Discussion.

The Author, in introducing his Paper, showed a series of lantern-slides illustrating the works described, and pointed out that one of the most interesting features of the work was the fact that the old cast-iron sheet-piling on the upstream side of the old floor of the barrage was in extremely good condition after 35 years' service.

The reasons for deciding to remodel, rather than to rebuild, the Assiut barrage, were set out in the Paper, and he thought that the success of the work had justified that rather bold decision. He wished to allude to the importance of the research station of the Irrigation Department, near Cairo. It had been of immense value while the work was in progress, and in the preparation of the design the large-scale models of sluices, gates, and so forth, had been extremely useful in the making of what might be termed intelligent guesses as to what was going to happen.

With regard to the Francois cut-offs, the original experiments were not mentioned in the Paper. They had been made on the site. Cement was tried for permeating the material which was at the bottom of the river bed, but it was quite useless; it would not permeate at all. Chemicals were also tried, but they required such high pressures that they could not be used with safety. A bituminous composition was then tried, and, as it proved satisfactory, it was adopted.

It might be thought that the sudds were too large and expensive, but it was necessary to prevent any possibility of damage to, or failure of, the existing structure; therefore the Engineers paid for the sudds in the contract price. The back ends of the sudds had to be made tight, because it was not considered safe to touch the old work. That was done by means of the Francois cut-offs underneath the old work and the sheeting underneath and above the new work. There was only one case of seepage, but it was noticed at once, due to the careful inspection of the sudds. There was some subsidence, which proved that there was water flowing, and an imperfect joint was found in the piling which was planted on top of the floor of the previous season. The variation in the hydraulic gradients in the sudds was very great. Experiments were carried out, and it was rather a question of averaging on the different sections taken. There was an enormous difference in the nature of the sand. On the upstream side the sand was very impermeable: the river coming down was full of vegetable and other matter which made the sand impermeable. That was proved by excavations in the sudds.

It was necessary to be very careful to remove all rubble in the bottom of the river. At the end of the third season a small quantity of rubble was left, with the result that a deep hole was formed.

The most serious case of leakage of water had occurred when the extension of the west lock wall was being carried out and a certain amount of subsoil water was tapped. Fortunately Mr. C. M. Norrie was there at the time, and he realized at once that it was necessary to localize and control the water immediately, as otherwise the whole wall would have been endangered. With that exception, very little trouble was experienced with water.

In the first season it was not possible to put the new gates into the sluices, because there was no operating machine, and the old gates, which had timber stanching-pieces on the bottom, had to be used on the new granite sills. It was found afterwards that there were some small holes in the bottom of the stanching-pieces, and erosion had taken place in the solid granite, amounting in one place to from $\frac{1}{4}$ inch to $\frac{3}{8}$ inch. That was evidently due to the passage through the small holes of the water and sand under a head, acting as a sand-blast on the granite. That showed the care that had to be taken to see that there was a dead tight fit between the bottom of the gates and the sills.

The reason why swing bridges were not put in was that the old foundations had to be used as far as possible, and the extra width required ruled that out.

He had not attempted to give any accurate information about the amount of pumping, because he did not think that it was possible to do so. In work of the kind in question the water to be pumped varied from day to day according to the state of the foundations and whether it was the beginning or the end of the season, so that the figures given in the Paper were only approximate.

When he went to the work on the Assiut barrage he had had practically no experience of the metric system, except in France during the last war, but he found it extremely simple and valuable. Within a month he was working in it and within 3 months he was thinking in it. He hoped that one day the metric scale would be adopted in Great Britain. As an instance of its simplicity, he would refer to the statement in the Paper that the amount of cement used in grouting under the new floors upstream of the barrage was 0·0195 cubic metre per square metre of floor : a glance showed that the average depth of cement underneath the floor was 1·95 centimetre.

In conclusion, he wished to express his gratitude to Mr. Vaughan-Lee, M. Inst. C.E., and his firm, for their help in the preparation of the drawings and in many other directions.

Mr. M. F-G. Wilson observed that he had not seen the work described in the Paper ; but its design and execution had been under the special charge of his partner, Mr. A. G. Vaughan-Lee, M. Inst. C.E., who had sent to him from Egypt a memorandum which might be of interest to the members.

In that memorandum, it was stated that the work of remodelling the barrage was of a delicate nature and required careful investigation, because in the event of a serious accident to the old structure, involving even its partial collapse, interference would have been caused to the whole of the irrigation system on the west bank of the river between Assiut and Cairo. Therefore it was essential that every precaution should be taken to avoid risk of damage to the old barrage by possible undermining of the foundations or the collapse of a sudd when the sluice-gates provided within each sudd section were out of action.

After receiving the report of the consulting engineers upon the tenders submitted, the Government accepted their recommendation to award the contract to Messrs. Cochrane. Unfortunately the award could not be made before October, so that the contractors were not allowed as much time as they would have liked to make their preparations for commencing the first season's work in December. The Government had already arranged to stop navigation through the lock during the first season, and that arrangement could not be altered, as the shipping companies had already provided for the distribution of their craft, some upstream and some downstream of the barrage. Accordingly, it was essential that the work at the west end of the barrage, including the lock, should be undertaken during the first season, thus throwing very heavy work upon the contractors during that season in comparison with the remaining three seasons; but, by energetic prosecution of the operations, the specially heavy first season's work was concluded successfully. It would have been more advantageous to commence work at the east end of the barrage, and to proceed westward, thus leaving the heavy work at that end, including the lock, until the last season, when the organization would have been more thoroughly trained to their work. Nevertheless, the work was completed satisfactorily before the annual flood, much to the credit of the contractors.

The essence of the work was the necessity of avoiding damage to the old structure, and the sudds were designed so that there could be no risk of failure, whilst the pumping arrangements were of ample capacity and were up to date in all respects. Those points were specially insisted upon in the contract and in interviews with the firms tendering. In order to avoid risk of undermining the old structure, the foundations of the latter were protected by Rotinoff reinforced-concrete sheet-piling, forming a cut-off, rather than by driving two rows of ordinary sheet-piling, excavating between them by sand-pumps, and filling in with concrete, as had been done in the cases of the Nag-Hamadi and Mohammed Ali barrages. It was felt that for such a structure ordinary steel sheet-piling would not form so satisfactory or permanent a cut-off as would the reinforced-concrete sheet-piling, provided that absolute continuity of the piling, without any breaks, could be ensured. Eventually the design submitted by the late Mr. Rotinoff was adopted, with certain modifications resulting from experiments carried out in England.

Further, in order to prevent undermining of the old structure by the longitudinal travel, under the floor, of water coming from outside the sudds, the provision of cut-offs formed by impregnating the ground below the floor of the barrage was included in the contract, and those were duly carried out. Holes were also drilled through the floor of the old structure, and cement grout was applied under pressure. Those precautions ensured the stability of the old work, and its foundations were rendered thoroughly solid and secure. The old structure had always been regarded as rather insecure, not because of any weakness in itself, but because of the risk, during exceptional floods, of heavy scour occurring downstream of the work and causing the formation of pot-holes, which, by cutting back, might undermine the floor and lead to collapse. That was by no means an imaginary risk, for serious scour had actually occurred, the holes thus formed being replenished with rubble; and, although at one time protection was provided by an apron of small concrete blocks, that protection was not completely effective and scour still continued. Doubtless the real cause of the trouble was the insufficient length of the downstream floor and its protective aprons; that defect had been remedied in the new design.

When the consulting engineers received instructions to proceed with the design for the remodelling of the barrage, it was not intended to provide new sluice-gates; but while the contract documents were being prepared the Government decided to install new sluice-gates with cast-iron grooves. That was a wise decision, as the old gates and grooves were of obsolete design and were in bad condition.

The actual execution of the work presented no special difficulties. Such as had occurred were mostly in connexion with the upstream floor and with the alterations and additions to the lock walls and their protective aprons. Once the foundations were in and the risk of undermining by springs and floors of sand was overcome, the widening of the superstructure of the barrage and the other works in the neighbourhood of the floor-level were quite simple.

The total cubic content of the permanent work was not large, and the contractors were paid directly for the cost of the sudds and the bituminous cut-offs. If those had not been included as separate items in the schedule of quantities, the overhead charges would have been unduly high.

The contractors should be congratulated upon having carried out the work so successfully and satisfactorily, and well within the contract time.

Mr. C. M. Norrie said that, with regard to the cementated cut-offs, the pressure required for the chemical process would have been up to 250 lb. per square inch, as compared with only about 30 lb. per square inch for the bituminous impregnation. Such a high pressure made the adoption of the chemical process out of the question. The bitumen system consisted of injecting a very fine emulsion of bitumen, there being in the mixture an emulsion breaker with a delayed action. The emulsion was so fine that it penetrated everywhere and filled all the voids in very fine sand, and the breaker then broke up the bitumen which filled the voids.

The first season's work, to which Mr. Wilson had referred, was, from the contractors' point of view, most strenuous. It was necessary to get the work started very quickly and in the face of certain immediate uncertainties. The first uncertainty was the possibility of driving the sudd piling through the rubble protection which had been deposited in former years downstream of the barrage. The second uncertainty was in regard to the old concrete blocks which had been deposited. It was first of all necessary to explore their extent, and then they had to be lifted out by a diver where the line of the sudd piling crossed the barrage. The old blocks had no lifting-holes in them and were rather closely set, but they had side grooves (which had to be cleaned out), and then slings had to be put down underneath them. It was a somewhat laborious and tedious task for a diver to do under water.

The rubble fortunately proved to be rather soft limestone and the piles went through fairly easily, only a comparatively small portion requiring cutting off at the bottom at the end of the season to make them fit for use in the next season's work.

All the pumping-sets in the sudded areas were on barges. They were the same pumping sets as had been used at the Nag-Hamadi barrage. It was thought that the most saturated area of the dried-out portion would be close to the inner toes of the upstream sudds, and, rather unfortunately, the pumping-sumps were placed in the first season close up to the toe, very close to the inner line of the sheet-piling. As the Author had pointed out, a great deal of water seeped in from the banks, and a considerable amount of trouble was experienced when trying to clear the foundations of water, because the pumping-sumps were too far away from the excavations. There was also another difficulty: the Rotinoff piling was jetted down, and the amount of water required for that operation was very much greater than had been anticipated, whilst unfortunately during the first year everything had to be so hurriedly done that the quickest method of getting down the piles had been adopted. In that method, which he could only describe as horrible, the pile was plunged up and down, whilst it was steadily lowered by its own weight. The result was, of course, that a thick "porridge" was brought to the surface, which clogged all the drainage channels and the pumps. In the following seasons, when there was no need for such speed, jetting and the hammer were used for getting down the piling, and everything was much more orderly, and there was not so much interference with the excavation operations.

The total dredging required for the four sudds was about 1,300,000 cubic metres, and the total length of pile-driving was about 3,800 metres, involving the handling, driving, and drawing of about 1,950 tons per season. After the initial de-watering of the sudd areas, the amount of pumping required ranged between 25 and 9 gallons per hour per square metre of dried-out area. Those figures included pumping from both upstream and downstream of the barrage. Gaugings taken towards the end of the second season's work gave figures of 7·8 and 12·0 gallons per hour per square metre, upstream and downstream respectively. It was peculiar that upstream, where there was a greater static head, less water had to be pumped than on the downstream side. The explanation might be that the rubble in the foundations downstream allowed a greater leakage through the sheet-piling. Also, the piling there was, he thought, a metre less in depth than the piling upstream.

As had already been mentioned, the sudds were of very ample cross-section. They could probably have been made less wide with safety, but it was considered better to run no risks. As an instance of a much narrower form of sudd or cofferdam, he might mention that his firm at present had one holding up 45 feet of sea-water, and it was formed of two rows of steel interlocking sheet-piling 34 feet apart, the rows being tied together with steel bars at intervals and filled in between with sand. During 2 years the total deflexion at the top had gradually increased to only about 2 inches. That barrier had been very successful and the rate of leakage through it had been very small. At Assiut it would have been quite impossible to put up that form of barrier; there was no time for it, and dredging and piling had to be carried on concurrently. The wide sudds at Assiut had proved to be of great value in that they formed splendid sites for the storage of the concrete aggregate and dressed stone-work required for the season's work, as the quarries were at a great distance from the site.

The rates of progress of the work were, roughly: excavation, over 3,200 cubic metres per week; concrete in mass, 3,800 cubic metres per week; concrete blocks, over 1,800 tons per week; stone-setting, 320 cubic metres per week.

He would like to record how very happy the work had been; the engineers and contractors had got to know each other and had worked well together.

Mr. W. T. Halcrow said that a description of the design and construction of a large engineering work was always of interest, but it was increasingly so when it included a record of the conditions of an existing structure, the foundations of which were exposed after 35 years of service. In the present case the old work was found to be good and was incorporated in the enlarged barrage.

On reading the Paper he had been impressed by the amount of work carried out in the first season. The contract was awarded as late as October, and piling commenced in November. The quantities given in the Appendix to the Paper (p. 329) indicated that the first season's work was the largest of the four required. There was an immense amount of preliminary work to be done on a large contract in the assembly of plant, labour, and material, and in the present case the contractors appeared to have achieved remarkable progress, necessitating good organization.

The presence of cavities between and around the rubble masonry was mentioned in the Paper, and that recalled arguments on the relative merits of masonry and concrete for gravity dams. It was more difficult to obtain homogeneity in a mass of rubble masonry in mortar than in a mass of concrete, and there was therefore some risk of voids which might fill with water and cause uplift pressure. On the other hand, the specific gravity of masonry was greater than that of concrete, and also—perhaps a more important point—it did not shrink as concrete did in setting. On the whole, the advantage lay with masonry. In the case of barrages which consisted of a series of piers supporting gates, the problem of uplift pressure was not serious.

He had intended to ask the Author what was the condition of the cast-iron sheet-piling when it was exposed, but the Author had already stated that it was in very good condition. As a pupil in the early years of the present century he had been engaged on the construction of a large graving-dock at Hebburn-on-Tyne, where cast-iron sheet-piling was used. It was driven in fine sand, where it had been found impossible to employ timber sheeting, the driving being done by means of an ordinary drop-hammer. To protect the head, a solid copper dolly was used, 6 inches square and covering the full width of the piles. The piling was so designed that a water-pipe could be inserted for jetting purposes between the inner part of the jaw and the bulb of the next pile, although actually that was not required. Trenches excavated behind the sheet-piling showed it to be watertight, and in only one or two cases was a short length—about a yard—of one side of a jaw broken off. There had been no opportunity of examining that piling since the work had been completed, as the dock was still in service.

The application of mild steel for piling was an obvious improvement on cast iron, and steel was used in two positions in the new work described in the Paper. In the third position, however, reinforced-concrete piles of a special design were introduced, the reasons for using which had been largely given in Mr. Vaughan-Lee's memorandum, read by Mr. Wilson.

It was stated in the Paper that special provisions with regard to the sudds were embodied in the contract. In view of their importance in the work where an existing structure had to be protected, he would like to ask whether the sudds were designed by the engineers or by the contractors. Whilst it was the British custom to place on the contractors the responsibility for the design of all temporary work, there were, in his view, cases where certain structures should be excluded. With regard to the sudds, he assumed that the engineers, when studying the designs of the permanent work, would have available data which it might not have been possible for the contractors to make full use of during the limited period allowed for tendering. What were the Author's views on the point as to whether or not the engineers ought, in the case of the sudds, to have designed the temporary works ?

He noted that the hydraulic gradient of the water in the sand was found to be higher than assumed, and it would appear that there was some doubt about the necessity for the inner row of sheet-piling. He appreciated, however, the advisability of taking every precaution in an important work of the kind in question, large sections of which had to be carried out in a limited season's work, to ensure freedom from water within the cofferdams so as to allow of speedy construction.

Mr. W. J. E. Binnie, Past-President, remarked that two points in the Paper interested him particularly. One, which had already been dealt with to a certain extent, was the question of the bituminous emulsion which was used to make cut-offs 5 metres wide and about 29 metres long. The Author had stated that 162 holes were drilled through the old floor and were treated, to a depth of 4 metres below the floor, with a bituminous emulsion, the quantities forced into each hole ranging from 360 to 720 litres. It would therefore appear that the ratio between the quantity of emulsion which was forced down and the bulk of the sand into which it was forced would be about 1 : 6, or one-sixth of the total volume. That, of course, did not take into account any emulsion which spread, as mentioned in the Paper, beyond the old floor, so that apparently it did not fill all of the voids in the sand. The sand was very fine, but no particulars about it were given in the Paper. If any mechanical analysis had been made of the sand, the results would be very interesting.

He would also like information as to the cost of the bitumen process, because he had never used that process himself. It appeared to be extremely promising, and the results presented were very satisfactory. He would shortly have to deal with a similar problem in connexion with the foundations of a large dam which would have to go down about 13 or 14 metres from the surface in an attempt to construct an impermeable barrier between the work and the sea a short distance away. The question of cost had to be considered, and he wished to find the best way to deal with the matter—whether to use a large quantity of piling and pumps or to make an impermeable barrier. Therefore he would be obliged if the Author could indicate the cost of the emulsion used, per litre, per square metre, or in any other way.

His second point had already been touched upon in the course of the discussion ; it concerned the diversion-walls or little weirs which had been evolved by experimental work. He remembered visiting the laboratory at the Delta barrage when experiments were being carried out in connexion with the Isna barrage, which was rather similar to the Assiut barrage. Both suffered from similar trouble due to the erosion which took place at the end of the apron. In the case of the Assiut barrage a cure appeared to have been effected by the very simple device of the diversion-wall. A valuable Paper[1] dealing with the prevention of scour by various methods had recently been presented to The Institution; but the method described by the Author appeared to be perfectly effective, and was very simple. The subject could be followed farther by reference to the Paper presented to The Institution by Messrs. A. D. D. Butcher and J. D. Atkinson, Assoc. M. Inst. C.E.[2], in 1934, which had resulted in expressions of opinion by many people all over the world on the problem of the prevention of scour. When the Assiut barrage was built very little was known about the subject, and in fact it was only since models had been made of structures, and experiments carried out with them, that knowledge had been gained of the means to overcome difficulties of that sort. That could not be determined by mathematics. Nothing was known as to what was going to happen, but that would be shown by the models. Therefore he considered that all such structures should be tested by means of models before their final design was established.

Mr. R. H. H. Stanger observed that the Author had referred to a mixture of tar, pitch, lime, and naphtha for the painting of steelwork. Considerable trouble had been experienced from time to time with some of the painting for the various dams on the Nile. He believed that the mixture mentioned in the Paper was found to be the best, and its value would probably be far higher than that of any protective bituminous paint. Actually the finished mixture would not contain 3 per cent. of lime; that percentage was used in making up the mixture for the purpose of neutralizing any acid, and for reducing the water, but the finished mixture probably contained rather less than 1 per cent. of lime. The consistency of the paint was such that at 60° F. it would just pour.

The Author had stated that the crushing load of concrete averaged about 5,000 lb. per square inch, but he did not say at what age. From Mr. Stanger's own records of concrete cubes which came home from the work, he found that the testing was done either at 45 days or at 90 days. If the cubes arrived in time, they were tested at 45 days. The concrete in the Rotinoff piles, which was a 4-to-1 mix, gave values of 6,800 lb. per square inch at 45 days and of 9,000 lb. per square inch at 90 days. The density ranged between 150 lb. and 153½ lb., so that it was very good concrete. The concrete in the toes, which was of 6-to-1 mix, gave 4,700 lb. per square inch at 45 days and 5,200 lb. per square inch at 90 days, whilst the 4-to-1 concrete in the arches and in the regulator of the barrage

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[1] R. V. Burns and C. M. White, "The Protection of Dams, Weirs, and Sluices against Scour." Journal Inst. C.E., vol. 10 (1938–39), p. 23 (November 1938).

[2] "The Causes and Prevention of Bed Erosion, with Special Reference to the Protection of Structures controlling Rivers and Canals." Minutes of Proceedings Inst. C.E., vol. 235 (1932–33, Part i), p. 175.

gave 6,800 lb. per square inch at 45 days and 7,500 lb. per square inch at 90 days. He thought, therefore, that it would be admitted that the concrete was very good.

Mr. William Allard said that those who referred to Mr. G. H. Stephen's Paper [1] would there learn of the part which the Assiut barrage had played in the development of the principles of design of that type of structure.

The obstruction by a barrage or diversion-weir of a river channel with a sandy bed created several problems. One was the possibility of erosion at the toe of the downstream apron; another was the undermining of the structure by water flowing through and removing the sand beneath it; whilst if the weir were pierced with sluices, a third problem was the disturbance of river-flow caused by the piers and sluices. Since barrage-building began, all those three problems had been solved or clarified to a very considerable extent by research work.

Mr. Binnie had referred to such research in respect of the first problem. With regard to the second, about the end of the last century there had been several collapses of Indian river-weirs, one of them (the Narora weir) failing at the time when the Assiut barrage construction was beginning. Meanwhile, there had been research work at Roorkee College in India, under the direction of Colonel Clibborn, and the theory of the distance of creep had been evolved. Mr. J. S. Beresford, an irrigation engineer in India, brought that information to the notice of a friend then at Assiut, with the result that the design of the barrage was modified. The theory mentioned was described in a book written by Mr. W. G. Bligh[2]. It had now been superseded by that of lines of equal pressure, mentioned in Dr. Karl von Terzaghi's James Forrest Lecture[3]. The design of the remodelled Assiut barrage seemed to conform with that later theory. The apron included a flexible portion resting on hand-packed limestone rubble, the two together forming a sponge-like mass through which the water brought under the floor to that point by pressure could escape freely. The application of the theory to the barrage design revealed the need for such free escape.

The Author had described (p. 304) the structural condition of the original barrage before remodelling began. It would be valuable to know also what difficulties its operation had presented; for example, in passing river-craft through the barrage, in operating the sluice-gates, and in river-training works, as well as what the total cost of repairing the downstream

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[1] "The Barrage across the Nile at Asyût." Minutes of Proceedings Inst. C.E., vol. clviii (1903–4, part IV), p. 26.

[2] "The Practical Design of Irrigation Works." Third edition (1927). (Constable & Company.)

[3] "Soil Mechanics—A New Chapter in Engineering Science." Journal Inst. C.E., vol. 12 (1938–9), p. 106 (June 1939.)

apron from time to time had been. Equally valuable would be the information that should now be available as to the results that had been obtained from the baffle and deflecting weirs on the downstream apron of the remodelled barrage.

Mr. Allard asked what was the maximum discharge of the Nile to be passed through the barrage, and suggested that the maximum flood-level anticipated downstream of the structure should be stated. The flood-level shown in Figs. 2, Plate 1, was naturally one that provided a large difference of head, and therefore exacting conditions for the barrage, but it was presumably accordingly the minimum flood-level that was to be expected with an upstream level of 52·20. The maximum level downstream might be, he assumed, about 3·70 metres higher, at say 51·90.

The Author mentioned (p. 303) that a third gate had been added to the two first provided for each sluice in the original barrage. The Nile flood of 1913 had been the lowest in the memory of people then living, indeed perhaps the fourth lowest in a period of over 900 years for which records existed. The river conditions observed then had caused the revision of the regulating arrangements. It would be noted (pp. 319, 320) that granite and cast-iron had been used for the lining of the lower portions of the sluice vents. Mr. Allard suggested that besides the reasons given by the Author for that, there might be the wish to use the barrage to measure river-discharges. Mr. A. D. Butcher had calibrated other barrages in Egypt for that purpose, the requisites being firstly a submerged orifice, and secondly observations of the height of orifice and the water-levels upstream and downstream of the orifice. That usually made it essential, especially when the downstream river-level was low, to pass all water underneath the lower gate-leaf. If then the river-level were high upstream and low downstream, the water emerging from under the gate would be moving at high speed. The measurement of its river-supplies was regarded by Egypt as a matter of constantly growing importance, which, it was suggested, rendered the protective vent-linings more necessary than ever.

With regard to the Author's advocacy of the metric system, Mr. Allard mentioned that it had already been adopted in Eire for the State hydrometric surveys.

Dr. Herbert Chatley said that the first point he wished to raise was with regard to the definition of the word "sudd." The word was used quite freely in Egyptian irrigation practice with respect to the marshes of the Sudan. Apparently, therefore, it was used with two meanings, which was a pity. He wished to inquire about the construction of the sudds or cofferdams at their junction with the barrage itself. It was not by any means clear how the watertight joint was made properly between the sudd and the barrage itself. He had had bitter experience with dams of the kind in question, and it seemed to him that very considerable precautions had to be, and doubtless were, taken, but some further information on the point would be of great interest. Mr. Norrie had explained how the piling was applied through the old aprons, but even that, he thought, might be dealt with a little more fully, because the watertightness of the cofferdam was the most essential feature of the whole of the design.

Finally, he entirely agreed with the Author in his opinion of the metric system. He had had the experience of working on two rivers at almost the same time. In one case everything was done in the English system and in the other case in the metric system, and the comparison between the two would hardly bear describing.

Dr. W. L. Lowe-Brown thought that he was the only person present who had been engaged on the original Assiut dam during its construction, and he wished to correct one or two points that had been made.

He was sorry that the Author had not explained in more detail why the alterations to the barrage had become necessary. The fact was that the barrage had for many years been used for flood-regulation, although it was not originally designed for that purpose, and it was now proposed to subject it to even more severe conditions.

The original barrage at Assiut was designed to raise the level at the entrance to the Ibrahimia canal at low Nile, sufficiently to provide perennial irrigation some distance downstream. Some of the land near to the Ibrahimia canal was to be irrigated by basin irrigation from the Nile flood, but it was never intended to raise the level of the Nile when it was in flood. The original barrage was therefore only designed for the sluice-gates to be closed when the river was low, to provide additional head in the canal for perennial irrigation some distance downstream ; at high Nile the gates were expected to be wide open to allow the river to flow normally through the sluiceways without any appreciable increase of velocity, and with a head of only 20 centimetres.

During the first year that the barrage was in full operation, however, the Nile flood was unusually low, and the then Director-General of Reservoirs, Mr. (afterwards Sir Arthur) Webb, M. Inst. C.E., took the decision to close down the gates against the flood and so raise the level of the river at the entrance to the canal and save the crops in the basins, which would otherwise have been short of water. He knew that the barrage had not been designed for that purpose, but he decided to take the risk, against the opinion of many. Before the gates were shut down he placed an order for 5,000 cubic metres of broken stone, which was quickly collected near the end of the barrage. He also gave Dr. Lowe-Brown instructions to have daily soundings taken to see what happened to the downstream apron, which he knew was far too light to stand the rush of water for long and might be seriously damaged. The daily soundings showed a gradual increase in the scour over the apron, but not until a hole over 30 feet deep had been scoured out in the apron did they begin to throw in the stone to fill the holes, and to lift the gates to reduce the velocity, but by then the upper basins had been flooded and the crops saved. That had been described in detail elsewhere[1].

The results of that season's work had been considered so satisfactory that it was decided to increase the width and depth of the downstream apron to permit flood-regulation to be carried out whenever necessary, and subsequently it was found that although the barrage floor had stood up relatively well to the pounding for which it had never been designed, it showed signs of deterioration; it was therefore repaired with granite. All barrages built on the upper Nile had since been designed to allow for flood-regulation.

The difference between holding up the river at low Nile in the way the original dam was intended to be used, and holding up the Nile during the flood, was very great, as the volume of water passing was probably more than ten times as much in the latter case as in the former case.

The impression created by the Paper seemed to have been that the quality of the work in the old dam was inferior; the number of inspectors employed was not very great, and it was necessary to place them on the most important parts of the work. All the underwater work of the old barrage was excellent. There might have been a few hollows in some of the piers at the top, but when there was only one inspector to every hundred Levantine masons the work might occasionally be scamped. On the part of the work that was important, however, and that had to withstand the hydraulic conditions, he did not think that there was any scamping.

Mr. George Rotinoff said that there were one or two points he would like to mention with regard to the concrete sheet-piling.

Mr. Norrie had said that the jetting of the piles had created a great quantity of water which had to be pumped out. It was found that in the first season's work, in order to speed up the driving, two pumps had had to be used. The pumps were of 25 horsepower, delivering together 12,000 gallons per hour, and one pump was intended to be a spare. It was found that one pump was insufficient to obtain the speed of driving required, and therefore the two pumps were used, whilst the jets were eventually enlarged when it was found that the piles were not penetrating sufficiently quickly.

Another point which might be of interest was that in experiments on the site it was found that the piles could not be driven down more than 4 feet without jetting, and that meant that they were jetted right to the bottom, except for the last metre or so.

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[1] *Discussion on* "The Nag-Hammadi Barrage, Upper Egypt." Minutes of Proceedings Inst. C.E., vol. 232 (1930–31, Part 2), p. 376.

Discussion on "The Causes and Prevention of Bed Erosion, with Special Reference to the Protection of Structures Controlling Rivers and Canals." *Ibid.*, vol. 235 (1932–33, Part 1), p. 226.

Sir William Wilcocks and J. I. Graig, "Egyptian Irrigation." Third edition (1913), vol. 2, p. 663.

The question might be asked why a Ruston-Bucyrus caterpillar navvy was used for driving the piles. He thought that the remarks he had just made with regard to the jetting would show that, when jets were used very close alongside the pile-frame, the water running away from the piles would undermine the pile-frame and prevent the piles being kept plumb during driving, and the navvy was used so that the jib could be employed for handling and pitching the piles and the pile driving could thus be kept away from the foot of the navvy. Some difficulty was found even with that arrangement. The navvy used to sink in the soft sand and difficulty was experienced in keeping the piles plumb, and for that reason several different shapes of pile were cast. Some of the piles used to "fan" to the extent of a foot or so during the driving of ten piles in the first season's work. That was eventually overcome by driving tapered piles. It was not possible to determine beforehand which way the "fanning" would take place; it depended upon how the jets were used and whether the men using them considered that the jetting pipes should be lowered or kept up high. The use of tapered piles enabled the last pile of the season to be driven absolutely plumb.

The Author, in reply, observed that, in regard to the relative advantages of Rotinoff reinforced-concrete piles and steel sheet-piling, he believed that the late Sir Maurice Fitzmaurice, Past-President Inst. C.E., gave the life of steel sheet-piles as 100 years. The reinforced-concrete piles would undoubtedly have a longer life. He explained a test made of driving, grouting, and bodily withdrawing a line of piles, which came out in one solid mass with no chance of water percolation in any way visible. He doubted if any steel sheet-piling subjected to a head were devoid of any seepage whatever.

Referring to the design of the temporary sudds, he could not, of course, speak for the consulting engineers. His own opinion was that in the case in point the engineers were right in having a voice in the design of the temporary work. The schedule of prices included a separate item for the four sudds. Conditions were included in the contract governing the design of the sudds, and such designs had to be submitted with the tenders.

In regard to the impregnation of the material below the barrage with bituminous emulsion, mechanical analysis of the material was made, but the results were not at present available. It might, however, be stated that the fine sand composing it was dense, with the voids largely filled with the fine Nile silt. That would reduce the amount of emulsion which could be injected. It might be added that it was soon seen that there was intercommunication between some of the injection-holes. Cement grout was therefore injected at each cut-off immediately below the barrage floor to seal any possible cavities, before the bituminous process was commenced. Experiments made showed that cement set satisfactorily in the presence of the bituminous emulsion.

Referring to Mr. Allard's inquiry as to what improvements in design could be made on the original structure so far as operation was concerned, experience had produced better and more efficient locks, gates, operating gear, sluicing culverts, and approaches, and also more efficient sluice-gates and operating methods, as well as subways to take water and other mains. Where feasible, such improvements were incorporated in the remodelling.

The Author had not heard of reports as yet as to beneficial or adverse results of the baffle and deflecting weirs downstream of the barrage. Compared with similar structures without weirs the effect of the baffle weir was obvious to the eye. The rapid and destructive rush of water issuing from the sluices was broken up by the weir soon after leaving the piers, and proceeded down across the apron and toe in a comparatively steady and regular flow. That would appear to be beneficial. The life of the granite weir would be of interest in the future.

The water-levels at the peak of the flood were not shown in Figs. 2, Plate 1. At that time, if all the sluice-gates were lifted, there was little difference in level on either side of the barrage. The flood-period levels as shown referred to regulation during that period.

The Author agreed with Dr. Lowe-Brown in that the original barrage and aprons had not been designed for regulation during the flood-period. He was also extremely sorry if Dr. Lowe-Brown considered that the quality of the old work was in any way criticized in the Paper. He had tried to make it clear that everyone on the remodelling considered that the old work was extremely good.

With regard to the making of a watertight joint between the existing barrage and the ends of the sudds, stop-logs were fitted in the grooves in the piers at the junctions. The outer row of the sudd sheet-piling was finished off hard up to the stop-logs and caulked. Other steps taken to render those points watertight were described in the Paper.

*** The Correspondence on the foregoing Paper will be published in the Institution Journal for October 1940; the Author, in his reply thereto, will deal further with certain points raised in the Discussion.—Sec. Inst. C.E.