a compact mass with the rubble. Perhaps a lighter cement had been used by Mr. Buckley. During the construction of the Suez Canal, hydraulic lime from Le Teil on the Rhone had been principally used for concrete. The specific gravity was somewhat less than that of most Portland cements, and the lime was also slower in setting. Where concrete must be deposited under water, the great difficulty was to prevent the fresh mixture from disintegrating. With concrete half set, this danger disappeared, and if deposited in the form of plastic lumps, it could still be closely packed and rammed down, and in this way form a compact whole, the lumps being still in a condition to adhere together as if they had been tipped in a continuous mass. With quick-setting cements, however, this was risky work, as with undue delay the final setting would be over too soon. With slow-setting mortars a few hours more or less were not of such great importance, and there was the advantage that by this method, with a comparatively small plant, larger quantities could be accumulated for use at the proper moment. But so much depended on circumstances, such as the climate, or the limes and cements available, that no fixed rules could be given: every case must be studied specially. Mr. Siccama.

Mr. Stephens's Paper was a valuable record of the successful building of a weir and lock on a quicksand, one of the most risky undertakings that engineers could have to perform. That it was a success no one could wonder who had seen Messrs. John Aird and Co.'s people at work. It would be interesting to have further information upon some points. For instance, it was a question whether in soft and sandy formations like that described in the Paper, water did not flow or percolate underneath the bed at greater depths than that reached by the cast-iron sheet-piling. If so, there appeared to be some danger that, sooner or later, the floor might be sapped. There was no doubt an excellent reason why cast iron was used instead of timber for the sheet-piling; but with timber piles a greater depth could have been reached, and they could have been driven so as to be perfectly water-tight. It was true that piles driven in a sandy bottom, whether with a pile-driver or by a water-jet, disturbed the soil, which took some time to settle again; and a streak of badly consolidated bottom underneath the floor, and so near to the weight-bearing part of it, would certainly have been a disadvantage; but the cast-iron sheeting must also have caused some movement of the sand near it. With the better regulation of the Nile, a larger volume than formerly must be available for cultivation, and less water be flowing uselessly into the sea. There must soon be enough to spare for supplying fresh water to the marshes and lagoons of the so-called lakes of Ballah and Menzaleh, after they had been embanked and drained. Doubtless the increase of the

Mr. Siccama. cultivable area of the Egyptian Delta in this way would come under consideration within a measurable time.

Mr. Verschoyle. Mr. K. E. VERSCHOYLE considered that the adoption of cast-iron piles had been amply justified, and they had since been used in connection with the Zifta Barrage on the Damietta branch of the Nile,[1] and its subsidiary works, which included two large head-regulators and lock-channels for main canals. In soft and sandy foundations these piles were very effective, giving a beautifully regular line, with no leakage. He had not yet seen them tried in stiff or gravelly soil. He agreed with Mr. Stephens's remarks as to the employment of wells. Much of the success of the work was due to the care taken never to neglect the smallest spring, and to the systematic way in which the springs had been treated. The results of the experiments alluded to on p. 59, comparing the results obtained by using lightly-burnt, well-burnt and over-burnt clay (known in Egypt as "homra," and in India as "surkhi"), for mixing with white lime to form mortar, confirmed, he thought, experience in Egypt and in India. Well-burnt homra was generally specified, as were under-burnt used the result would be a very raw material indeed. The regulation on the Asyût Barrage during the very low flood of 1902 was calculated to have been worth £E.600,000 to the country. The barrage itself had cost £E.720,000. It could probably be shown to be justifiable to construct one or two barrages south of Asyût, in order to ensure the country against the effects of low floods. There was little doubt that, granted the same conditions as regarded foundations, the construction of any such barrages would follow closely the example of the Asyût Barrage, which had now stood the test of two flood-seasons, and had cost little in maintenance. The fact that about 18,000 cubic feet of cement had been introduced into the foundations of the Delta barrages had engendered more confidence as to the stability of the work; while the fact that there existed cavities in the foundations capable of taking this quantity showed how well justified were the apprehensions experienced for years by the officers in charge of the barrages, during many summers when the latter had been called on to sustain a head of 4 metres for periods of several months. Now, with the subsidiary weirs completed, and a maximum head of 3 metres on the barrages, no anxiety was felt. The most perfect set of wells could never have approached the core-walls, formed of grouted blocks, in perfection of alignment

[1] Minutes of Proceedings Inst. C.E., vol. clvi. p. 327.

and invisibility of joints; nor could well-construction have approached this method of grouting in rapidity of execution. As these weirs by coming into action had practically saved the cotton crop in the terrible year of 1900, rapidity of execution would have justified much heavier expenditure than that incurred. The Rosetta weir contained 1,150 lineal metres of core-, footing- and cross walls, and had been practically built in 8 months—a wonderfully rapid rate of progress. The weirs had now stood for four flood-seasons without giving any trouble or causing any anxiety. Before the construction of these weirs the most critical time to carry the valuable summer crops of the Delta over had been from about the middle of July to the end of August. In his annual report for 1903 he had noted that the weirs had reduced the length of the period of very short supply in the Delta by 1 month, and that, in conjunction with the Assuan reservoir, they had reduced it by 2 months in the summer of 1903, during which the period of short supply had been only 38 days. As the tension increased with the length of period of short supply, it followed that it had become much less severe than in the years preceding 1900. As mentioned in Sir Hanbury Brown's Paper, the cement-grouting process had been successfully applied in several instances since it was first tried at the barrages. The Abu Zabel siphon was a small but very instructive case. The siphon consisted of a steel pipe sunk in a dredged trench under the Ismailia Canal, the banks being remade over the pipe when sunk. Springs and running sand having baffled all attempts to get in the stone revetments round the ends of the pipes, wells had been sunk as close to the pipe-ends as possible; but there had still remained spaces of 13 centimetres and 19 centimetres (5 inches and 8 inches) between the wells and the ends of the pipes. At Sir Hanbury Brown's suggestion the junction between the pipes and the wells had been finally effected by excavating, with the aid of divers, an inverted cone round the ends of the pipe, closing the latter with wooden doors fixed by divers, then filling in round the ends with rubble stone into which grouting pipes were introduced. A solid block of masonry had thus been obtained under the end of the pipe abutting against the well. On this foundation, rubble enclosed in a timber casing had been built up and grouted in. After a couple of days the wells had been unwatered, when everything had been found perfectly stanch, and no difficulty had been experienced in enlarging the hole in the side of the well (previously commenced but stopped by the inrush of water and sand) to the diameter of the pipe, and sawing out the wooden cover. The construction of expensive cofferdams and heavy

Mr. Verschoyle.

Mr. Verschoyle. pumping had thus been avoided. The lock-floor of the Ismailia canal-head was another successful piece of cement-grouting work. The system had come to stay.

Sir Hanbury Brown. Sir HANBURY BROWN, in reply, observed that the method of stopping leaks in rock and in dams during the construction of a dock at Malta, described by Mr. Colson, was very similar to that adopted during the building of the additions to the Rayyah Beherah headworks at the Delta Barrage, referred to in the Paper. The new part of this work had had to be built in a deep pit immediately behind the abutment of the old work, the masonry of which was so defective that large leaks in it had permitted much water to find its way through from the canal, which had had to be kept flowing during the progress of the work. These leaks had been stopped by forcing cement backwards along the runs under a head of grout sufficient to overcome the pressure of the water. So also springs rising between sheet-piling had been stanched by placing pipes with perforations horizontally along the top of the piles, and, at intervals, other pipes placed vertically and communicating with the horizontal pipe. Earth had then been heaped up over the horizontal pipe and pile-heads, the mound enclosing the lower ends of the vertical pipes also. The water had then been allowed to rise to its natural level, to stop the flow of the springs, and cement grout had been poured down the vertical pipes until it forced its way upwards through the overlying earth. From the observations of the travel of cement grout along narrow spaces between two surfaces, made during the preliminary experiments carried out before the weirs were built, the success of Mr. Colson's ingenious method of preserving a large dam from the attacks of the *Teredo* could easily be understood. As to the test-conditions and composition of the cement used in the weirs, the cement had been ordinary Portland cement of the usual chemical composition. Its analysis was not available. It had been expected to satisfy the usual tests for tensile strength and setting, but the chief test had been a special one, made by grouting up under water a block of concrete metal, in a model of the box used in the weirs, and examining the set block after 12 hours, and again by breaking it to pieces after a week's immersion in water. If the setting and strength were suited to the requirements of the work to be carried out, the rest mattered little, as a stable water-tight wall was required, and not one that was capable of resisting stresses of compression or tension. Another test applied, which had horrified the representative of a cement works skilled in laboratory tests of the orthodox order, was to shake up the cement in a glass vessel, half filled with water and half with cement, and then to leave the cement to subside to the

Sir Hanbury Brown.

bottom and set. After about 48 hours the glass was broken, the set block was sawn in half, and the stratification was examined to see if the cement was made up of materials of different specific gravities which would be likely to separate when the cement was used as thin grout.[1] The soft layer of the upper surface of the grout, referred to by Mr. Colson, had been observed both in the core-blocks and in the lock-foundations; and, where grouting was not continuous, it was not improbable that such a skin of inferior cement formed a separation between the earlier and later grouted portions. But in such masses as the core-blocks and lock-platforms, formed of irregular rubble, a skin of that kind would not cause danger. In the case of the top surface of the core-blocks it had been found that the skin, though soft at first, hardened after a day or two, though it never became so hard as the rest of the cement. In the case of the lock-platform this defective surface had been scraped off before beginning to build. Still water had been produced for the grouting operations by the banks of sand created by the dredging of the trench in which the weir was to be formed. A few only of the last-formed boxes had had to be put together in the current of the river; but the current had been slight, as the Barrage upstream had been tightly closed. A little increase of difficulty had resulted in putting the boxes together; but, the box once formed, the water inside it had been still—an indispensable condition for satisfactory work with cement grout. Mr. Jaffrey appeared to have overlooked the passage in the Paper in which it was stated that Mr. Kinipple's Papers, advocating stock-ramming and cement-grouting, had attracted attention in the Irrigation Department of Egypt, the footnote to which passage called attention to the articles in *Engineering*, where Mr. Kinipple's description of the work on the Hermitage Breakwater might be found. The original idea of using cement grout on the Barrage must undoubtedly be traced to Mr. Kinipple's Papers. The strange thing was that it had been impossible to persuade Mr. Kinipple himself that cement grout, and not stock-rammed clay, was the proper material for strengthening the Barrage; so that the Egyptian Irrigation Department, in using cement grout in spite of Mr. Kinipple, had shown more appreciation of the method employed at the Hermitage Breakwater than Mr. Kinipple himself, whose attitude towards cement grout in connection with the Barrage was accurately stated in the Paper. His pluck in facing work in Egypt at his advanced age had excited every one's admiration, and no one who had made his

[1] This method of examining the constituents of cement for grouting purposes was probably borrowed from the late Mr. Kinipple.—R.H.B.

Sir Hanbury Brown. acquaintance then would wish to withhold from him his due. To what extent the reading of his papers had helped to solve the problems of construction in the case of the weirs, it was difficult to determine: doubtless it had helped not a little. Be that as it might, the description of the Delta Barrage weirs and that of the Hermitage Breakwater were both available for the information of the engineering profession, the object for which each Paper was written; and that was all that was important in this connection. With regard to Mr. Siccama's inquiry about the filling of horizontal joints between the rubble, the advantage of rubble over rectangular blocks was that a mass of it had no horizontal joints—at least, other than of small dimensions. As regarded squared blocks, it was stated in the concluding paragraph of the Paper that Mr. Buckley's conclusions had been confirmed when some of the ashlar coping of the Barrage weirs had to be removed. As had been the case in Mr. Kinipple's experiments according to Mr. Siccama, the cement grouting at the Barrage with rubble had filled all interstices perfectly, and formed a compact mass. Probably the horizontal joints of the blocks in the Hermitage Breakwater would, if examined, be found to be unfilled by cement, as Mr. Carey suggested. Mr. Verschoyle's appreciation of the weirs was welcome, as not only had he seen the building of them, but he had now been in charge of them, and of the country affected by them, for two summers.

Mr. Stephens. Mr. STEPHENS, in reply, stated that the average cost of excavation from the foundations in the river-bed at Asyût was about 1*s.* per cubic metre (9¼*d.* per cubic yard). He did not think the work could have been done more cheaply by machinery, which could have been only partially used. Egyptian labour was very cheap, and, as an example, it might be mentioned that the yearly silt-clearances in the summer canals were generally done at 2½*d.* to 4*d.* per cubic metre. As to the piling, iron piling cost more than timber, but the additional cost was more than saved by the greater speed at which the iron piling could be driven. Further, iron-piling possessed the advantages of greater certainty of making the joints water-tight—even if the wooden piles were grouted with cement similarly to the iron piles—and greater durability. He could not agree with Mr. Siccama that a greater depth could have been reached with wooden piles. Iron piles, fitted with extension-pieces, were easily driven to a depth of 32 feet. He must also beg leave to differ from Mr. Siccama in his opinion that wooden piles could have been driven perfectly water-tight. The experience gained when driving the wooden piles at the back of the lock-wall, which was referred to in the Paper (p. 37 and elsewhere), showed that in the soil met with here they could not be driven water-tight. Of course they could have been made so after sinking by grouting with cement, or by stuffing with some bituminous packing an arranged void between the tongue and the groove, as with the iron piles. It must also be remembered that about twice as many joints would have had to be dealt with had wooden piles been used. Timber piles 16 inches square, grooved on two faces, had, as stated in the Paper, been used as angle-piles of the lock-foundations, owing to the non-arrival of the special iron angle-piles, and the slowness with which these could be driven would alone have made the use of iron piles advisable. With regard to the mortar, tests should, of course, be made in each case, as Mr. Robertson pointed out; but, unless the clay was highly charged with salt, Mr. Stephens was of opinion that, generally, the clay used for mortar was burnt too much. As to the possibility of the floor being undermined by percolation beneath the piles, as suggested by Mr. Siccama, with the joints made water-tight this was impossible, even were the piles driven only to the depth designed for the curtain-wells, which from previous experience was known to be sufficient; but, in order to provide a further margin of safety, the up-stream piles had been sunk 3 metres, and the down-stream piles 2 metres, below the intended bottom of the curtain-wells. Mr. Stephens.

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22 March, 1904.

Sir WILLIAM H. WHITE, K.C.B., D.Sc., LL.D., F.R.S., President, in the Chair.

The PRESIDENT announced that at the Council Meeting held that day it had been unanimously resolved to signify the great regret which was felt at the bereavement that had fallen upon the Royal Family, and the loss which had been sustained by the nation, by the death of H.R.H. the Duke of Cambridge. The resolution of the Council ran as follows: "That the Council deeply regret the death of H.R.H. George, Duke of Cambridge, K.G., P.C., who has been an honorary member of the Institution since May, 1855."

The discussion upon the Papers by Sir Hanbury Brown and Mr. G. H. Stephens on "The Use of Cement Grout at the Delta Barrage in Egypt" and "The Barrage across the Nile at Asyût," occupied the evening.