Paper No. 6229

**The design and construction of a dry dock at South Shields
for Messrs Brigham & Cowan Ltd†**

by

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Discussion

Mr F. S. Jackson (Director, Marples Ridgway & Partners Ltd) observed that the cost of the excavation of a dry dock was usually a substantial part of the total cost. Obviously it was liable to vary considerably between one method and another, and also between different estimates for the same method. With regard to method, the contract documents usually confined themselves to saying that the contractor was deemed to know all sorts of things which in the time available for tender he usually had little opportunity to investigate fully. This combination of variables and unknowns was liable to result in the ultimate cost of the work to the client, to the contractor, or to both being greater than it need be. In this case, however, the Engineers had defined in detail in the contract documents an obviously economical method of carrying out the excavation. It was true that, from the design of the dock structure, it was reasonable to assume that some such method would be practicable, but even so, so clear a declaration of the Engineers' opinion must have been very encouraging to the estimators' morale, with a consequent benefit to the client.

139. Although Mr Jackson realized that this procedure of specifying or at least strongly recommending constructional procedure for a substantial part of the work might be viewed with some wariness by consulting engineers, he suggested that it might be worthy of wider application. He believed that the Authors had had other experience in the use of this procedure, and he asked if they had found that experience to be encouraging or otherwise.

140. The work had been carried out generally in accordance with the Engineers' scheme, the variation mentioned being mainly in the point at which the excavation was commenced. The original scheme had been to make a start near the apex, and the actual sequence, as described, had been adopted partly for certain detailed benefits, but mainly because it meant that the first excavation to full depth would be over the length where the boulder clay extended to a substantial depth below formation. In the event, the sidewalls had behaved very well both at the clay bottom and in the sand, but the sight of the nearly vertical and entirely unsupported clay face about 40 ft high had taken a little getting used to, even as seen from a hard clay bottom. Probably it was just as well that it had been first seen that way and not from wet sand. The excavation bench level mentioned had been arrived at after some trial-and-error to suit the machines employed, the disposal system, and the digging characteristics of the clay. The drag-shovels had been particularly effective and, after the usual practice by the operators, had been able to give a very close approximation to the side profile and left very little hand trimming. The handling and setting of the buttresses had been quite a straightforward job, in spite of the awkward shape.

141. The Authors had mentioned the use of double-drum derricks for this purpose.

† Proc. Instn civ. Engrs, vol. 8, p. 161 (Oct. 1957).

With those machines it was very important to have the correct detailed sequence of operations if aerial manoeuvres were to be avoided.

142. The number of piling hammers adopted had been a consequence of isolated peaks in the requirements of the work and not of its extent or difficulty. The jib-length of the 15-ton derrick was 120 ft, not 150 ft as stated in the Paper.

Mr R. W. A. Fane (Director, Alderton Construction Co. Ltd) paid a tribute to Mr G. A. Maunsell for the part he had played in making this perhaps surprising design a complete success. It was only because Mr Maunsell and his team, headed by the Authors of the Paper, had realized the possibilities of the boulder clay and had had the courage to use the properties of that clay to the full that this extraordinarily cheap method of construction had been possible. As Mr Jackson had said, one had had an extraordinary feeling in standing underneath the 40-ft vertical face of boulder clay and realizing that one had some responsibility for the safety of the workmen who hand-trimmed it, and worked underneath it. The conditions had been extremely unusual but there had been surprisingly little trouble.

144. The coffer-dam itself was really three coffer-dams, and that meant that in no less than four places the steel sheet-piles had been driven through the old quay wall. That wall was very old and parts had been rebuilt more than once. Great difficulty had been experienced in driving those piles which passed through the old wall. It had eventually been necessary to call in a demolition expert, who had inserted light shattering charges in boreholes put down along the centre-line for that purpose. The piles were then driven easily in their right position.

145. Mr Fane then referred to the dewatering problem. There had been lenses of sand which tended to hold their water and in the early stages it had appeared that the pumping would be ineffective. But gradually the wet patches dried out. There had continued to be some inward leakage, but it was a small proportion of the total volume of water pumped out. When the dewatering was under control the ground conditions had changed completely, and the whole operation became far easier than at one time had appeared possible.

Mr T. F. Burns (Partner, T. F. Burns & Partners, Consulting Engineers, London) pointed out that the dock was immediately across the river from the one he had himself been concerned with about 3 years previously.¹ He had therefore been interested in seeing how another engineer had tackled a very similar problem. The ground conditions at both sites were very similar in many respects.

147. The bold conception of leaving the clay sides vertical without supports had apparently been quite successful; but had any slips occurred or had it been necessary anywhere to shore the face, could it be assumed that the construction of Smith's Dock had contributed to that idea? What was the reason for battering the earth face near the formation? Was it done to minimize the risk of a collapse, or for any other reason?

148. While he approved the introduction of new features into dock construction, he felt that careful consideration should be given as to whether those features, satisfactory as they might be in other construction work, were likely to be equally satisfactory in a dock, which suffered from treatment such as few other structures did. He did not like the reinforced concrete buttresses; he considered that in the course of a few years they would have sustained considerable damage, in the form of broken corners and exposed reinforcement, from steel plates and prefabricated sections which inevitably would be lowered between the ships and the side of the dock. They might also suffer damage from the ships, and the effects of leaking steam and water pipes, together with alternating wet and dry conditions, would probably produce, over a number of years, elements conducive to rapid corrosion. Once started, corrosion would give rise to a very serious

¹ T. F. Burns, "The design and construction of No. 8 dry dock at North Shields for Smith's Dock Co. Ltd". Proc. Instn civ. Engrs, Pt II, vol. 4, p. 355 (June 1955).

maintenance charge. The close centres of the buttresses seemed to make it difficult to run services along the bottom of the dock, except in very short lengths. He did not approve of the drainage hole through each buttress. It seemed that this would offer restriction to the flow and need constant cleansing. In fact, he felt that in a modern dock there should not be drainage channels along the sides. It appeared to him that the decision to adopt these buttresses had been perhaps unduly influenced by the constructional need to secure a reasonably quick support to the clay face without perhaps more consideration of the objects to a permanent wall of the dock.

149. The general impression he gathered in reading the Paper was that many features had been pared down to the minimum. For instance, 17-in.-wide altars in the buttresses seemed to be rather dangerous. The services subway was only 4 ft 3 in. high; maintenance work would be more difficult than if the full headroom had been provided, and in these days of difficult labour conditions it was surprising that the job had been made more difficult. It also seemed that the openings to this subway were at such levels as to permit flooding under exceptional high tides. No doubt there was a good explanation for all these criticisms, and he was sure that the Authors would supply it.

150. Collapsible handrails were not usually considered necessary nowadays. If there were no protrusions along the top, the ropes would slide over quite smoothly, and the collapsing and re-erection of all the handrails represented quite a lot of unnecessary labour. In fact, there was a dock on the North-East Coast built in the early 1920s where the handrails had been fixed, and they had never been moved since.

151. The crane seemed to be of a relatively low capacity for a dock of this size, and it was certainly less than that of others recently completed or under construction. Swan Hunter's, for instance, had a 50-ton crane, and Falmouth would have a 65-ton portal-type travelling crane, both with two other types of crane of smaller capacity. Most ship repairers considered undercrane a big mistake. Why had a 22-ft gauge crane track been used? It seemed to be unusually narrow and would consequently produce heavier wheel-loadings. What method was used for laying the crane rails and had they been satisfactory? There seemed to be frequent difficulties with crane tracks of this type which could only be overcome by experience and careful site supervision.

152. He noted that the entrance gate had four bearings, as compared with the two which were more usual for gates of this kind. Had this been specified by the Consultants, and if so, why? Or had it been the makers' idea, and what were the advantages of having four bearings? Had the Authors considered the idea of operating the gate by compressed air—a flotation method—instead of by electric winch? That method was used in America, and it would seem that it had possibilities of development, since there was always an ample supply of compressed air in these ship-repairing yards which was not being used when the gate was being operated.

153. Had there been any silting in the north-east corner of the entrance, and had the question of getting silt off the apron been considered?

Mr R. H. Vincent (Agent for Balfour Beatty & Co. Ltd) commented on the judgement of the Engineers in assessing the outstanding capabilities of Tyneside boulder clay. To design on the assumption that clay would stand in a near-vertical 40-ft face without any form of support for a period of up to 6 months was asking a lot of the clay and quite a lot of the contractor. Both had stood up to the stress reasonably well. However, during the course of construction, three clay slips had occurred, one inconveniently in front of the batching plant, one to the east of the pump-house, and one to the east of the south entrance pier. All had been of a relatively minor nature, and in all instances the difficulty had been overcome by driving steel sheet-piling behind the line of the dock wall, strutting this piling from the dock floor, and then proceeding with buttress erection and concreting the sidewall panels in the normal manner.

155. In all cases the ground had given adequate warning of its impending slip, and the remedy had therefore been well advanced when the slip occurred, so that little delay had been caused. The two slips at the river end of the dock could be attributed to

disturbed ground resulting from works carried out in the vicinity some years before the present dock scheme.

156. The bulk excavation of the dock barrel had offered little difficulty, although the quality and appearance of the clay had varied. At the river end of the dock, at a point about 270 ft east of the meeting-face, the brown clay had changed to a greyish clay which was far tougher both to dig and trim. This had necessitated using a $\frac{3}{4}$ -cu.-yd face-shovel on the -10 bench to assist the $1\frac{1}{2}$ -cu.-yd and subsequently the $1\frac{1}{2}$ -cu.-yd draglines forming the -10 bench.

157. The trimming of the sidewalls had been carried out by a combination of $\frac{3}{4}$ -cu.-yd-capacity face-shovel and drag-shovel, with the emphasis on the latter. By continuous checking, or more probably by weighting the bonus paid to machine drivers with an "accuracy" element, overdig was controlled to a reasonable margin, and as a result hand trimming had been practically eliminated.

158. Although it had initially been found that the submersible pumps effectively dewatered the sand, as work proceeded to the dock head the tubewells dewatering the sand under the east half of the dock floor proved to be less efficient. The first alternative to be tried had been the well-point system, which initially had met with success, but had subsequently proved to be not entirely satisfactory. This was due to lenses of silt in the sand and a decrease in sand particle size.

159. An attempt had then been made to utilize one of the box piles, which at that stage were being used instead of broad-flanged beams as anchor piles in the dock floor, as a tubewell. The pile had been shod, slotted, and driven, and a section of perforated tubewell casing inserted into the pile. The space between the pile and the casing had been filled with pea gravel and a submersible pump installed inside the casing. For a number of reasons, the time factor being the predominant one, this scheme had been unsatisfactory.

160. The difficulty had been finally overcome by forming a number of perforated sump boxes, the spacing of those boxes depending on local ground conditions, containing the rose of a lift and force pump surrounded with a graded ballast filter. The pumped water had been carefully examined for pumped material to minimize loss of ground from the working area. The most effective sump box had proved to be a 40-gallon Diesel-oil drum pierced by pickaxe at suitable centres.

161. The concreting arrangements had been of a straightforward nature. In the main the mixer had discharged into 1-cu.-yd concrete skips or bogies which had been hauled along the south side of the dock to the operating radius of the 15- and 10-ton derricks. In general, two skips had been handled at a time by the derrick for the dock floor panels.

162. The ballast used for the contract had been a washed river gravel from the River Wear, while the sand used had been sea sand dug from the South Shields beach. What was the Authors' opinion on the use of sea sand as a concreting material both for docks and for other classes of construction work?

163. Turning to the work at the river entrance, the piling to the dams in the main had been straightforward. It had been noted, however, that the driving of the piles at the south-west corner of the main dam had been particularly easy. Unconfined compression tests had therefore been taken as excavation proceeded, and as a result of those tests it had been decided to splice and redrive these piles a further 6 to 8 ft. In view of the subsequent request to drive broad-flanged beams under the nose of the south entrance pier, the decision to redrive the skin piling had been undoubtedly justified.

164. With regard to the 12-ft 9-in.-long precast meeting-face units, the limits specified would normally be of greater interest to the mechanical rather than the civil engineer. However, the fact that the finished article had been successful, coupled with the saving effected by this scheme compared with the more traditional method, must have been of satisfaction to the designers and repaid, to some extent, the endeavours of the contractor.

165. The general advantages of the design were apparent from the Paper; had

alternative schemes been prepared in the preliminary stage; what were they; and why had the precast concrete form of construction been adopted?

166. Finally, one of the more encouraging features of the construction work was the similarity between the pre-planned programme and the contract progress. This was in no small way due to the willingness of the designers to modify details when necessary to suit site conditions.

Mr J. H. Jellett (Docks Engineer, Southampton Docks, British Transport Commission) said that he had been associated with Mr Maunsell in certain works during the war, and congratulated him on the astounding success of his very bold move in relying on the properties of the boulder clay. It was distressing that there was in contemplation legislation which could only have the effect of discouraging engineers from embarking on ventures of this sort. The regulations to bring works of engineering construction within the scope of the Factories Act had first been circulated in draft in 1945 and they made it quite clear that any contractor undertaking an excavation in this manner would be responsible for a breach of law should a slip occur. There was no let-out in the phrase so beloved of the legislators "within the opinion of a competent person". It was a statement of fact: if a slip occurred, timbering was therefore necessary, and if it was necessary, it should have been provided. Mr Jellett felt that those who had the opportunity to do so should still make every effort they could to see that this sort of regulation did not reach the Statute Book.

168. He had been rather surprised to see that Mr Maunsell had not, as he might have been expected to do, carried the use of precast work a stage further and used it instead of shuttering for the facing of the sidewalls. It would have been a reasonable proposition to cast the buttress units with slots in the side and to take, say, a 4-in. precast and probably prestressed plank which would then function as shuttering and remain in the finished structure. This was a technique which had been claimed to have been applied to dock construction by the Russian Authors of one of the Papers² contributed to the proceedings of the 19th Navigation Congress this summer. Had consideration been given at any stage to proceeding on those lines?

169. Had there been any suggestion of correlating the resistance to driving of the broad-flanged sections that had been used as piles over part of the area with their resistance to uplift? Mr Jellett noted that the latter resistance had been based on experiments on single piles, but it was common experience that even in quite uniform pile-driving conditions one pile might occasionally require to be driven to perhaps twice the penetration of its neighbours before a set for normal bearing was obtained. There seemed to be no reason why this might not happen in the reverse direction, but the driving for this purpose did not use each pile as its own test piece, as was the normal occurrence. He realized that there was a factor of safety of 3, which was rather more than was usually employed, and possibly that had been held to cover it.

170. In § 17 the Authors used the term "long-hallowed" as applied to the more old-fashioned types of mass construction. The use of that term suggested that perhaps dry docks built in those days had had their design based on something less than scientific reasoning, and he thought it would be only fair to their predecessors to recall that they had designed their dry docks for ships of somewhat different profile from the ships that had to be catered for nowadays, and that the multiple-altar type of construction which was necessary for those ships dictated the mass construction which had been used. Moreover, at the time when those structures had been designed, the concrete and the labour for laying it had been relatively cheap materials and there had been no particular urge to avoid their use.

171. The coping bar was a detail that he had not seen before, and he would like to

² N. N. Djunkovski and A. A. Kasparson, "Some modern tendencies in the design and construction of dry docks and locks in the Soviet Union". Proc. 19th Int. Nav. Congr., 1957, Sect. II, Commun. No. 2, p. 187. Perm. Int. Ass. Nav. Congr., 1957.

hear in due course how successful it was. He did not see that it was going to perform any useful function. Normally when ships were docking, the ropes rose from the cope to the deck of the ship and not down into the water, so that its function of keeping the rope from fraying against the edge of the dock would seem to be of only intermittent value. On the other hand, it was a structure at the dock edge which seemed likely to give rise to accidents. Men might trip over it and fall into the dock. So it appeared to him to be a feature of somewhat uncertain value.

172. Mr Burns had referred to the collapsible handrail. Mr Jellett would go a stage further than Mr Burns had and say that he saw no reason for handrails round the edge of a dry dock. The Institution had gone on record³ in 1952 in stating that the provision of these handrails was statutory in the United Kingdom. With all due respect to the learned members who had compiled that document, it was a figment of their imagination. The only regulations which were relevant to the subject were the Shipbuilding Regulations of 1931, which had been current at the time the Memorandum was prepared and were current now, and there was nothing in those regulations to require the fencing of the edge of a dry dock. He would again utter a warning. The new regulations, which were in draft, did require such fencing to be provided. But so far as the matter had been referred to the dock authorities at Southampton, they had always resisted this suggestion. They thought it was much better that men should learn to pay proper respect to the edge of a dry dock as a dangerous place and not cultivate any false sense of security from the presence of a collapsible railing which might have been collapsed at the critical moment when a man was in danger of falling over.

173. It was stated in the Paper that the handrails were arranged so that they would readily drop down into the slots provided, but he could not help feeling that once the posts had taken a few cracks from a crane hook, which they would undoubtedly get, the operation of collapsing them into those slots would not be quite so easy.

174. He had taken the trouble to look up the records for the past 11 years in seven dry docks. In the 11 years there had been one casualty due to a man falling into the bottom of the dock, and he had fallen in circumstances in which the railing would undoubtedly not have been there if handrails had been provided.

Mr J. A. Williams (Senior Civil Engineer, Messrs Wilton and Bell, Consulting Engineers, London) said that the structural advantage of the buttresses was obvious, but when one normally strove to get as much clearance as possible at the bottom of a dry dock, he wondered if, from the dock operator's point of view, they were merely making the best of a necessary evil.

176. In regard to the floor and the tension piles, Mr Williams had been brought up on the rule of thumb that a tension pile, irrespective of ground conditions, was good for 10 or 12 tons, and he was very glad to see that at last someone had had the courage to state in print that a tension pile could take 30 tons. He had had an opportunity of testing a considerable number of piles, particularly broad-flanged beams, during the past few years, and there was no doubt in his mind that over a very wide range of ground a broad-flanged beam with reasonable penetration was good for at least 30 tons in tension.

177. Why, after having pinned the floor down, was it thought necessary to have the relief drains? Having decided upon them, however, the Authors had constructed them in a proper manner. Their clients would eventually be grateful for relief drains which really were drains and not just holes formed hopefully through concrete.

178. Referring to the gate and meeting-faces, while all dock engineers admired the craftsmanship which could dress concrete, granite, and greenheart to such fine tolerances, these materials could never produce such a good seal as rubber. If used properly rubber

³ "Dry docks: memorandum on construction and equipment". Spec. Jt Ctee, 1952.

gave literally a watertight gate. He felt that the answer was to concentrate on the rubber and to relax the tolerances on the granite or the precast concrete.

179. He was sure that the coping bar was the worst feature of the dock, and that it would never satisfy the Factories Act; sooner or later somebody was going to fall into the dock, especially at night.

180. The Authors had made an excellent fitting-out quay by using broad-flanged beams on a solid concrete deck. He suggested that they had not developed the design to its furthest extent. Broad-flanged beams welded to the piles for both portal beams and longitudinals provided an excellent grid for hanging the shuttering for the solid concrete deck, and the whole operation would be even easier than it had been in the present case. It might be argued that the fitting of steel beams to driven piles was difficult for the contractor, but it had not worked out that way in practice. If the piles were too much out of line to spring in, it was only necessary to order the beams in double lengths and cut them to tailor-fit the actual bents.

181. The North-East Coast was notoriously difficult for good concrete. Had all the aggregate come from the River Wear for all classes of concrete and had there been any difficulty in maintaining the specification?

182. Over the past 6 or 10 years Mr Williams had worked out the cost of a large number of docks, both those of which he had had personal experience and those for which figures had been published, and he had concluded that in average conditions the cost of a dry dock was about 10s 0d/cu. ft of dock volume. That included a gate and a set of pumps. The figure for this dock worked out at 5s 6d. The difference might to some small extent be due to a paring of detail, but the figure of 5s 6d did nevertheless pay a tribute both to the design and the construction.

Mr D. C. Copsey (Technical Manager, Dock and Harbour Equipment Department, Head Wrightson Teesdale Ltd) described the construction of the entrance gate. It had been designed by consideration of the moment of resistance provided by the meeting-faces taken in conjunction with the distribution of pressure from the maximum head produced when water outside the dock was at the top of the gate. It was of welded construction, the principal dimensions being 98 ft 3½ in. between centres of end posts, height 30 ft 2 in. from underside of sill timber to top deck, and mould width 7 ft 1½ in. outside skin plates.

184. Fig. 25 was a diagrammatic view of the gate. There were seven horizontal decks, four vertical watertight diaphragms, with intermediate non-watertight plate diaphragms, and angle frames spaced at about 2-ft centres between the watertight and the non-watertight diaphragms. The diaphragm catered for redistribution of deck loading and the angle frames provided additional vertical stiffening. Below deck No. 1 there was an open keel section approximately 7 ft 8 in. deep.

185. Air tanks were positioned to reduce the maximum pull required from the operating machinery. A permanent buoyancy chamber was arranged in the middle section of the gate between decks 1 and 2. The remainder of the gate between decks 4 and 7 provided temporary ballast varying with the level of the tide, the wing tanks between decks 1 and 2 providing permanent ballast.

186. The method of supporting the gate had been referred to by the Authors, as also had been the additional seal provided by a rubber angle on the outer edge of the meeting timbers.

187. Two flooding valves were arranged to admit the necessary water ballast through the bottom of the gate and also to control buoyancy during the stepping and unstepping operations. Six 27-in.-dia. sluice valves were arranged horizontally between decks 2 and 3. An electrically driven haulage winch was arranged to operate the gate in approximately 4 min. The situation of the machinery and the arrangement of the rope had been mentioned by the Authors. The electric motor which drove the winch was of squirrel-cage design with double shaft extension. It developed 65 B.H.P. at 975 r.p.m. and was non-reversing.

188. The gate was raised by the engagement of a gear train through a scoop-

controlled fluid coupling and it was lowered by a secondary coupling of similar design, but lower rating, located on the opposite side of the motor and leading into the main drive through an idler pinion. When the scoop of one coupling was engaged the scoop of the other coupling was automatically at neutral and no torque was transmitted.

189. The gate had been fabricated in the flat position on one of Head Wrightson's slipways. The outer skin had been laid down first and had been built up by shrinking each longitudinal strake by finish welding before bringing up the adjacent plate and taking up lateral shrinkage with two longitudinal runs. Skins had been made from three plates to each strake. The section of each weld immediately under diaphragms and stiffeners had been completed. Decks and diaphragms had then been positioned and all vertical welds made at diaphragms. Decks had been made from two plates to each strake. Stiffeners had been tacked to skin plates and decks, and this had been followed by the fitting of the end plates, the keel section diaphragms, and the bottom flange plate. The inner skin had then been positioned and fitted in the same way as the outer skin.

190. All plating had thereby been virtually complete for the gate proper, but no final welds had been made except at the vertical joints in the skin plating and between diaphragm and deck plates. Welding had subsequently been carried out, working from the centre outwards. The skin welds were single U-preparation, downhand for both skins, being chipped out from the underside in each case. A single downhand run had been made at all joints between diaphragms and decks with the skin. This had been followed by a single vertical and overhead run, finishing runs being carried out in the same sequence working always from the centre outwards. On completion of welding, the greenheart posts and sill timbers had been fitted and dressed before testing was carried out.

191. Before launching the gate into the River Tees, two chambers between decks 6 and 7 at the top of the gate (see Fig. 25) had been converted into ballast chambers giving approximately 30 tons to counteract the deadweight of the keel section and so balance the gate for towing purposes.

192. On arrival at site, those chambers had been pumped out and the gate floated into position with the keel section towards the meeting-faces. Top and bottom cross-wires had been attached and a T-shaped tank at the centre of the gate immediately above the bottom deck was filled with water. This had provided approximately 20 tons of additional ballast.

Mr J. S. S. Ramsay (London Manager, Sir William Arrol & Co. Ltd) observed that it was stated in the Paper that the original intention had been to build the gate in situ, but the idea had had to be abandoned because the gate makers could not phase their programme with that of the general contractor. Surely that was very unusual. There was generally ample time to fabricate and erect a gate during the period required for the construction of the dock.

194. It was stated that it had thereupon been decided to adopt what the Authors termed the "orthodox" procedure, namely, to build the gate at the makers' yard, launch from there, and tow it to the site. Why had the original scheme been considered unorthodox? There were many gates erected on the floor of the dock—probably more than there were erected in the makers' yards. This had the advantage that when the dock was flooded for the first time the gate floated and was put in position before the coffer-dam at the entrance was removed. That allowed any adjustments to the gate or to the seal to be done under the protection of the coffer-dam. If necessary, the dock could be pumped dry and the adjustments made in the dry. There was the further advantage that the gate could be stepped with a constant level of water, which was preferable to doing it on a rising or a falling tide, although there was generally no difficulty about that. It also avoided any risk of damage to the gate, or even the total loss of the gate, during the towing.

195. The method of constructing the meeting-faces shown in Fig. 19 was interesting. It looked as if the engineers or the contractors had been anxious to make doubly sure of

FIG. 25

PLAN

ELEVATION

SECTION

making a satisfactory job. The use of the reinforcing and the precast slab for the sill was unusual. It did not appear to be a necessity. Surely it could have been made in plain concrete with a larger section if required? What did the unit rate of £6 15s/sq. ft of meeting-face, given in § 113, include? Presumably the total meeting-face taken to arrive at that unit rate would be only the area which was in direct contact with the greenheart.

196. In § 124 it was stated that "In carrying out the stepping, the gate was first winched into position across the entrance. Controlled flooding of the bottom wing ballast tanks then gradually tilted the structure which all the while was held close to the meeting-face by wires from the near-by handling winches." So far as he could see, the only point of contact with the concrete must have been the rubber sealing strip. Had any damage been done to that strip during the operation? He asked because Fig. 11 showed that there were four bearings along the keel. As Mr Burns had mentioned, even in much larger gates it was the custom to have only two end-bearings, and they had the effect, although that was not the intention, of keeping the meeting-faces away from one another and preventing damage.

197. In Box's original design, the keel had been continuously supported along its whole length—greenheart and cast iron—without any rubber seals, as in the case of the gates for the Dover Train Ferry Dock. Flap gates seemed to have become extremely popular with dock engineers. They were being adopted in all the new docks.

198. Was there likely to be any trouble due to silting in the recess for the gate in the down position, and if so, what steps had been taken to deal with it?

Mr G. P. Martin (Partner, T. F. Burns & Partners, Consulting Engineers, London) referred to the description of the floor design. It was a very bold step to assume that no water pressure would develop under the floor of the front portion resting on the boulder clay, which in this district contained sand lenses which might easily connect with the river. Had any such conditions been found?

200. Had the Authors considered the possibility of something akin to pumping action taking place with a heavy ship-load being imposed and then released on the relatively flexible floor?

201. The Authors stated that the piles at the other end of the dock were required to support the ship. On a recent dock of about this size with which Mr Martin had been concerned, a keel-load of about 60 tons/ft run had been considered, and he believed that the Memorandum⁴ on dry-dock design had suggested an even greater load. Sixty tons/ft would give a load of at least 160 tons per pile, even if the three rows were considered to act. Had a lower keel-load in fact been used or had the ground been assumed to take some of this load?

202. Could the Authors give an indication of the methods used to determine the group action of piles in tension, as mentioned in § 33. It was evident that the single test-pile failure load of about 100 tons could not represent the failure load of one pile in a group, for if the total weight of sand between the piles for their full depth was considered it would appear that there was only 69 tons available for uplift. That assumed that the sand was immersed in water and in this connexion it would be interesting to know if the testing had been carried out when the sand had been dewatered. This load of 69 tons ignored the question of the inverted-cone principle, which must surely give a considerable further reduction of weight available.

The following contributions were received in writing.

Mr A. R. Thomas (Consultant) referred to § 31 in which it was stated that in the clay area it was reasonable to assume that significant hydrostatic pressures would not develop between floor and clay. This allowed a comparatively thin floor to be specified and no piles were considered necessary to pin the floor to the strata beneath as were provided

⁴ See reference 3 on p. 546.

where the floor rested on sand. It would be of interest to know on what evidence this assumption was based and how it was reconciled with evidence of uplift beneath masonry dams founded on rock⁵.

204. A distinction was necessary between transmission of pressure through the clay and transmission along the joint. Both processes might be very slow. There could of course be no uplift from the former process if the concrete was more permeable than the clay. It would be of interest to know if this was the case and if any special measures had been taken to improve the bond between floor and underlying clay.

Mr F. C. Greenfield (Senior Engineering Assistant, Messrs Brandt & Odell, Consulting Engineers) remarked that in confining the use of mass concrete to the minimum the Authors had avoided the age-old scourge of this material, namely the differential setting of the cement within the mass and its attendant problems. Perhaps the success of tension piles in resisting hydrostatic pressure might inspire a bolder outlook to dock floor designs and the days of the thick mass-concrete floor might well be numbered.

206. One of the few drawbacks with the dock wall design seemed to be the vulnerability of the projecting buttresses to damage by a vessel and its shoring. While such damage might be superficial in the case of mass concrete the results could eventually be serious with reinforced concrete should the reinforcement become exposed. (Was that why there were so few reinforced concrete dock walls in existence?) To that end a concrete composed of a granite aggregate and a high-alumina cement might have been justified. Presumably the cement would also have accelerated manufacture and erection of the buttresses.

207. The anti-siphon discharge pipes would seem to be an excellent system for preventing damage due to sudden stoppage of the pumps. It was surprising that the Authors had not found such an arrangement considerably cheaper than a conventional system including, as it must, expensive self-closing valves. Certainly the complications have been reduced. Were isolating valves provided on the suction side of the pumps to facilitate their removal?

208. In recent years the "submersible" type of pump, in which the motor was fixed to the lower end of the pump and immersed with it, had become increasingly popular in the water engineering field. The advantages of this type of pump over a vertical- or horizontal-spindle type were well known and included general simplicity, exceptional ease of installation and removal, and the ability of the actual windings to be immersed in water. There seemed no reason why such advantages should not be applied to dry docks. In the present example the pump-house could have been reduced to about 6 ft × 6 ft and the upper reinforced concrete floor dispensed with, the pumps being suspended from a steel platform integral with the staircase landing. The roof could have been, in effect, a large manhole facilitating the use of a dock-side crane for work in the pump-house, thus dispensing with the need for the pump-house crane. The priming pumps could also have been discarded and one of the submersible pumps could also have dealt with seepage-water. If the switchgear had been housed in one of the dockside buildings no heating would have been required in a submersible pump-house. With the present arrangement the pump-house would have to be kept permanently warm to protect the switchgear and pumps.

209. Whatever the type of pump used, emergency operation would have been greatly improved if the pumps could have been controlled in a readily accessible building at ground level.

210. Had a removable grid been provided at the entrance to the filling culvert? Had adjustable sleeves been provided to facilitate removal of the inlet control valve?

211. Had the Authors considered the use of a floating caisson type of gate? It would seem that ample space would have been available along the quay on the south side

⁵ Final Report of Subcommittee on Uplift in Masonry Dams. Trans. Amer. Soc. civ. Engrs, vol. 117 (1952), p. 1218.

of the entrance for berthing the caisson when not in use. It was well known that a Box gate can suffer from the problem of siltation of the apron while the gate was in position, such siltation having to be removed before the gate could be lowered.

212. Had sanitary facilities been provided in the dock itself—say by a sewerage system which could be connected to the vessel in dock, thus making use of the ship's facilities?

213. There seemed to be no mention of fire-fighting pumps. Presumably they were required for the fire-fighting system?

The Authors, in reply, referred to Mr Jackson's question in § 139 regarding their experience in indicating to tenderers a recommended method of construction. It was the practice of their firm to do this not only in dock work but also in a variety of other classes of work and they were convinced that it was to the benefit of everyone concerned. Contractors did not always adopt the Engineers' proposals, but even then the procedure was advantageous, since the presentation of one sound method stimulated detailed thought on the subject and the scheme eventually adopted was therefore generally more closely investigated than it might otherwise have been.

215. In the work under discussion, a considerable amount of thought had been given to the quality of the clay and its influence on the constructional approach, and it had seemed essential to include with the tender documents a detailed scheme of working. There was no doubt that this had been successful. The lower tenderers especially appeared to have been heartened by the scheme, in their pricing of the work, to eliminate a lot of hidden contingencies.

216. Many speakers, and Messrs Vincent and Fane in particular, had referred to the reliance placed on the stability of the 40-ft wall of boulder clay, but the danger to personnel had been negligible—much less in fact than in a rock excavation or a quarry where falling material might present a hazard. The decision to rely on the clay standing as it did had been taken only after observation of the fact that the same material was actually standing without support in excavated trenches nearby. These trenches were about 25 ft deep and had been standing open for some time without any apparent deterioration or collapse at the time of observation. •

217. There had been twenty-six boreholes on the site. Eleven of them had been taken some years earlier and strong reliance could not be placed on them, since the description had not been particularly full or accurate; however, they had backed up the results of the fifteen put down to establish what the actual conditions were.

218. Boulder clay was a notoriously variable material, and there were surprisingly wide variations in the type of material described as boulder clay. It was essentially a very stiff clay, but the proportions of sand lenses and the water-bearing characteristics of those lenses varied from position to position. The Authors therefore had been able to rely only on the number of bores they had to give them, on perhaps a statistical basis, an assurance that sand pockets, the chief danger to the stability of banks, would be unlikely to give trouble. At the entrance of the dock they had found sand lenses which did communicate with the tide very freely, as was only to be expected, since the overburden of the river-bed was not sufficient to blanket them off from the river-water; however, in the body of the dock the lenses were not thick and were invariably dry with the exception of a particularly large lens underlying the landward half of the dock, which had been dealt with specially. This large body of sand was reasonably compact, and pumping tests had shown that it could probably be dried out so as to render loss of material from underneath the clay banks on either side an unlikely proceeding.

219. Replying to Mr Vincent's question in § 162, the Authors had no objection to the use of sea sand for concrete-making provided that the material complied with such requirements of grading and purity as are applied to sands from other sources.

220. It was true, as Mr Burns had stated in § 149, that the service subway should be subject to flooding under exceptionally high tides, but the subway drained easily and the client had not considered the point a serious objection. All electrical services were located at a high level clear of the level of exceptionally high tides.

221. The Authors had been very much interested in Mr Jellett's remarks about the Factories Act and its application to this type of construction. That certainly gave one food for thought.

222. The need for dockside handrailing and whether this should be removable or collapsible were questions on which opinions differed and, while the Authors agreed with much that had been said, the draft regulations to which Mr Jellett referred in § 172 were a considerable influence. In the operation of the dock it had been found that with the handrailing arrangements provided, no difficulties arose. As Mr Jellett had implied, no protection was necessarily required in an installation where some men had to go into positions of danger in any case. There were many operations round the dock where some men had to go to an unprotected cope edge, and those men learned to take care, and there was no reason why many men in other categories should ever come close to the cope.

223. In § 151 Mr Burns mentioned crane capacity and the gauge of the crane track. The former was a requirement of the client and the latter had been dictated by the space limitations of the site. Even with the gauge adopted it had been necessary to remove the corner of an existing building. The crane rails were set on steel packings on the foundation slab and the grouting-up had not proved to be entirely satisfactory, so that some refixing work had been necessary.

224. The use of four bearings to support the gate (§ 152) was agreed by the Consultants in conference with the manufacturers as providing a more robust hinge than the two-bearing support could do. Operation of the gate by compressed air had been considered but the idea was discarded, since it would have restricted gate movements to the upper ranges of the tide.

225. When in operation, the main pumps discharged across the apron behind the gate and it was expected that this would assist in keeping the apron free from silt. No trouble had been experienced to date by deposition of silt in this area, so that the expectation had apparently been justified.

226. Referring to Mr Jellett's remarks in § 168 on the use of precast work, the extension of this form of construction to the wall faces between buttresses had been considered but was decided against for the reason that the most intimate contact between the boulder-clay backing and the concrete wall was considered desirable. A packing of concrete between a precast wall and the excavated face was thought to be less suitable.

227. The driving resistance of the B.F.B. piles was not strictly comparable with their resistance to extraction and no exact correlation had been attempted.

228. Replying to the points raised by Mr Williams, the Authors agreed that the buttresses might appear to encroach on the total area at the dock bottom but in fact this did not occur and the working clearances provided met the client's requirements. The spaces between the buttresses were extra to requirement and had the filling concrete been lined up with the front faces of the buttresses instead of the rear faces, it was unlikely that the question would have been raised.

229. The relief valves had been provided to make doubly sure that the dock bottom was secure against uplift—a most important consideration—but it could not be said that they were essential.

230. The coping bar was a client's requirement.

231. All the coarse aggregate used had come from the River Wear and the sand was seashore sand won locally. The contractor had generally succeeded in meeting the concrete specification.

232. The Authors had been most interested to learn of the unit-cost figure of 10s 0d/cu. ft quoted by Mr Williams in § 182 for other docks. The very favourable comparative figure of 5s 6d/cu. ft, which Mr Williams had worked out from the figures presented in the Paper, was actually slightly on the high side if the cost of diverting River Drive was deducted as a charge related to the site rather than to the dock construction.

233. Mr Ramsay, in § 195, had queried the use of reinforcement in the precast
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stones of the meeting-face. This had been necessitated by the length adopted for the stones, which would have cracked while being handled had the steel been omitted. Long pieces had been specified in order to minimize the number of joints and the Authors were of the opinion that the necessity for providing reinforcement was a small disadvantage far outweighed by the advantage of having fewer joints.

234. The rate of £6 15s 0d/sq. ft of meeting-face included costs of manufacture of the precast stones, the casting beds for these, and the fixing in position and alignment of the stones. In arriving at this rate the area taken was that of the full-face area of the meeting-face stones—not just the area in contact with the greenheart.

235. With reference to the question in § 194 on the original scheme for gate erection, this had been considered something out of the ordinary, since the gate was to be built in the vertical position on its bearings, i.e. in what would be its closed position when the dock was in operation. The success of this scheme had depended on the gate being completed in such time as would enable it to take over the coffer-dam duty of excluding water from the works and thereby enabling the link-up to be effected between dock barrel and entrance. As stated in the Paper, the programmes could not be phased together, and the gate had, in consequence, been built at the makers' yard in the more ordinary way.

236. The gate could have been built on the flat on the dock floor and then stepped after the initial flooding operation, but a much larger and more expensive coffer-dam would have been needed in view of such stepping operations. During the stepping operation the gate had been held "close to" the meeting-face, not in contact with it, and consequently no damage to the sealing strip was possible.

237. Silting of the gate apron had not caused any operational difficulty.

238. Referring to Mr Martin's questions, the Authors stated that no sand lenses had been found over the outer portion of the dock floor. The clay was considered well able to withstand the slight action envisaged by the questioner in his reference in § 201 to pumping caused by ship-loads. The floor design had been based on the assumption of a keel-load of about 60 tons/ft, part of which would be taken on the ground. It had been realized that the extraction test on a single pile did not give a true indication of the uplift which could be carried by a pile forming part of a group and the tests had merely established that the resistance could be developed. The immersed weight of the sand between the piles available for holding down was calculable as approximately twice the working load of 30 tons, or about 70 tons, and the ratio between this and the working load assumed conformed to conventional safety factors.

239. Replying to Mr Thomas (§ 204), the Authors stated that no special measures had been adopted to improve the bond between the concrete and the clay.

240. Several of the contributors had commented on the likelihood of damage to the buttresses, but this fear appeared to be unfounded because after approximately 2 years' continuous service no such damage had occurred. The Authors did not share the apprehension which had been expressed and did not consider the use of granite aggregate and high-alumina cement, as suggested in § 206 by Mr Greenfield, to be necessary. It had also to be remembered in this connexion that the effective reinforcement was located a long way from the surfaces where possible abrasion might occur.

241. A removable screen had been provided at the entrance to the filling culvert, while a flap valve fitted at the inlet would facilitate the removal of the flooding sluice. Adjustable sleeves and isolating valves had not been fitted.

242. A floating caisson had not been considered the ideal solution for closing the dock, since the flap gate was simpler and speedier in operation.

243. Sanitary facilities had been provided alongside the dock but these were simply an extension of existing arrangements and were not capable of being linked with facilities aboard ship.

244. Fire-fighting facilities consisted of a supply system in the service duct, which was connected to the town water supply. At the various manhole positions through the duct roof, the dock supply line had valved connexions for coupling-up hoses.

245. Reference has been made to the paring of detail on the dock and to the overall

cost. In a case like this, where a dry dock which was virtually an open-air factory was being built, obviously the man who was going to work that factory had to have a big say in the details, and such had certainly been the case. This dock, which had certain unique engineering features, was really a joint endeavour to enable Messrs Brigham & Cowan Ltd to double their facilities on the Tyne at one stroke, and they had had to have a limited objective. They could not have the perfect ship-repairing installation centered round the large dock from the word "Go"!

246. Looking back on it, the Authors thought that it had been done satisfactorily. There were some details which might have been better for a few more pounds being spent on them at the time—the service ducts, for instance, were a case in point. It might not have cost much more to make them big enough for a man to walk through and to alter the arrangement into a slightly more convenient form. But it was one aspect of the search for economy—the making of the job possible from the customer's point of view—that that detail, among others, should be pared down to a minimum provision.

247. In conclusion, the Authors had to return to the question of the clay. Mr Vincent had remarked in § 154 that it had been assumed that the clay would stay exposed at 40-ft heights for up to 6 months. That had not been an assumption in the original stage of the job, and in fact it had been partly with the thought that a rapid construction would be helpful if trouble was experienced with the clay that the buttress wall had been adopted. It had proved, in fact, that the clay did not deteriorate when exposed substantially, and the short rapid bursts of construction moving along the sides of the dock as originally envisaged had not been necessary; the work as a whole had progressed in a steady cyclic manner without any attempt to try to win a section of wall in quick time.